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Woody Species Diversity and Community Analysis of Sekelamariam Forest in Denbecha, Northwestern Ethiopia

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Abstract

The study of woody species diversity and community analysis of Sekelamariam forest was conducted in Denbecha, Northwestern Ethiopia. This study revealed composition, diversity and community analysis of woody species; identifying community types of the forest. Systematic sampling method was used to collect vegetation data from forty two 20 m x 20 m sample plots for woody. The sample plots were laid at every 50 m interval along altitude and transects laid at 100m apart. Then, DBH>2.5cm and height>2 m, were measured and recorded in each plot. The vegetation classification was performed using PC-ORD software package. Vegetation classification following R-3.3.2 software resulted three communities, namely, Galiniera saxifrage Community, Calpurnia aurea-Nuxia congesta, Maesa lanceolata –Croton macrostachyus community. Sorensen's similarity among the communities revealed that those communities are 60-71% similar. Thus, all the communities identified were important in terms of woody species diversity and sensitivity from conservation point of view. The quantitative species diversity, richness and evenness were computed to describe plant diversity in each community type. A total of 59 woody plants belonging to 39 genera and 38 families were identified. Fabaceae family had the highest number of taxa followed by Euphorbaceae. Woody species densities for mature individuals were 750 stem/ha. The total basal area of the forest was 7.4 m2/ ha. Grazing and other human impacts were evident in the lower elevation, leading to depletion of locally useful woody species. Moreover, this forest is the only remaining natural forest whose conservation will be a source of gene pool for afforstation in the surrounding areas.

Keywords: Conservation; Dry Afromontane Forest; Plant Community; Population Structure; Species Diversity.

Introduction

Ethiopian is endowed with various landscape types resulted in different agro-ecological zones and vegetation types. The vegetation types varied from the tropical rainforest and cloud forests in the southwest to the desert scrubs in the east and northeast Ethiopia (Bongers and Tenngkeit, 2010). The structure and species composition of the natural vegetation types are also diverse due to the existence of wider physiognomic and climatic landscapes in the country. Plant species diversity is vital issue of biological diversity and the diversity of woody species is fundamental to whole forest biodiversity, because woody species offers resources and habitats for almost all other forest species. The use of forests and forest products should be in a way that could not affect or harm the coming generation. But today, clearing of forest resources is increasing due to agricultural expansion, timber production, fire wood, charcoal and construction materials leading to ecosystem degradation and loss of critical biodiversity.

This clearing of forest has also resulted in soil erosion, land degradation, biodiversity loss and ecosystem disturbance, which is affecting the whole ecosystem of the world today. High level of dependency on agriculture, high rate of population growth and non-integrated investment activities are main factors that provoked deforestation in Ethiopia (Ensermu Kelbessa and Teshome Soromessa, 2008). Therefore, better understanding of woody species diversity, composition, and other ecological perspectives is very vital for conservation and sustainable utilization of forest resources. Depend on the classification of the vegetation types found in Ethiopia; there are twelve major vegetation types in Ethiopia. These are: 1) Desert and semi-desert scrubland, 2) Acacia Commiphora woodland and bush land, 3) Wooded grassland of the western Gambella region, 4) Combretum Terminalia woodland and wooded grassland, 5) Dry evergreen Afromontane forest and grassland complex, 6) Moist evergreen Afromontane forest, 7) Transitional rain forest, 8) Ericaceous belt, 9) Afro alpine belt, 10) Riverine vegetation, 11) Salt lakes, salt-lake shores, marsh and pan vegetation and 12) Freshwater lakes, lake shores, marsh and floodplain vegetations.

The Ethiopian highlands contain large coverage of the land area with Afromontane vegetations, of which dry evergreen Afromontane forests form the largest part. It occurs in an altitudinal range of 1800-3000 m, with average annual temperature and rainfall of 14-25°C and 700-1100 (rarely up to 1700 mm), respectively [1]. The forests in this vegetation types have greatly decreased due to the expansion of agriculture and other interference by people and domestic animals and have been replaced by bush land and scrub in most areas. The characteristic emergent species of this vegetation type include Olea Europea, Juniperus procera, Prunus Africana, Euphorbia ampliphylla, Dracaena spp. Carissa spinarum, Euclea divinorum, Rosa abyssinca, Mimusops kummel, Ekebergia capensis, etc (CBD, 2009). Of the above vegetation types, the current study area, Sekelamariam natural forest, might fit the characteristics of the Dry evergreen montane forest in the country. Sekelamariam forest is one of the forest areas of Ethiopia and it is one of the remnant dry Afromontane forests in this country with a diversity of flora and fauna (Zerihun Woldu, 1999 as cited NBSAP, 2005). Ecological assessments of this forest would serve as a basis for meaningful planning, sustainable utilization, and conservation of this valuable natural resource. For effective management and conservation of this ecosystem, there is an imperative need to develop a successful management plan and this, in turn, requires detailed knowledge base regarding the ecology of the area. As a result, a scientific study on floristic composition of a given forest is needed for determination of a forest status to take appropriate

conservation measures [2]. So, the current work on the study area is believed to contribute a lot to the effort being made in the development of an efficient management plan for effective conservation of the forest [3].

