



Vegetation structure in pioneer forest patches of wombera district, Benshangul, Gumuz regional state, Ethiopia

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Abstract

Three Forest patches in Wombera district, Benshangul, Gumuz regional state, Ethiopia, were evaluated for vegetation structures along succession gradients. Three pioneer forest patches were selected, to study patch dynamics in species composition and structures along disturbance gradients. Along with altitude, transect lines were laid 300 meters apart; plots were laid every 150 meters along the transects. Cover-abundance, height, DBH of woody plant species, and landscape variables were recorded in 54 (20× 20) main quadrants. In five (5 m × 5m) in each quadrant, nested in the larger quadrates: shrubs, seedlings, and saplings were collected. In 1 m × 1 m quadrants nested in the 5 m × 5m quadrants herbs and grass species were collected. Frequency, density and abundance were calculated by using excel. Diversity, evenness and richness analyzed by R-software version 4.3. The IVI of a species signifies the sum of its relative density, relative frequency and relative dominance. Along with the vertical structure, the vegetation was stratified into lower, medium, and upper canopy layers. Lower canopy trees had the highest frequency, density, dominance, and IVI than middle and upper canopy trees respectively. Pioneers trees can grow and survive under poor soil.

Keywords: vegetation structure, frequency, important value index, density, abundance, pioneer

Introduction

Ethiopia owns extreme altitudinal ranges from lowland below sea level (Danakil Depression 110 mbsl) to top mountains (Ras Dashen (4532masl) (Woldu, 1999) ^[1]. The Great Rift Valley is also the other landscape that runs from northeast to southwest of the country and separates the country into Northwestern and Southeastern highlands enables to own semi-arid lowlands to the east, south, and west of the country (Friis, 1986; Bekele, 1993) ^[2, 3]. These diversified landscapes and altitudinal ranges have given rise to diversified agro-ecological zones, temperature, rainfall patterns, soil texture, and wind patterns in Africa (Friis *et al.*, 2010) ^[4]. The diversified environmental conditions and landscapes also resulted in diversified flora and fauna (Bekele *et al.*, 1999; Woldu, 1999) ^[1, 5].

Ethiopia is home to about 6,500 species of higher plants with approximately 12% endemism, and hence one of the six plant biodiversity-rich countries of Africa (UNEP, 1995) ^[6]. Ethiopia also has two of the 34 global biodiversity hotspots, namely the Eastern Afrotropical and Horn of Africa biodiversity hotspots (Myer *et al.*, 2000) ^[7]. Ethiopia is a regional centre for biological diversity due to its wide range of altitude, its high geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains (Kelbessa *et al.*, 1992; Woldu, 1999) ^[1, 8].

In contrast, many studies show that most of the vegetation cover of the country has been deforested and few remnant high land forests remaining southwestern and western parts and as patches in conservation areas, churches (Bekele, 1993) ^[3] and sacred sites in the country (Friis, 1992; Wassie *et al.*, 2005; Senbeta, 2006; Demissew & Friis, 2009) ^[9-12]. Ethiopian highlands were the oldest settlement regions of the country (Woldu, 1999; Friis *et al.*, 2011) ^[1, 13].

Vegetation structure of Forest was characterized using Height, DBH size class distribution, density, frequency and basal area (Bekele, 1994) ^[14]. Frequency is the number of sampling plots in which a given species occurred in the study area. It gives an indication for homogeneity and heterogeneity of given vegetation (Lamprecht, 1989) ^[15]. Frequency classes show floristic homogeneity or similar and heterogeneity species composition (Aye *et al.*, 2014) ^[16]. According to Gentry (1988) ^[17], the density of woody plants in the montane forests of 132 Africa is relatively high as compared to other tropical montane forests. The results of a basal area analysis provide a better measure of the relative dominance of woody species in a forest (Cain and Castro, 1959) ^[18]. Importance Value Index (IVI) is an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht, 1989) ^[15]. It combines data from three parameters, i.e., relative frequency, relative density and relative dominance (Kent and Coker, 1992) ^[19], and hence many ecologists consider it as the most realistic aspect of vegetation study (Curtis and McIntosh, 1950) ^[20]. This study investigated the vegetation

structure and composition of three pioneer forests (10- 20 years) by using frequency, abundance, density, dominance and important value index.

Materials and methods

1. Descriptions of the study area

Wombera ditrict is 658km from Addis Ababa, the capital city. It is found in the Metekel administrative zone of Benishangul Gumuz national regional state in the northwestern part of Ethiopia. The district is one of the largest districts in the Metekel administrative zone. It is bounded by the districts of Guba and Dangur in the north, Bullen in the east, Agallometi, and Yaso in the south, and Serba Abbay and Sherkole in the west. The latitudinal and longitudinal extent of the district range from $9^{\circ} 57' 30''$ to $11^{\circ} 08' 45''$ N and $35^{\circ} 09' 09''$ to $35^{\circ} 50' 25''$ E respectively (Fig.1).

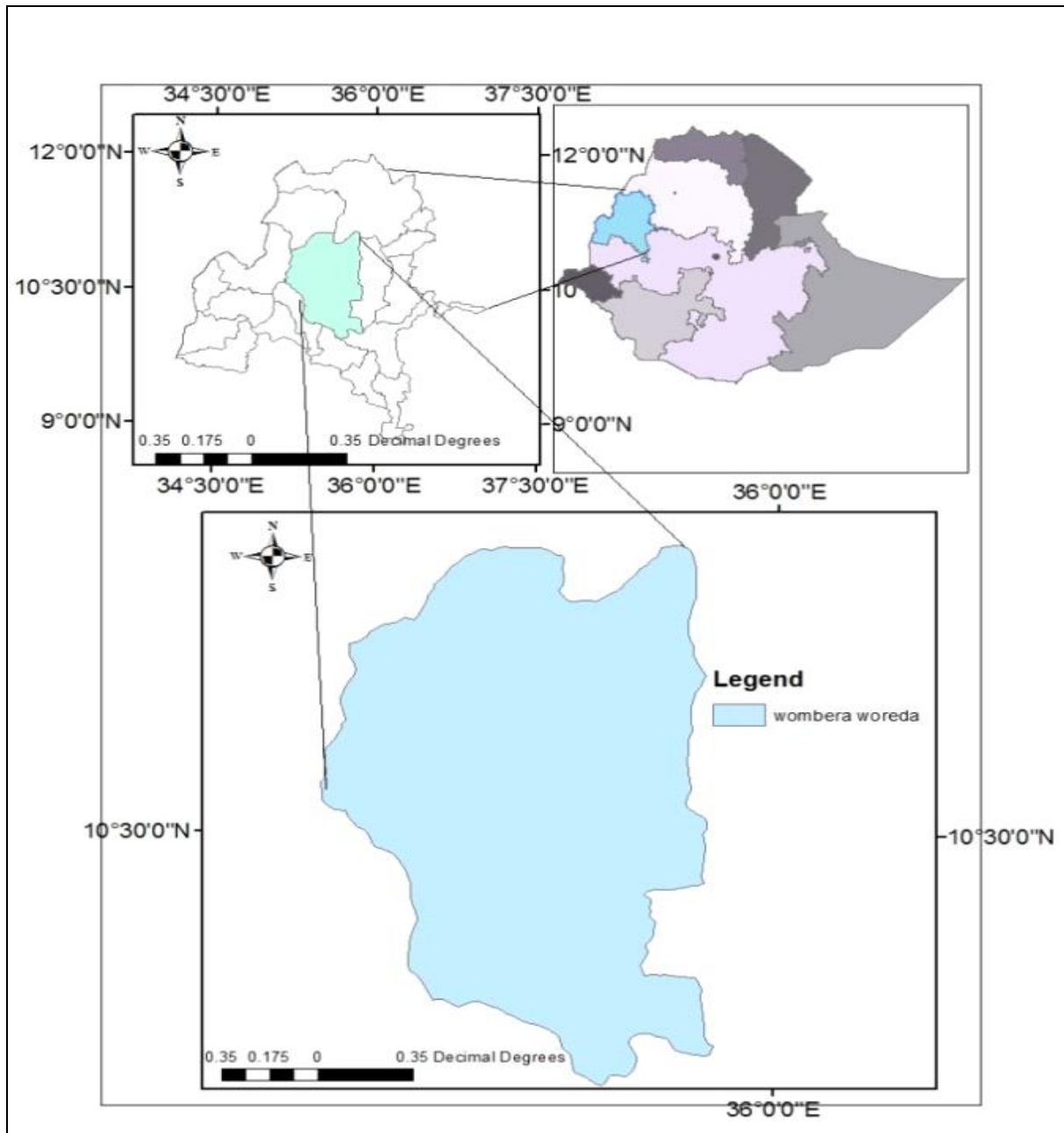


Fig 1: Map of Wombera district

2. Climate and temperature

Nineteen years of climate data were taken from Ethiopian metrological station. Annual temperatures range between a minimum of 7.2°C and maximum of 26°C with average 15.9°C . The average annual rainfall was 1942mm (Fig. 2).