Woody species study can provide basic information about particular vegetation in relation to its ecological region and thus indicates directions of future conservation measures the vegetation needs. Since, diversity of woody species in Sekelamariam natural forest have not yet been investigated, this study proposed to generate basic scientific information on the woody species composition, community analysis found in the area and in order to supply scientific information to the conservation, management and sustainable utilization of these forest resources in particular and the biodiversity in general. Accurate data on forest resources for management and planning is not well documented in the study area. Lack of such basic information is one of the serious problems that hamper sufficient conservation and management of the forest [4]. Therefore, this study intended to solve such a basic problem hindering observation of the next phenomenon. There is a need for data that would contribute to the conservation and sustainable use of this forest. Consequently, species documentation, community identification and description of this forest are imperative and this study is initiated to offer primary information about woody species diversity, and community type of this forest. Ultimately, the study would be used as a baseline in providing information to policy-makers, agricultural and forestry research centers, forest enterprises, NGOs and development agents [5].

Materials and Methods

Study area

This study would be conducted in Sekelamariam forest which is located in West Gojjam Zone of Amhara National Regional State, Ethiopia at about 350 km north of Addis Ababa (Figure 1). The forest lies between latitudes 100 35'- 10037' N and longitudes 370 28' - 37 0 30 'E. It covers an area of 532ha Amhara National Regional State Forest Enterprise (ANRSFE, 2016). The altitude of the forest ranges from 2266m to 2460ma.s.l. The study area is categorized by mid highlands locally known as Woina-dega agro-climatic zone and has unimodal rainfall distribution. The forest has the natural forest (227ha) and plantation forest (305ha) coverage (ANRSFE, 2016).

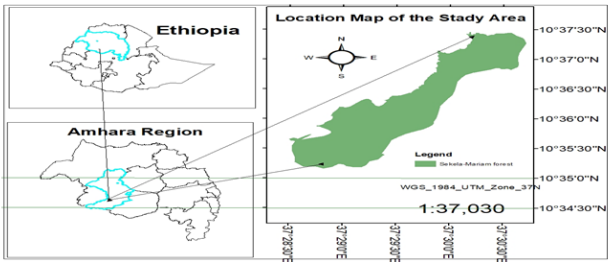

Figure 1: Location map of Sekelamariam forest

Topography and Climate

The major soils colors are red (65%), brown (25%), and black (10%) Denbecha District Agricultural and Development Office (DDADO, 2008). Metrological data from 1986-2016 obtained from National Meteorology Agency of Dembecha was extracted, analyzed and presented in climadiagram (Figure 2). The mean minimum and maximum temperature of the study area were 8.5 0C and 290C, respectively and had an average temperature of 18.5 0C. The area received high amount of rainfall during kiremt season (June, July, August and September). The average annual rainfall was 1368 mm and had unimodal rainfall distribution.

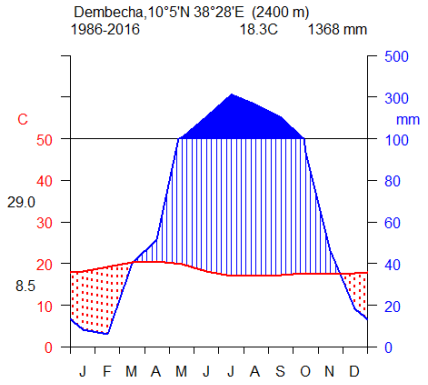

Figure 2: Climadiagram showing rainfall distribution and temperature variation from 1986 – 2016 at Denbecha station. (Data source: ENMA, 2018)

Fauna and flora

Sekelamariam forest is categorized under dry evergreen montane forest of vegetation classification of Ethiopia [6] and is characterized by Croton macrostachyus, Albizia gummifera, Calpurnia aurea, Acacia abyssinica, Maytenus obscura, Buddleia polystachya, Bersama abyssinica, Carissa spinarum, Nuxia congesta, Acacia philisipina, Clausena anisata, Rosa abyssinica, Grewia ferruginea, Vernonia auriculifera, Pavetta abyssinica among others, Moreover, the forest encompasses plantation of Cupressus lusitanica, Eucalyptus globulus, E. citriodora, E. camaldulensis, and Acacia decurrens. There are various wild animals in Sekelamariam forest including mammals, birds, reptiles, amphibians and insects like wild honey bees and monkeys, apes, Columbus monkeys, bush-buck, hyena, antelopes and porcupine are some of the mammals. There are also different types of bird species in the forest. However, these wild animals are under severe threat due to human interferences and high rate of destruction of the forest personal observation.

Methodology

Site selection and establishment of quadrats

First, a reconnaissance survey was carried out on the second week of October 2017 in order to obtain an impression of the site condition and to determine the sampling methods to be used for vegetation data collection. During the period, overall information on the study site was obtained and sampling method to be used would be identified. Then, systematic sampling method was used to collect the data [7]. At the site, line transects was laid at 100m apart and quadrats of size 20m X20m was established systematically at every 50m interval along these line transects starting from the bottom to the top of the forest following altitudinal gradient at appropriate direction. According to Sukumar et al (1992), sampling intensity, a total of 42 sampling plots with size

(20mx20m) would be systematically established for the documentation of trees, shrubs and lianas following the Braun Blanquette approach. Plots having equal size of 20 m x 20 m (400 m2) was laid out to collect the data on woody species [8].