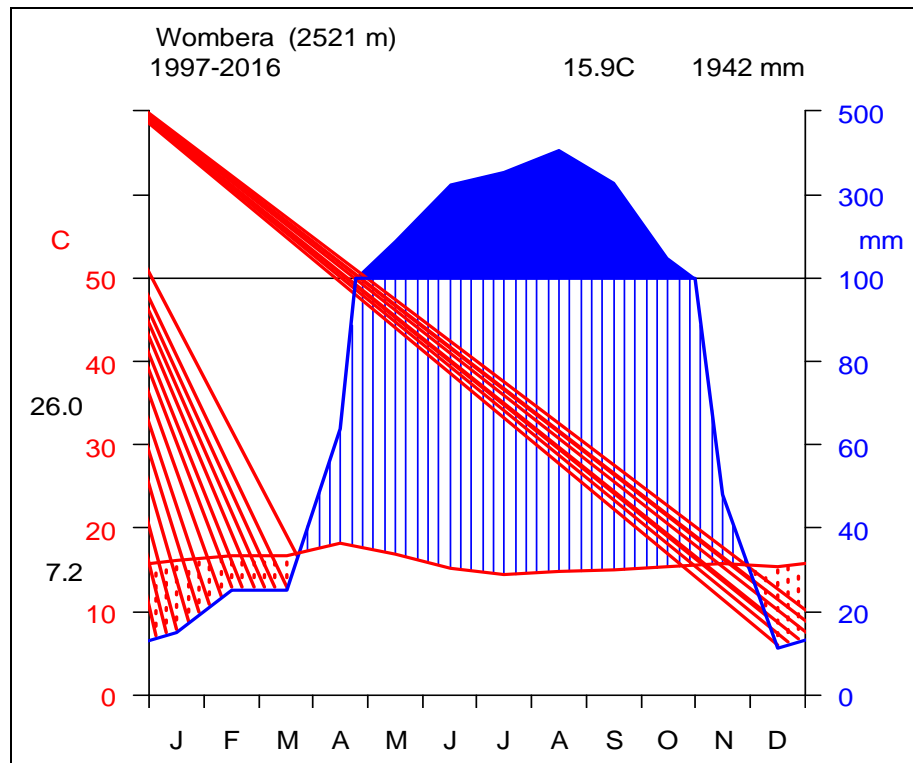


Fig 2: Climate diagram of wombera district showing temperature and rain full from 1997-2006

Sampling design and procedure

Forest patch selection

The forest patches were selected based on their accessibility and distance from roads and residents. Gesengesa-Tumi forest patch (GTFP), Senkora-Lopi patch (SLFP) and Menesib-Babo patch (MBFP), Bolele-Minjo patch (BMFP); were selected to study patch dynamics in species composition and structure along disturbance gradients in pioneer forests.

The local communities have indigenous cultural practice to conserve a forest. They names of the forest were given after distinguished person or leader of clan. A forest named after a person were not freely over-extracted. They also conserve forests for keeping honey bee hives, farming, hunting, and shelter for cattle during long rainy season, harvesting medicinal plant, and making house utensil and farm tools. However, in the last two to three decades an administrative change was made to control armed rebel and conflict among ethnic groups. These situations aggravated the unwise uses the forest resources. On the other hand, the abandonment farm land due to the administrative change in recent years has created a favorable condition for rehabilitation of forest vegetation. As result the Classifications of forest were mainly based on age of forest and disturbance level. The disturbance levels were classified based on intensity, frequency, severity and extent of disturbances (Ayenekulu, 2011) ^[21]. Age based classification was carried out with assistance of focused group discussions with residents living around the forest area. The forests were classified into three age classes. Each age classes of forest were reclassified based on anthropogenic and natural disturbance levels.

Vegetation data were collected in pioneer forest patches of different age classes (pioneer, intermediate and climax) at the end of rainy season, from November to December 20018 in three forest patches (GTFP, SLFP, MBFP) A series of nested quadrates following (Stohlgren *et al.*, 1995) ^[22] were established at 150 m intervals along parallel transect which were 300m apart along altitudinal gradient. The following quadrates sizes were used: (1) in 20 m × 20 m with trees with stem diameter at breast height (DBH) >2.5 cm were collected; (2) in 5 m × 5 m quadrates nested in the larger quadrates shrubs, seedlings, saplings and in (3) 1 m × 1 m quadrates nested in the 5 m × 5 m quadrates herbs and grass were collected.

All plant specimens were collected, temporarily tagged with plot numbers and temporary labels assigned to species (fast method), pressed and brought to the National Herbarium (ETH) for identification and storage. Species were identified at the National Herbarium (ETH) of Addis Ababa University by using the taxonomic keys in the various volumes of the Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989; Edwards *et al.*, 1995; Phillips, 1995; Edwards *et al.*, 1997; Hedberg *et al.*, 2003; Tadesse, 2004; Hedberg *et al.*, 2006, 2009a, 2009b) ^[23-31]. The specimens were also compared with authenticated specimens. Botanical names and authorities were verified using the species and family lists in Volume 8 of the Flora of Ethiopia and Eritrea (Hedberg *et al.*, 2009) ^[31].

Data analysis

Floristic richness, diversity and evenness indices were calculated using R Package 3.4.3 (Zerihun woldu, 2017) ^[32].

Frequency and Relative Frequency of species

Frequency is defined as the probability or chance of finding a species in a given sample area or plots. Relative frequency in this study is expressed as a percentage of the total number of plots in which individuals of a given species were recorded divided by the sum total number of the plots taken in the study area.

The following formulas were used in Microsoft Excel spreadsheet programme.

$$\text{Frequency (F)} = \frac{\text{Number of plots in which species occur}}{\text{Total plots laid}}$$

$$\text{Relative frequency (R}_{fi}) = \frac{\text{Frequency of species}}{\text{Total frequencies}} * 100$$

Population structure (DBH and height class distributions)

The study on the population structure, which is defined as the frequency and distribution of individuals defined by DBH or height classes, was carried out for woody species based on most widely used DBH and height classes in Ethiopia (Dalle, 2015; Berhanu *et al.*, 2017) [33-34].

The population structure is important indicator of forest reproduction and recruitment (Schulz *et al.*, 2009) [35].