Vegetation data collection

Vegetation data was collected between December and January 2017-2018. All the woody
plant species encountered in each sample plot was recorded using vernacular or local names in each plot, trees and shrubs with DBH > 2.50cm were measured and recorded. Diameter of trees and shrubs with Diameter at Breast Height (DBH)>2.5cm would be measured using a diameter tape at each of the established plots. Counting of trees, and shrubs with DBH> 2.5cm and translation of Diameter at Breast Height to basal area was made. The measurement was taken for trees and shrubs with the height>2m and DBH > 2.5cm and for trees and shrubs that were branched around the breast height, the circumferences were measured separately and averaged [9]. In each quadrate, data on species identity, abundance, height, and Diameter at Breast Height (DBH) of woody plant species and altitude were recorded. The heights of these species were taken by using laser Ace range finder and visual estimation. All individuals of each study species were categorized into DBH and Height classes. Physiographic variables such as altitude, latitude and longitude were recorded for each sampling plots using GPS. Voucher specimens were collected and pressed for identification of the species in the study area and brought to the Ethiopian Biodiversity Institute, where they properly identified to species level. The identification was done using the Flora of Ethiopia and Eritrea. The nomenclature of plant species followed the Flora of Ethiopia and Eritrea (Volume 1-7) and Azene Bekele, 2007. The vouchers were deposited at the Ethiopian Biodiversity Institute [10].

Data Analysis

Community type classification

Classification of plant community types was determined by using multivariate computer program of R-3.3.2 version software, agglomerative hierarchical cluster analysis using similarity ratio. The floristic and structural data analysis was based on 59 species that were recorded and collected within the sampled plots. The analysis was based on the abundance data of the species (number of individuals). The Indicator species analysis was used to compare the species present in each group. Species indicator values were calculated by using Dufrene and Legendre's (1997). These values obtained by combining the relative abundances and relative frequency of each species. Indicator values are measures of the fidelity of occurrence of a species in a particular group (McCune and Mefford, 1999) and its values ranges from zero (no indication) to 100 (perfect indication). Indicator species are the characteristic species of each group found mostly in a single group of typology, and present in the majority of sites belonging to that group. The plant community types were named after one; two or three dominant indicator species selected using the relative magnitude of their indicator values. The communities were described based on their importance value and synoptic cover values. The resulting groups were recognized as community types and the species occurrences were summarized by synoptic cover abundance values. A combination of dominant or characteristic species with high synoptic values in each community types were used to name these plant community types.

Shannon diversity index (Krebs, 1989) calculated as follows;

$$H'=-\sum_1^s PilnPi----------1$$

Where: s = the number of species, Pi = the probability or proportion of individuals in the ith species, Ln = natural logarithm.

Species richness was undertaken from all species encountered in each plot.

S = number of species/plot……..2

Shannon's equitability (Evenness) calculated by dividing H by Hmax (where Hmax = lnS).

$$E=H`/\ Hmax=H`/lnS.....3$$

The species evenness that quantifies the equity of species in a given sample area is represented by 0 and 1, where 0 indicates the abundance of few species and 1 indicates the condition where all species are equally abundant (Whittaker, 1975).

The similarity between identified plant communities type in the forest were measured by using the Sorensen's similarity index (Sorensen, 1948).Index of similarity

$$(S)=S_s=\frac{2a}{2a+b+c}$$

Where, a=Number of common species in both forest a; b = Number of species in the forest a; c =. Number of species in the forest b

Results and Discussion

Woody species diversity and community type

A total of 59 woody species belonging to 39 genera and 38 families were identified in study area (Appendix1). The number of species (59) recorded in the study area was lower than that of reported for Angada forest 87 (Shambel Alemu, 2011), Aba Asrat monastery forest 76 (Gojjam Bayeh, 2013), Sesamariam monastery forest 113(Birhanu Woldie et al, 2015), Yelat forest 60 (Sisay Tegegne, 2016), Debrelibanos monastery forest 61 (Getachew Demie, 2015), Boda forest 95 (Fekadu Erenso, 2014). Menagesha Suba state forest 112 (Dinkissa Beche, 2011), and Sanka Meda forest 82 (Shambel Bantewalu, 2010), Gedo forest 130 (Birhanu Kebede, 2010), Denkoro forest 64 (Abate Ayalew, 2003), Anabe forest 120 (Mesfin Tadesse, 1993). But higher than Yemrehane Kirstos church forest 39 (Amanuel Ayanaw, 2016), Banja forest 29 (Fentahun Abere, 2016), Kurib forest 39 (Molla Belay, 2016), Guangua Yilal forest 48 (Alemu Ayen, 2015), Tara Gedam forest 41 (Mohammed Gedefaw et al, 2014), Denaba community forest 16 (Muluken Nega, 2014), and Munessa Shashemene state forest 36 (Getachew Tesfaye, 2007).

No	Scientific name of woody species	Families	Local name	Habit
1	Acacia abyssinica Hochst. ex Benth	Fabaceae	Bazira Girar	T
2	Acacia pilispina Pic.Serm.	Fabaceae	Cheba	T
3	Acanthus pubescens (Oliv.) Engl	Acanthaceae	kosheshila	S
4	Albizia gummifera (J. F. Gmel.) C. A. Sm	Fabaceae	sesa	T
5	Allophylus abyssinicus Hochst.) Radlkofer	Sapindaceae	Embus	T
6	Apodytes dimidiata E.Mey. ex. Arn	Icacinaceae	Donga	T
7	Arundo donax L.	Poaceae	Shenbeko	S
8	Asparagus africanus Lam.	Asparagaceae	Yeset kesit	S
9	Bersama abyssinica Fresen	Melianthaceae	Azamir	S
10	Bridelia micrantha (Hochst.) Baill	Euphorbiaceae	Yenebir tifir	S
11	Buddelja polystachya Fresen	Loganiaceae	Nech anfar	S
12	Calpurnia aurea (Ait.) Benth	Myrtaceae	Ligta	S
13	Carissa spinarum (Forssk.) Vahl	Apocynaceae	Agam	S
14	Clausena anisata (Willd.) Benth	Rutaceae	Midib	S
15	Clutia abyssinica Jaub. & Spach	Euphorbiaceae	Fyelefeg	S
16	Combretum molle R.Br.ex.G. Don	Combretaceae	Aballo	S
17	Cordia africana Lam	Boraginaceae	Wanza	T
18	Croton macrostachyus Del	Euphorbiaceae	Bisana	T
19	Dodonaea viscose L.f.	Sapindaceae	Kitkita	S
20	Dombeya torrida (J.F.Gmel.) P. Bamps	Sterculiaceae	Wulkfa	T
21	Dovyalis abyssinica (A.Rich.) Warb	Flacourtiaceae	Koshim	S
22	Ekebergia capensis Sparrm	Meliaceae	Lol	T
23	Embelia schimperi Vatke	Myrsinaceae	Enkoko	S
24	Entada abyssinica Steud. ex A. Rich.	Fabaceae	Kentafa	C
25	Erythrina brucei Schweinf	Fabacae	Korch	T
26	Euclea divinorum Heirn	Ebenaceae	Dedeho	T
27	Euphorbia abyssinica Gmel.	Euphorbiaceae	kulkual	T
28	Ficus sur Forss .K	Moraceae	Shola	T