Woody species density, basal area and dominance

Density (De) - is the number of individuals per unit area. It is calculated from the count of all the individuals from the study area on hectares basis (Mueller-Dombois and Ellenberg, 1974) [36]. Woody species density was expressed as number of individuals of a species per hectare. The density and relative density of woody species were computed in Microsoft Excel Spreadsheet program. The total species density, which is expressed as the sum total of all Individuals of all species in a hectare was also computed to calculate the relative density. Density was calculated using the following formula:

$$\text{Density (De)} = \frac{\text{Number of species counted}}{\text{Sampled area in hectare}}$$

The relative density was calculated using the following formula:

$$R_{de} = \frac{De}{\sum_{i=1}^s De} * 100$$

Where, R_{de} is the relative density of a species and De is density of the i^{th} species (s); Basal area ($m^2 ha^{-1}$) measured as the cross-section area of a tree at breast height, is computed from the measurement of DBH as follows in Microsoft Excel spreadsheet programme: $Ba = \pi d^2/4$, where $\pi = 3.14$, Ba is basal area, and d is DBH (m). However, since DBH was measured in centimeters, the formula was converted to square meters. Thus, $Ba = \pi d^2/40,000$ or $0.0000785d^2$, where d is DBH in centimeters. The mean basal area of all investigated plots was converted to mean basal area per hectare. Basal area provides a better measure of the relative importance of tree species than Simple stem counts (Bekele, 1993) [3].

The dominance and relative dominance were calculated as follows:

$$Do = Bi \times Ni,$$

Where Do is dominance of a species, Bi is mean basal area per species and Ni - number of Individuals in the i^{th} species

$$R_{do} = \frac{Do_i}{\sum_{i=1}^s Do_i} * 100$$

Where, R_{do} is relative dominance and Do_i is dominance of the i^{th} species (s).

The variations of structure (density, basal area and dominance) among the forest patches was

Important value index (IVI)

Importance Value Index (IVI), besides its use in indicating the relative ecological importance of a given woody species in a particular site, is one of the important tools used to identify threatened woody plants in a specific site or area (Kent And Coker, 1992) [19]. The IVI of a species signifies the sum of its relative density (RDE), relative Frequency (RFR) and relative dominance (RDO). That is, $IVI = RDE + RFR + RDO$. The IVI was computed in Microsoft Excel spreadsheet programme. Consequently, woody species having the least IVI values were prioritized for the purpose of conservation and management interventions.

Results

1. Composition and diversity

MBFP intact part had the highest species and Shannon diversity followed SLFP and GTFP. GTFP highly disturbed forest patches had highest species richness (Table1).

Table 1: species richness and diversity in pioneer forests

Forest patches	Index	Intact	Mdis	HDI
GTFP	Richness	32	33	39
	H	3.26	3.31	3.43
	SH. Evnness	0.95	0.95	0.94
SLFP	Richness	39	43	31
	H	3.49	3.59	3.27
	Sh. Evnness	0.98	0.95	0.95
MBFP	Richness	45	50	31
	H	3.64	3.77	3.27
	Sh. Evnness	0.98	0.95	0.95

GTFP= Gesengesa-Tumi forest patch, SLFP = Senkora-Lopi Forest patch, MBFP= Menesibu-Babo forest patch, Int=intact, Mdis=moderately disturbed and Hdis=highly disturbed, SH= Shannon diversity

2. Structure woody Species

2.1 Frequency of woody plants in pioneer forests

Acacia abyssinica, *Maesa lanceolata*, *Nuxia congeta*, and *Maytenus arbutifolia* were the most common lower layer canopy species in Pioneer forests, followed by Shrubs and climbers *Vernonia amygdalina*, *Bersama abyssinica*, and *Brucea antidysenterica*. *Hagenia abyssinica*, *Dombeya torrida*, and *Allophylus abyssinicus* were the most common intermediate layer canopy trees, in that order. The trees in the top canopy were the least abundant (Table 2, 3& 4)

2.2 The density of woody species pioneer forests

The lower canopy trees had the highest density per hectare; dominant species, for instance, *Acacia abyssinica* had the highest density per hectare in GTFP, SLFP and MBFP. In MBFP, GTFP, and SLFP, *Maesa lanceolata* had the highest density per hectare; however, in SLFP, GTFP, and MBFP, *Nuxia congeta* had the highest density per hectare. In MBFP, GTFP, and SLFP, *Maytenus arbutifolia* had the highest density per hectare. Among the middle layer canopy trees, *Hagenia abyssinica* had the highest density in SLFP and GTFP. *Dombeya torrida* has the second-highest density per hectare in SLFP. In the upper layer canopy tree, *Syzygium guineense* had the highest density in GTFP and MBFP, while *Apodytes dimidiata* in GTFP and SLFP and *Ekebergia capensis* in GTFP and MBFP had the highest density per hectare (Table 2, 3& 4).

2.3 Basal area and dominance of woody species in pioneer forests

Acacia abyssinica, *Nuxia congeta*, *Maytenus arbutifolia*, and *Maesa lanceolata* in GTFP; *Nuxia congeta*, *Acacia abyssinica* and *Maesa lanceolata* in SLFP; and *Maesa lanceolata*, *Nuxia congeta* and *Maytenus arbutifolia* in MBFP had the highest basal area per hectare respectively in the pioneer forests. *Bersama abyssinica*, *Vernonia amygdalina* from GTFP; *Rosa abyssinica*, *Rubus steudneri*, *Stephania abyssinica*, *Bersama abyssinica*, *Rosa abyssinica* and *Rubus steudneri* in MBFP were the most dominant shrub species in the pioneer forest patches.