29	Galiniera saxifrage (Hochst.) Bridson	Rubiaceae	yetota kolet	T
30	Gnidia glauca (Fresen) Gilg.	Thymelaeaceae	awura	S
31	Grewia ferruginea Hochst.ex.A.Rich	Tiliaceae	lenkuata	T
32	Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	kosso	T
33	Hypericum revolutum Vahl	Guttiferae	yedegaAmija	S
34	Justicia schimperiana (Hochst.ex Nees) T	Acanthaceae	simiza	S
35	Maesa lanceolata Forssk	Myrsinaceae	Kelewa	T
36	Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae	Atat	S
37	Maytenus obscura (A.Rich.) Cuf.	Celastraceae	Koba	T
38	Maytenus senegalensis (Lam.)	Celastraceae	Nech atat	S
39	Myrica salicifolia A.Rich	Myricaceae	Shinet	T
40	Nuxia congesta R. Br. ex. Fresen	Loganiaceae	Atkuar	T
41	Olea capensis subsp. Macrocarpa	Oleaceae	Damot woira	T
42	Olea europaea .subsp. cuspidata (Wall.ex G. D)	Oleaceae	Woira	T
43	Osyris quadripartita Decne	Santaleceae	Keret	S
44	Pavetta abyssinica Hochst. Ex A. Rich	Rubiaceae	Dingayseber	S
45	Phoenix reclinata Jacq	Arecaceae	Senel	S
46	Phytolacca dodecandra L'Herit	Phytolaccaceae	Endod	S
47	Prunus africana (Hook. f.) Kalkm	Rosaceae	Koma	T
48	Pterolobium stellatum (Forssk)) Brenan	Fabaceae	Gumero	S
49	Rhamnus staddo A. Rich.	Rhamnaceae	Tseddo	S
50	Rhus glutinosa A. Rich subsp. glutinosa	Anacardiaceae	Kamo	T
51	Rosa abyssinica Lindley	Rosaceae	kega	S
52	Rubus apetalus Poir	Rosaceae	Enjori	C
53	Rumex nervosus Vahl	Polygonaceae	Emboacho	S
54	Schefflera abyssinica (Hochst. ex A. Rich.)Harms	Araliaceae	Gitem	T
55	Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	Yeshkoko Gomen	S
56	Stereospermum kunthianum Chami.	Bignoniaceae	Zana	T

57	Urera hypselodendron (A.Rich.) Wedd	Urticaceae	Lankuso	S
58	Vernonia amygdalina Del	Asteraceae	Grawa	S
59	Vernonia auriculifera Hiern	Asteraceae	Gengerita	S

Appendix 1: List of woody species in the study area

The forest has an overall stem density of 750 ± 51 stems/ha (mean ± SE), a basal area of 7.4 ± 0.62 m2/ha, species richness of 10 ± 0.3 species per plot (0.04 ha), evenness of 0.76 ± 0.01, Shannon diversity of 3.1 ± 0.2, and Simpson index of 0.88 ± 0.25 and Simpson evenness of 0.24± 0.06. Fabaceae was the most dominant family comprising of 6 species followed by Euphorbiaceae, Rosaceae, Asteraceae, Celastraceae, with each represented 4, 4, 3 and 3 respectively. Acanthaceae, Loganiceae, Myricaceae, Oleaceae, Rubiaceae, Sapindaceae each represented by two species whereas, the rest families each represented by a single species. The dominance of plant families varies from one vegetation type to another in Ethiopia because of variation in topography, ecology, environment and climate(Zewdie Achiso,2014) Another study by Amanuel Ayanaw (2016), Fentahun Abere (2016), Birhanu Woldie et al (2015), Getachew Demie (2015), Zewdie Achiso (2014), Mohammed Gedefaw and Teshome Soromessa(2014), Tamene Yohannes et al (2013), Abeje Zewdie (2013), Ermias Aynekulu (2011), Shambel Alemu (2011), Dinkissa Beche (2011), Motuma Didita et al (2010), Kitessa Hundera and Tsegaye Gadissa (2008), Getachew et al (2008), Dereje Mokonnen 2006 and Haileab Zegeye (2005) at Yemrehane Kirstos church forest, Banja forest, Sesamariam Monastery forest, Debrelibanos Monastery forest, Abay Gorge to Choke mountain, Tara Gedam forest, on Awash national park, Hugum burda forest, Angada forest, Menagesha Suba state forest, on Dello Mena forest, Belete forest, on eastern escarpment of Welo, Dilfakar regional park, Tara Gedam and Abebaye forests, respectively indicated the dominance of Fabaceae family [10]. The dominance of Fabaceae could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions (Ensermu Kelbessa and Teshome Soromessa, 2008).Woody species in the area contains trees(27), shrubs(30), and climbers(2). Tree species were less than shrubs in the area. This is inconsistence with Zegie Peninsula forest (Aleminew Alelign, et al., 2007) which, trees were more than shrubs.

Endemic woody species

Three endemic plant species were identified in the study area: Erythrina brucei, Rhus glutinosa and Solanecio gigas. Out of 120 threatened endemic plant species listed from Ethiopia, 35 species were from dry Afromontane forests. This shows that endemcity is high in the dry Afromontane forest. But, out of the 59 plant species identified in the present study, only three (5.1%) are endemic to Ethiopia. Feyera also reported low number of endemic plants (only 3%) from Sheko forest and Yohannes Mulugeta (2013) (only 5.3%) Gera forest in Southwestern Ethiopia. According to IUCN red list category Rhus glutinosa is categorized under vulnerable, that means the species facing a high risk of extinction in the wild (Appendix 2). Therefore, the conservation and management action to this ecosystem could contribute to the conservation of these species too. This showed that Sekelamariam forest is not only a home of diverse woody plant species but the home for endemic species. The forest also contained 5 out of 24 major commercial indigenous tree species reported by EFAP (1994). These tree species include Albizia gummifera, Croton macrostachyus, Ekebergia capensis, Hagenia abyssinica and Prunus Africana. These are extremely important tree species in Ethiopia both economically and ecologically.

No	Scientific Name	C-1	C-2	C-3
1	Acacia abyssinica	2.17	2.1	1.83
2	Acacia pilispina	1.5	0.53	0.83
3	Acanthus pubescens	0.17	0.03	0
4	Albizia gummifera	1.5	1.83	1.33
5	Allophylus abyssinicus	0.17	0.07	0
6	Apodytes dimidiate	0	0.07	0
7	Arundo donax	0	0.1	0
8	Asparagus africanus	0	0.03	0
9	Bersama abyssinica	1	1.67	0.33
10	Bridelia micrantha	0	0.03	0.5
11	Buddelja polystachya	4	0.27	0
12	Calpurnia aurea	5	2.63	16
13	Carissa spinarum	0.33	0.77	0.67

14	Clausena anisata	9.33	1.3	1.33
15	Clutia abyssinica	0	0.03	0.17
16	Combretum molle	0.5	0.4	0
17	Cordia africana	0	0.1	0
18	Croton macrostachyus	4.5	3.13	2.5
19	Dodonaea viscose	0	0.1	0
20	Dombeya torrida	0.17	0.07	0
21	Dovyalis abyssinica	1	0.07	0.17
22	Ekebergia capensis	0	0.03	0
23	Embelia schimperi	0	0.07	0.17
24	Entada abyssinica	0	0.03	0
25	Erythrina brucei	0	0.03	0.17
26	Euclea divinarum	0	0.2	0
27	Euphorbia abyssinica	0	0.03	0
28	Ficus sur	0	0.2	0
29	Galiniera saxifrage	2.83	0.13	0
30	Gnidia glauca	0	0.3	0.67
31	Grewia ferruginea	0	0.47	0.33
32	Hagenia abyssinica	0	0.03	0
33	Hypericum revolutum	0	0.3	1
34	Justicia schimperiana	0	0.33	0
35	Maesa lanceolata	0	1.1	0
36	Maytenus arbutifolia	0	0.27	0
37	Maytenus obscura	0.5	0.17	0.33
38	Maytenus senegalensis	0	0.4	0
39	Myrica salicifolia	0.17	0.1	0
40	Nuxia congesta	0	0.37	2.33
41	Olea capensis	0	0.03	0.5
42	Olea europaea	0	0	0.17
43	Osyris quadripartita	0.83	1.6	10.5
44	Pavetta abyssinica	0	0.03	0
45	Phoenix reclinata	0	0.03	0
46	Phytolacca dodecandra	0	0.03	0
47	Prunus africana	0	0.03	0.17
48	Pterolobium stellatum	0	0.1	0
49	Rhamnus staddo	0	0.07	0

50	Rhus glutinosa	0.5	1.3	0.5
51	Rosa abyssinica	0.83	0.67	2.67
52	Rubus apetalus	0.17	0.03	0.17
53	Rumex nervosus	0	0.03	0
54	Schefflera abyssinica	0.5	0	0
55	Solanecio gigas	0.17	0.1	0
56	Stereospermum kunthianum	0	0.13	0
57	Urera hypselodendron	0	0.03	0
58	Vernonia amygdalina	0.67	0.13	0.17
59	Vernonia auriculifera	1.17	0.3	0.33

Appendix 2: Synoptic table of identified community types in Sekelamariam forest

Plant community types

Three community types were identified from vegetation classification of 59 plant species at 1.5 to 2 dissimilarity levels for Sekelamariam forest (Figure 3). The name for each community type was given based on high importance value of tree and/or shrub species (Appendix 3).

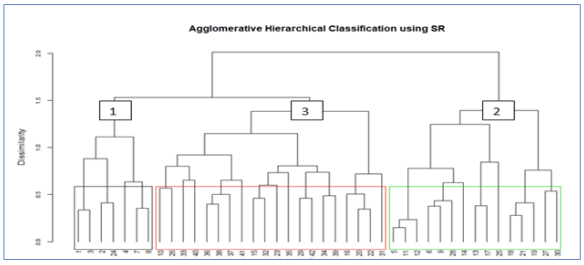

Figure 3: Dendrogram of the clusters community types of the study area.