Allophylus abyssinicus exhibited the largest basal area per hectare among the intermediate layer canopy trees in three forest patches, followed by *Hagenia abyssinica* in SLFP and *Dombeya torrida* in MBFP. Among upper canopy trees *Apodytes dimidiata*, *Ekebergia capensis*, *Prunus africana* in MBFP, and *Apodytes dimidiata* in GTFP had the highest basal area per hectare (Table 2, 3&4)

2.4 Importance value index of woody species in pioneer forests

Among Lower layer canopy trees in GTFP, *Acacia abyssinica*, *Nuxia congeta*, *Maesa lanceolata* and *Maytenus arbutifolia*; *Nuxia congeta*, *Acacia abyssinica*, *Maesa lanceolata* and *Maytenus arbutifolia* in SLFP; *Maesa lanceolata*, *Maytenus arbutifolia*, and *Nuxia congeta* in MBFP had the highest IVI value. Among the shrubs, *Bersama abyssinica* and *Vernonia amygdalina* in GTFP; *Rosa abyssinica*, *Rubus apetalus* and *Stephania abyssinica* in SLFP; and *Bersama abyssinica* and *Vernonia amygdalina* in MBFP had the highest IVI value. In the middle layer canopy trees, *Allophylus abyssinicus* in GTFP and MBFP, and *Dombeya torrida* from SLFP had the highest IVI. *Syzygium guineense* from GTFP and MBFP and *Apodytes dimidiata* from SLFP had the highest IVI value among the top upper canopy trees (Table 2, 3&4).

Table 2: Population structure of pioneer forest patches in GTFP

Species	PT	CT	F	Ab	Rfr	Ba	Do	Rdo	De	Rde	IVI
<i>Acacia abyssinica</i>	T/Sh	LC	9	62	6.66	1.75	109	31.14	172.22	14.6	52
<i>Nuxia congeta</i>	T/Sh	LC	7	55	5.18	1.55	85	24.5	152.78	12.95	43

<i>Maesa lanceolata</i>	T/sh	LC	8	45	5.92	1.41	64	18.23	125	10.59	35
<i>Maytenus arbutifolia</i>	T/sh	LC	5	40	3.7	1.13	45	12.96	111.11	9.42	26
<i>Syzygium guineense</i>	T	UC	4	17	2.96	0.8	14	3.9	47.22	4	11
<i>Vernonia amygdalina</i>	sh	LC	6	16	4.44	0.5	8	2.3	44.44	3.77	11
<i>Bersama abyssinica</i>	T/sh	LC	6	19	4.44	0.04	0.7	0.2	52.78	4.47	9.1
<i>Brucea antidysenterica</i>	sh	NC	7	11	5.18	0.26	2.9	0.83	30.56	2.59	8.6
<i>Hagenia abyssinica</i>	T	MC	6	10	4.44	0.47	4.7	1.35	27.78	2.35	8.1
<i>Periploca linearifolia</i>	CL	NC	6	14	4.44	0.02	0.3	0.09	38.89	3.3	7.8
<i>Rubus steudneri</i>	CL	NC	6	11	4.44	0.02	0.2	0.07	30.56	2.59	7.1
<i>Allophyllus abyssinicus</i>	T	MC	6	7	4.44	0.33	2.3	0.66	19.44	1.65	6.8
<i>Stephania abyssinica</i>	CL	NC	5	12	3.7	0.01	0.1	0.03	33.33	2.82	6.6
<i>Rosa abyssinica</i>	CL	Nc	6	7	4.44	0.01	0.1	0.03	19.44	1.65	6.1
<i>Acanthus pubescens</i>	Sh	Nc	6	6	4.44	0	0	0	16.67	1.41	5.9
<i>Apodytes dimidiata</i>	T	UC	4	9	2.96	0.28	2.5	0.73	25	2.12	5.8
<i>Ekebergia capensis</i>	T	UC	3	8	2.22	0.31	2.5	0.72	22.22	1.88	4.8
<i>Pittosporum viridiflorum</i>	Sh	LC	3	8	2.22	0.02	0.2	0.05	22.22	1.88	4.2
<i>Prunus africana</i>	T	UC	3	5	2.22	0.24	1.2	0.34	13.89	1.18	3.7
<i>Vernonia ruppellii</i>	Sh	NC	3	6	2.22	0.02	0.1	0.03	16.67	1.41	3.7
<i>Rhoicissus tridentata</i>	CL	NC	3	6	2.22	0.01	0.1	0.02	16.67	1.41	3.7
<i>Teclea nobilis</i>	Sh	LC	2	7	1.48	0.22	1.5	0.44	19.44	1.65	3.6
<i>Olea europaea</i>	T	UC	3	4	2.22	0.19	0.8	0.22	11.11	0.94	3.4
<i>Salix mucronata</i>	T	MC	2	6	1.48	0.19	1.1	0.32	16.67	1.41	3.2
<i>Rhus glutinosa</i>	T	MC	2	5	1.48	0.16	0.8	0.23	13.89	1.18	2.9
<i>Rytigynia neglecta</i>	T	LC	2	5	1.48	0.12	0.6	0.17	13.89	1.18	2.8
<i>Ficus sure</i>	T	UC	2	4	1.48	0.22	0.9	0.25	11.11	0.94	2.7
<i>Solanum marginatum</i>	sh	NC	2	5	1.48	0	0	0.01	13.89	1.18	2.7
<i>Justicia schimperiana</i>	CL	NC	2	5	1.48	0	0	0.01	13.89	1.18	2.7
<i>Rhus vulgaris</i>	T	LC	2	4	1.48	0.09	0.4	0.11	11.11	0.94	2.5
<i>Rubus apetalus</i>	CL	NC	2	3	1.48	0.05	0.2	0.05	8.33	0.71	2.2
<i>Phytolacca dodecandra</i>	CL	NC	2	3	1.48	0.03	0.1	0.03	8.33	0.71	2.2