Scientific Name	Cluster 1	Cluster 2	Cluster 3
Bersama abyssinica	0	0	2.86
Calpurnia aurea	0	12	2.87
Croton macrostachyus	0	0	2.94
Galiniera saxifrage	10	0	1.5
Maesa lanceolata	0	0	6.2
Nuxia congesta	0	10.5	1.33
Osyris quadripartita	0	10.3	1.6

Appendix 3: Species which have importance value for the three community types

Galiniera saxifrage community type one

Galiniera saxifrage Community consisted of 7 plots and 24 species between the altitudinal range of 2296 and 2432ma.s.l. This community is represented by Galiniera saxifrage, Croton macrostachyus, and Rhus glutinosa, Acacia abyssinica, Acacia pilispina, from tree species and Calpurnia aurea, Clausena anisata and Buddelja polystachya from shrub species were characteristics species of this community with higher synoptic cover value. The herb layer was dominated by Clematis simensis, Cyathula uncinulata and some grass species. Embelia schimperi, Entada abyssinica were lianas found in this community. These are ecological and economical important species.

Calpurnia aurea - nuxia congesta Community type two

This community type was the second species rich of the communities found in the forest. This might be because the community had relatively little interference from anthropogenic factors, it was found within mid altitudinal range or the adaptive ability of species for different environmental factors. The community was distributed within the altitudinal range 2330-2431ma.s.l. This community contained 15 plots and 40 species which are situated around the middle of the area. This community was represented by tree species Calpurnia aurea and Nuxia congesta. In addition to these two species Calpurnia aurea, Osyris quadripartita, Croton macrostachyus, Acacia abyssinica, Albizia gummifera had higher synoptic cover value. Phytolacca dodecandra, Rubus apetalus were

liana species which found in this community. The herb layer was mainly dominated by Clematis hirsutum species.

Maesa lanceolata – croton macrostachyus community type three

This community type was the most species rich of the communities found in the area. This might be because the community has relatively little interference from anthropogenic factors, it found with in mid altitudinal range or the adaptive ability of species for different environmental factors. The community is distributed within the altitudinal range 2337-2433ma.s.l contained 20 plots and 49 species which were situated around the top of the area. This community was represented by tree species Maesa lanceolata and Croton macrostachyus. In addition to these two species, Acacia abyssinica, Bersama abyssinica, Calpurnia aurea, and Acacia pilispina has higher synoptic cover value. Embelia schimperi and Urera hypselodendron were liana species which found in this community.

The herb layer is mainly dominated by Clematis simensis and Passiflora caerulea species.

Even though it depends on intensity and persistency of influences, factors like human and environmental influences have a strong impact on forest structure, composition and species richness. The value of Shannon evenness was lower than Zegie Peninsula 0.84 (Aleminew Alelign et al., 2007). Low species evenness can be attributed to excessive environmental disturbance, variable conditions for regeneration and selective exploitation of some species. The highest species numbers were found in low disturbance intensities (far from local people) (community III) while there was a drastic decrease in high disturbance area (personal observation). The result of the present study agrees with the regarding species diversity and richness. Diversity Index of the area were 3.1 which was higher than Yemrehane Kirstos church forest 2.88, Yelat forest 2.94, Menagesha Suba state forest 2.57, Harenna forest 2.60, but lower than Debre Libanos monastery forest 3.5.

Community type	Richness	Shannon's diversity	Simpson's index	Shannon Evenness	Simpson Evenness
1	24	2.61	0.85	0.82	0.4
2	40	2.62	0.51	0.71	0.19
3	49	3.2	0.81	0.81	0.33
Overall	59	3.1	0.89	0.76	0.24

Table 1: Species richness, diversity, and evenness of the three community types in the forest.

Overall, the possible reason for variability of each value between each community type could be the difference in number of species, cover abundance values, degree of disturbance in the community and other related factors. Similar findings were reported by Abiyou and. Grazing and anthropogenic impacts (cutting, fuel wood collecting,) can affect the natural distribution patterns of plant species. According to Cavalcanti and Larrazabal (2004), Shannon diversity index considered as high when the calculated value was >3.0, medium when it was between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it was <1.0. Thus, Sekelamariam forest had higher Shannon wiener diversity (3.1); and Simpson diversity (0.89), in other words, lower dominance.

The Similarity between the community types

Based on similarity index measures, similarity in species composition slightly varied among communities. The highest similarity was observed between community II and III (71%) due to they were found relatively in the middle and top of the forest far from local people. Relatively the least similarity was observed between community I and III followed by I and II 60.6% and 61.3% respectively. Generally, community type I was the least similar with others, because this community was the most disturbed found at the lowest extreme altitudinal range, receiving the highest degree of anthropogenic interactions as it was exposed to all incoming disturbances (Personal observation). However, there were more or less slight variations; the communities had shown relatively higher similarity among each community, probably because they might have similar: resource base, growth habits, physiological and environmental factors, tolerance to prevailing environmental stresses and similar species compositions. Because of low range in altitudinal gradients (2296-2433ma.s.l.) much significant and abrupt change in vegetation composition and zonation was not expected in the study forest. This is in line with (Teshome Gemechu, 2015). Hence, Croton macrostachyus, Calpurnia aurea, Clausena anisata, Osyris quadripartita, Acacia abyssinica, and Albizia gummifera were distributed almost throughout all the communities (Appendix 4).

No	Species	RD (%)	RF (%)	RDO (%)	IVI%	Rank
1	Acacia abyssinica	7.063	7.417	25.78	40.26	1
2	Acacia pilispina	2.381	2.871	1.154	6.4	10
3	Acanthus pubescens	0.159	0.478	0.017	0.65	47
4	Albizia gumufera	5.714	6.938	10.8	23.45	4

5	Allophylus abyssinicus	0.238	0.718	0.581	1.54	32
6	Apodytes dimidiate	0.159	0.239	0.344	0.41	45
7	Arundo donax	0.238	0.239	0.013	0.48	51
8	Asparagus africanus	0.079	0.239	0.006	0.32	57
9	Bersama abyssinica	4.603	5.742	2.906	10.35	7
10	Bridelia micrantha	0.317	0.478	0.074	0.87	41
11	Buddelja polystachya	2.54	1.675	2.147	6.36	12
12	Calpurnia aurea	16.27	7.417	6.91	30.6	3
13	Carissa spinarum	2.302	3.349	0.596	6.25	13
14	Clausena anisata	8.175	6.699	2.117	17.28	5
15	Clutia abyssinica	0.159	0.478	0.046	0.68	46
16	Combretum molle	1.349	1.914	0.172	3.46	21
17	Cordia africana	0.238	0.718	1.383	2.34	26
18	Croton macrostachyus	10.79	8.852	19.35	39	2
19	Dodonaea viscosa	0.238	0.478	0.026	0.74	44
20	Dombeya torrida	0.238	0.478	0.961	1.68	31
21	Dovyalis abyssinica	0.714	0.957	0.32	2	29
22	Ekebergia capensis	0.079	0.239	0.124	0.44	52
23	Embelia schimperi	0.238	0.718	0.088	1.04	37
24	Entada abyssinica	0.079	0.239	0.051	0.37	54
25	Erythrina brucei	0.159	0.478	0.729	1.37	34
26	Euclea divinarum	0.476	0.718	0.831	2.03	28
27	Euphorbia abyssinica	0.079	0.239	0.172	0.49	50
28	Ficus sur Forss	0.476	0.718	2.828	4.02	16
29	Galiniera saxifrage	1.667	1.196	1.029	4.61	17
30	Gnidia glauca	1.667	1.914	0.915	4.5	15
31	Grewia ferruginea	1.27	1.675	0.569	3.51	20
32	Hagenia abyssinica	0.079	0.239	0.205	0.52	49
33	Hypericum revolutum	1.19	1.914	0.685	3.79	18
34	Justicia schimperiana	0.794	1.914	0.184	3.39	23
35	Maesa lanceolata	2.698	1.675	1.411	5.78	14
36	Maytenus arbutifolia	0.635	0.957	0.27	1.86	30

37	Maytenus obscura	0.794	1.435	0.301	2.53	25
38	Maytenus senegalensis	0.873	1.914	0.234	3.02	22
39	Myrica salicifolia	0.317	0.718	1.116	2.15	27
40	Nuxia congesta	1.984	1.914	2.471	6.37	11
41	Olea capensis	0.397	0.718	0.349	1.46	33
42	Olea europaea	0.079	0.239	0.228	0.44	48
43	Osyris quadripartita	9.206	4.306	3.005	16.52	6
44	Pavetta abyssinica	0.079	0.239	0.124	0.44	53
45	Phoenix reclinata	0.079	0.239	0.005	0.78	58
46	Phytolacca dodecandra	0.079	0.239	0.046	0.36	55
47	Prunus africana	0.159	0.478	0.521	1.16	36
48	Pterolobium stellatum	0.238	0.478	0.085	0.8	43
49	Rhamnus staddo	0.159	0.478	0.366	1	39
50	Rhus glutinosa	3.254	3.349	2.698	9.3	8
51	Rosa abyssinica	3.333	4.067	1.021	8.42	9
52	Rubus apetalus	0.238	0.718	0.014	1.01	40
53	Rumex nervosus	0.079	0.239	0.004	0.32	59
54	Schefflera abyssinica	0.238	0.239	0.536	1.01	38
55	Solanecio gigas	0.317	0.478	0.037	0.83	42
56	Stereospermum kunthianum	0.317	0.718	0.306	1.34	35
57	Urera hypselodendron	0.079	0.239	0.01	0.33	56
58	Vernonia amygdalina	0.714	1.435	0.536	2.69	24
59	Vernonia auriculifera	1.429	1.914	0.211	3.55	19
	Total	100	100	100	300	

Appendix 4: Importance Value Index of woody plant species of Sekelamariam forest.

Note: RD=Relative density, RF=Relative frequency, RDO=Relative dominance, IVI= Importance value index

Phyto-geographic Comparison

The geographical position of a flora plays a more important role in determining the composition of floristic elements than climate. This may be in part because floristic elements are defined by their geographical, rather than ecological distributions (Qian et al., 2006). The direct comparison of the species diversity of one forest with other forests is not realistic because of the variations in size, survey methods used, and objective of the study among forests (Tadesse Woldemariam, 2003). However, the overall species richness of the forest can give more or less a general thought of their diversity and phyto-geographical similarity. In this regard, Sekelamariam forest is compared with eight dry evergreen Afromontane forests in the country to see the distribution pattern of woody species in the study area and to know the relative similarity in its woody species composition (Table 9). These are Angada forest, Aba Asrat forest, Yemrehane Kirstos Church forest, Tara Gedam, Yelat forest, Boda forest, Menagesha Suba state forest, and Sanka-Meda dry evergreen Afromontane forests. In the analysis of the data from the eight forests, Sorensen's (1948) similarity index was used with the formula,

$$Ss=2a/2a+b+c$$

Ss=Sorensen's similarity coefficient; a=number of woody species common to Sekelamariam and other forests in comparison; b=Number of woody species found only in Sekelamariam; c=Number of woody species found only in the forest in comparison with Sekelamariam forest