F=Frequency, Ab=Abundance, Do= Dominance, Rfe= relative frequency, Ba=Basal area, De=Density, Rde= Relative density, Rdo=Relative dominance, and IVI= important value index, LC = Lower canopy, MC = Middle canopy, UC = Upper canopy, NC = None canopy, PT= Plant type, CT= Canopy type, T= tree, Sh= shrub/L= climber or lianas

Table 3: Population structure Senkora-Lopi pioneer forest patches in SLFP

Species	PT	CT	F	Ab	Rfe	Ba	Dom	Rdo	De	Rde	IVI
<i>Nuxia congeta</i>	T/Sh	LC	9	58	8.25	1.64	95.1	30.96	161.1	14.54	53.8
<i>Acacia abyssinica</i>	T/Sh	LC	9	50	8.25	1.57	78.5	25.56	138.9	12.54	46.4
<i>Maesa lanceolata</i>	T/sh	LC	9	40	8.25	1.13	45.2	14.72	111.1	10.03	33
<i>Maytenus arbutifolia</i>	sh	LC	7	35	6.42	1.37	48.1	15.66	97.22	8.77	30.9
<i>Dombeya torrida</i>	T	MC	8	15	7.34	0.71	10.6	3.45	41.67	3.76	14.6
<i>Hagenia abyssinica</i>	T	MC	5	15	4.59	1.06	15.9	5.18	41.67	3.76	13.5
<i>Rosa abyssinica</i>	CL	NC	5	18	4.59	0.02	0.41	0.13	50	4.51	9.23
<i>Apodytes dimidiata</i>	T	UC	4	9	3.67	0.71	6.36	2.07	25	2.26	7.99
<i>Rubus apetalus</i>	CL	NC	4	13	3.67	0.04	0.48	0.16	36.11	3.26	7.08
<i>Rubus steudneri</i>	CL	NC	4	13	3.67	0.03	0.33	0.11	36.11	3.26	7.04
<i>Vernonia amygdalina</i>	Sh	LC	4	12	3.67	0.09	1.13	0.37	33.33	3.01	7.04
<i>Acanthus pubescens</i>	Sh	NC	4	13	3.67	0.02	0.2	0.06	36.11	3.26	6.99
<i>Stephania abyssinica</i>	CL	NC	4	12	3.67	0.02	0.18	0.06	33.33	3.01	6.74
<i>Brucea antidysenterica</i>	Sh	NC	3	14	2.75	0.02	0.25	0.08	38.89	3.51	6.34
<i>Bersama abyssinica</i>	Sh	LC	3	13	2.75	0.02	0.21	0.07	36.11	3.26	6.08
<i>Phytolacca dodecandra</i>	CL	NC	4	9	3.67	0.01	0.1	0.03	25	2.26	5.96
<i>Clematis simensis</i>	CL	NC	4	9	3.67	0.01	0.1	0.03	25	2.26	5.96
<i>Allophyllus abyssinicus</i>	T	MC	3	7	2.75	0.49	3.46	1.13	19.44	1.75	5.63
<i>Rhus glutinosa</i>	T	LC	3	10	2.75	0.08	0.79	0.26	27.78	2.51	5.51
<i>Jusminum abyssinicum</i>	CL	NC	3	10	2.75	0.01	0.13	0.04	27.78	2.51	5.3
<i>Pittosporum viridiflorum</i>	Sh	LC	2	13	1.83	0.02	0.21	0.07	36.11	3.26	5.16
<i>Ficus sure</i>	T	UC	2	6	1.83	0.57	3.39	1.1	16.67	1.5	4.44
<i>Prunus africana</i>	T	UC	2	6	1.83	0.42	2.54	0.83	16.67	1.5	4.17
<i>Ekebergia capensis</i>	T	UC	2	4	1.83	0.28	1.13	0.37	11.11	1	3.2

<i>Olea europaea</i>	T	UC	2	3	1.83	0.21	0.64	0.21	8.33	0.75	2.79

F=Frequency, Ab=Abundance, Do= Dominance, Rfe= relative frequency, Ba=Basal area, De=Density, Rde= Relative density, Rdo=Relative dominance, and IVI= important value index, LC = Lower canopy, MC = Middle canopy, UC = Upper canopy, NC =None canopy, PT= Plant type, CT= Canopy type, T= tree, Sh= shrub/L= climber or lianas