Forest	Altitudinal range	a	b	c	Ss	Source
Angada	1050 - 2800	24	44	15	0.45	Shambel Alemu, 2011
Aba Asrat	2100-2479	40	19	17	0.69	Gojjam Bayeh, 2013
Yemrehane Kirstos Church	2565-3135	24	35	15	0.51	Amanuel Ayanaw, 2016
Tara Gedam	2217-2457	26	33	15	0.52	Mohammed et al, 2014
Yelat	1699-3502	23	46	37	0.36	Sisay Tegegne, 2016
Boda	200-3288	25	34	14	0.51	Fekadu Erenso, 2014
Menagesha Suba state	2200-3385	43	16	69	0.5	Dinkissa Beche, 2011
Sanka Meda	1200 - 3574	29	30	53	0.44	Shambel Bantewalu, 2010

Table 9: Phyto-geographical comparisons between Sekelamariam and other forests

Sorensen's similarity index which is dependent on the number of common species shared by the forests being compared indicated that Sekelamariam and Aba Asrat monastery forests show the highest similarity (69%). This was followed by Tara Gedam, Yemrehane Kirstos church forest and Boda dry ever green forests with similarity of 52%, 51%, and 51% respectively (Appendix 5).

The Sekelamariam and Yelat forest forests had the lowest similarity of 36%. The implication for high similarity between Sekelamariam and Aba Asrat monastery forests is that both forests are located close to each other on the West - East Gojjam landmass of the same altitudinal range as well as geological formation and topography.

On other side these two places are located in the same vegetation type, the dry evergreen montane forest as well as the same sampling method followed during the study. Tara Gedam and Yemrehane Kirstos church forest also have high similarity with Sekelamariam forest due to all are located on northern Ethiopia high lands. Dissimilarities between Sekelamariam and Yelat & Angada forests may arise from their location (far apart from Sekelamariam forest), altitudinal differences and climatic conditions.

The distribution range of a species which is controlled by environmental factors and evolutionary changes that greatly influence the potential range of species may also indicates high dissimilarity between species confined to Sekelamariam and those two forests.

Appendix 6: Materials and activities during data collection

Management practices and threats to sekelamariam forest

As it was seen during field work, Sekelamariam forest is poorly protected by all the concerned bodies including local communities. Agriculture is the main threat, coupled with exploitation of trees for fuel wood and timber. The expanding rural population in the area which utilizes this forest for construction material, firewood and charcoal, and also urban peoples use for firewood threatened the forest. In addition, the forest provides grazing area to the local communities. This may have a greater influence on the regeneration of species. Even if, local peoples are symbolized as guarded for the forest, currently the conservation status of the Sekelamariam forest is at low stage (from field observation). At present, the largest proportion of this forest has been burned and cleared for cultivation, grazing and the forest shows shrinkage (information from local community). Disturbances are important determinants of species distribution and

community structure (Ermias Aynekulu, 2011). These factors are important and need to be considered in the design of biodiversity conservation programs. Soil moisture is a major limiting factor for the regeneration of dry forest species (Ermias Aynekulu, 2011). Thus, maintaining a high canopy cover may create a better soil moisture environment for a successful regeneration and seedling establishment.

Conclusions

This study generated knowledge on diversity, structure and regeneration status of the woody species in the less studied forest of Sekelamariam. This forest is one of a few remaining dry ever green forest of North West part of Ethiopia. Fifty nine species of woody species belonging to 39 families and 38 genera were identified. Family Fabaceae was the most dominant followed by Euphorbiaceae and Rosaceae. Three woody plant species endemic to Ethiopia that has been recorded in the red data list of IUCN were found in the study forest. The density of woody species in Sekelamariam forest decreases with increasing DBH and height classes implying good recruitment. However, analysis of population structure of most common species of trees and shrubs revealed different patterns of population structure, indicating a high variation among species. Disaggregating the population structure of the most common species indicated that a reversed J-shape, J- shape, Bell shape, and irregular patterns. These later three population dynamics within the forest revealed the signs of disturbances and implies that the populations with an unhealthy population structure are at high risk of depletion. Thus in the long run Sekelamariam forest may risk ecosystem simplification. It is investigated that economically important indigenous species such as Hagenia abyssinica and Prunus Africana were poorly represented. Moreover, Hagenia abyssinica was the most critically vulnerable species followed by Olea europaea and Prunus africana. This pattern is mainly the result of selective harvesting of locally useful species and associated unfavorable micro environment for recruitment.

Recommendations

Sekelamariam forest and its woody species inside the forest are the potential stock for future genetic resources and have a significant contribution to the people in the area. The loss of forest would have great local, regional as well global implications for the environment, biological diversity and socio-economic importance setup of the local communities. Hence, the study recommended effective conservation and management of the forest in a sustainable way should be applied. Subsequent ecological studies are vital concerning species composition, diversity, and distribution of possible plant communities with respect to human and other environmental factors. Raising awareness of local communities on the value of forest resources and ecological consequences of deforestation. Creating mechanisms such as participatory forest management by which human impacts can be minimized through discussion and consultation with the local communities. The present study was limited to diversity, and community type woody species, further studies on soil seed bank and soil property, seed physiology, detailed ethno- botanical studies, herbaceous plants and land use management system in the area are recommended. Based on the finding, the forest has to be managed for biological diversities found in the area and for carbon sequestration. Tree planting by the local community has to be encouraged to reduce the pressure on the natural forests and natural regeneration of species in the forest can be facilitated through reduced grazing pressure.

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