Table 4: Population structure in Menesibu-Babo pioneer forest patches

Species	PT	CT	F	Ab	Rfe	BA	Do	Rdo	De	Rde	IVI
<i>Maesa lanceolata</i>	T/Sh	LC	9	60	6.12	1.7	101.74	33.79	166.67	13.52	53.43
<i>Maytenus arbutifolia</i>	T/Sh	LC	8	62	5.44	1.46	90.53	30.06	172.22	13.97	49.47
<i>Nuxia congeta</i>	T/sh	LC	9	45	6.12	1.06	47.69	15.84	125	10.14	32.1
<i>Bersama abyssinica</i>	sh/sh	LC	9	25	6.12	0.03	0.79	0.26	69.44	5.63	12.02
<i>Maytenus undata</i>	T/Sh	LC	8	22	5.44	0.17	3.8	1.26	61.11	4.96	11.66
<i>Vernonia auriculifera</i>	Sh	NC	4	15	2.72	0.5	7.51	2.49	41.67	3.38	8.59
<i>Brucea antidysenterica</i>	Sh	LC	8	13	5.44	0.02	0.2	0.07	36.11	2.93	8.44
<i>Syzygium guineense</i>	T	UC	5	10	3.4	0.71	7.07	2.35	27.78	2.25	8
<i>Rubus apetalus</i>	CL	LC	4	14	2.72	0.44	6.15	2.04	38.89	3.15	7.92
<i>Vernonia amygdalina</i>	Sh	LC	4	15	2.72	0.35	5.3	1.76	41.67	3.38	7.86
<i>Rubus steudneri</i>	Cl	NC	6	16	4.08	0.02	0.3	0.1	44.44	3.6	7.79
<i>Rosa abyssinica</i>	Cl	NC	6	15	4.08	0.02	0.28	0.09	41.67	3.38	7.55
<i>Dombia torrida</i>	T	MC	5	12	3.4	0.34	4.07	1.35	33.33	2.7	7.46
<i>Kalanchoe petitiiana</i>	CL	NC	5	13	3.4	0.02	0.21	0.07	36.11	2.93	6.4
<i>Allophylus abyssinicus</i>	T	MC	4	9	2.72	0.49	4.45	1.48	25	2.03	6.23
<i>Rhamnus staddo</i>	CL	NC	3	12	2.04	0.28	3.39	1.13	33.33	2.7	5.87
<i>Stephania abyssinica</i>	CL	NC	5	10	3.4	0.01	0.13	0.04	27.78	2.25	5.7
<i>Ekebergia capensis</i>	T	UC	4	7	2.72	0.38	2.69	0.89	19.44	1.58	5.19
<i>Prunus africana</i>	T	UC	3	8	2.04	0.44	3.52	1.17	22.22	1.8	5.01
<i>Vernonia ruppellii</i>	Sh	NC	5	5	3.4	0.21	1.03	0.34	13.89	1.13	4.87
<i>Teclea nobilis</i>	Sh	LC	2	8	1.36	0.59	4.7	1.56	22.22	1.8	4.72
<i>Rhus vulgaris</i>	T/sh	LC	3	5	2.04	0.24	1.18	0.39	13.89	1.13	3.56
<i>Rumex nervosus</i>	sh	NC	3	6	2.04	0.01	0.04	0.01	16.67	1.35	3.41
<i>Periploca linearifolia</i>	CL	NC	4	2	2.72	0.15	0.29	0.1	5.56	0.45	3.27
<i>Phytolacca dodecandra</i>	CL	NC	2	8	1.36	0.01	0.08	0.03	22.22	1.8	3.19
<i>Ficus sure</i>	T	UC	3	3	2.04	0.22	0.66	0.22	8.33	0.68	2.94
<i>Rhus glutinosa</i>	T	LC	3	3	2.04	0.07	0.21	0.07	8.33	0.68	2.79
<i>Pittosporum viridiflorum</i>	Sh/T	MC	3	3	2.04	0.04	0.11	0.04	8.33	0.68	2.75
<i>Apodytes dimidiata</i>	T	UC	2	4	1.36	0.25	1	0.33	11.11	0.9	2.6
<i>Olea europaea</i>	T	UC	2	4	1.36	0.25	1	0.33	11.11	0.9	2.6
<i>Salix mucronata</i>	T	MC	2	4	1.36	0.13	0.5	0.17	11.11	0.9	2.43
<i>Rytigynia neglecta</i>	Sh/T	LC	2	4	1.36	0.13	0.5	0.17	11.11	0.9	2.43
<i>Rhoicissus tridentata</i>	CL	NC	2	4	1.36	0	0	0	11.11	0.9	2.26

F=Frequency, Ab=Abundance, Do= Dominance, Rfe= relative frequency, Ba=Basal area, De=Density, Rde= Relative density, Rdo=Relative dominance, and IVI= important value index, LC = Lower canopy, MC = Middle canopy, UC = Upper canopy, NC =None canopy, PT= Plant type, CT= Canopy type, T= tree, Sh= shrub/L= climber or lianas

Discussion

1. Richness and diversity

The species richness varied significantly along the disturbance gradients (intact, moderately disturbed and highly disturbed) in three forest patches (Table 1). Anthropogenic disturbances like livestock grazing and logging have altered an ecosystem's richness, variety, distribution pattern, and vegetation structure (Gebrehiwot et al., 2020) [37]. In moderately disturbed forest patches, the free space formed by disturbances allows the entry of other species. Moderate forest disturbances may allow less adaptable species to cohabit with more adaptable ones (Connell and Slatyer 1977) [38]. The highest Species evenness was in intact forest patches were due natural distribution of plant species. The less evenness in moderately disturbed forest patches was due to the extraction of forest resources by the residents.

2. Frequency

The highest frequency of lower canopy tree: *Acacia abyssinica*, *Nuxia congeta*, *Maytenus arbutifolia* and *Maesa lanceolata*, and shrubs *Brucea antidysenterica* and *Bersama abyssinica* is related to their fast growth rate, ease of dispersing, and ability to grow and mature under poor soil conditions.

3. Density in pioneer forest patches

The higher density woody trees in pioneer forests than intermediate and Climax forests correspondingly were attributed to the dominance of lower canopy trees. Many pioneer species may establish and expand in high density during early succession development until they reach the peak stage when competition eliminates many individuals (Girma, 2011)^[39]. Compare to other dry Afromontane forests, the density of total woody trees in pioneer forest patches: GTFP(1130 individuals ha⁻¹), SLFP 1180 individuals ha⁻¹), and MBFP(1238.89 individual ha⁻¹) were also higher than Bore-Anferara (1,047 individuals ha⁻¹)(Wolde Mariam,2017)^[40], Komto (952 individuals ha⁻¹) (Gurmessa *et al.*, 2012^[41]), Jibat (702 individuals ha⁻¹) (Burju *et al.*, 2013^[42]), and Gedo (781 individuals ha⁻¹) (Kebede *et al.*, 2014^[43]), however, the density of woody trees in pioneer forests were lower than Belete (1482 individuals ha⁻¹) (Hundera and Gadissa, 2008)^[44], Masha-Anderacha (1,709 individuals ha⁻¹) (Yeshitila and Bekele, 2003)^[45] and Tara Gedam (3,001 individuals ha⁻¹), Zege(Zegeye *et al.*, 2011)^[46] forests. In addition, the density of woody trees in intermediate and climax forests were less than above-cited forest patches.

4. Basal area and dominance woody tree types in pioneer forests

The Higher basal area and dominance of lower canopy trees were associated with their abundance in pioneer forests, followed by the upper canopy trees, which had larger diameters than the intermediate canopy tree species. The highest basal area per hectare of lower canopy trees species: *Acacia abyssinica*, *Nuxia congeta*, *Maytenus arbutifolia*, and *Maesa lanceolata* in GTFP, *Nuxia congeta*, *Acacia abyssinica* and *Maesa lanceolata* in SLFP and *Maesa lanceolata*, *Nuxia congeta* and *Maytenus arbutifolia* in MBFP are related to their high frequency and abundance in pioneer forest patches. The basal area per hectare of species with high use-value is less than species with lower use value such as *Syzygium guineense* and *Apodytes dimidiata*.

5. Importance value index of woody species in GTFP Pioneer forests

Among the vegetation evaluating parameters, Importance Value Index (IVI) is an important parameter of the ecological significance of species (Lamprecht, 1989)^[15]. It is a combination of three parameters, i.e., relative frequency, relative density and relative dominance (Kent and Coker, 1992)^[19]; hence many scholars believe that IVI value is the most indicator of the ecological significance of species (Curtis and McIntosh, 1950)^[20]. The IVI of lower canopy trees in pioneer forests ranges from 26.08 to 52.39 in GTFP, 30.85 to 53.75 in SLFP, and 32.10 to 53.43 in MBFP, indicating that they have high ecological value. The IVI values *Acacia abyssinica* were highest in GTFP (52.39) and second SLFP (46.35) and absent in MBFP; In the GTFP and SLFP *Acacia abyssinica* is the best-known pioneer species which have high use value and multiple ways of regeneration; the roots grow into the stem when the stem part is removed or damaged. The soil seed bank and seed rain germinate massively, and the stem regenerate when the stem part is damaged; They are fast-growing species. In the pioneer forest patches, *Maesa lanceolata*, *Maytenus arbutifolia*, *Nuxia congeta* and *Acacia abyssinica* were the most important lower canopy trees to build the pioneer forests.

Conclusion

The frequency, density, abundance, relative density, dominance and important value index of Lower canopy trees: *Acacia abyssinica*, *Nuxia congeta*, *Maesa lanceolata* and *Maytenus arbutifolia* were highest in the pioneer forests followed none canopy, middle and upper canopy trees in the three forest patches. Lower canopy trees are able grow and survive under poor soil condition: in abandon farm lands, bare lands and degraded area.

Abbreviation

Fig =Figure, DBH= diameter at breast height, F=Frequency, Rfr =Relative frequency, Ab=Abundance
Do= Dominance, Ba=Basal area, De=Density, Rde= Relative density, Rdo =Relative dominance
IVI= important value index, GTFP= Gesengesa-Tumi Forest patch, SLFP =Senkora-Lopi Forest patch
MBFP =Menesibu-Babo Forest patch, LC = Lower canopy, MC = Middle canopy, UC = Upper canopy, NC
=none canopy, PT = Plant type, CT = Canopy type, T= tree, Sh = shrub, C/L= climber or lianas, Int=intact,
Mdis=moderately disturbed and Hdis=highly disturbed

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Declaration of Competing Interest

Ethical statements

Data collection methods were conducted following the protocol of vegetation survey Guidelines. Data were accessed with the permission of government offices. Vegetation data collections were also recognized the community cultural values.

Authors declare no conflict of interest

Contribution: Girma Gudesho designed the research methods, collected and analyzed data, and organized the manuscript.

Zerihun Woldu (Prof): Supervise the researcher

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