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Vegetative structure, floristic composition and natural regeneration of a species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

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Abstract. *Tegegne S, Workineh B. 2017. Vegetative structure, floristic composition and natural regeneration of a species in* Ylat Forest *in Meket Woreda,* Northeastern *Ethiopia. Asian J For 1: 40-53.* The high level of biodiversity comprised in natural forests in Ethiopia is threatened by various anthropogenic factors. Therefore, efforts to reveal biodiversity information are urgently required before such forests are gone. This study aimed to examine taxonomic richness, floristic composition and structure, and natural regeneration of vegetation in natural forest of Ylat in Meket Woreda, Northeastern Ethiopia. A systematic sampling design was used in this study to gather vegetation information. For each of the sampling sites, five transect lines totaling fifty-four primary plots with 400 m2 (20m × 20m) each were laid out to gather information on woody species along 200m line transects. A total of 60 vascular plant species belong to 41 families and 56 genera were identified of which 13 species (21.67%) were trees, 31 species (51.67%) bushes, 6 species (10%) climbers and 10 species (16.66) of herbs. Of all the families of woody plants, Lamiaceae was the family with the largest contribution of species (8.33%), followed by Fabaceae, Rosaceae, Solanaceae and Euphorbiaceae with 3 species (5%), then Sapindaceae, Aloaceae, Ranunculaceae, Poaceae, Oleaceae, Polygonaceae and Cucurbitaceae contains 2 species each (3.33%). A total of 2652 woody plant species individuals (1227.77 individual/ha) were found of with the most abundant was *Myrsine africana* with 405 individuals, while *Millettia ferruginea* had the lowest with 19 individuals. The total basal area was 1 m2 /ha and frequency of woody species was 258. The overall Shannon-Wiener diversity and evenness indices of woody species was 2.94 and 0.84, respectively, both are classified as high in diversity and distribution. The woody plant species having the highest importance value index (IVI) were *Erica arborea* (36.31%) followed by *Allophylus abyssinicus* (28.65) whereas *Hagenia abyssinica*, *Myrica salicifolia*, *Euphorbia tirucalli*, *Calpurnia aurea* were the lowest IVI and should be given conservation priority. Finally, this study showed that the population structure of most woody plant species in Ylat Timberland was in a great state of regeneration recruitment level.

Keywords: Floristic composition, vegetation structure, regeneration status, Ylat Forest

INTRODUCTION

Ethiopia is considered as one of the top twenty-five richest countries in the world in terms of biodiversity (WCMC 1994). Around 6000 species of higher plants are estimated, of which about 10% are endemic (Ensermu and Sebsebe 2014). At the level of Africa, Anon (1997a, b) states that Ethiopia has the fifth largest flora. The very heterogeneous flora and high endemism are considered to be caused by the diversity in climate, vegetation and terrain. A report from Kelbessa et al. (1992) indicated that six endangered endemic plant species are found in Ethiopia especially in the Ogaden region only, which is floristically the richest in endemism in Ethiopia.

Vegetation is defined as an assemblage of plants growing together in a particular location and characterized either by its component species or by the combination of structural and functional characters that determine the appearance or physiognomy of vegetation (Goldsmith et al. 1986). In some definitions, vegetation is referred exclusively to as a system of largely spontaneously growing plants, meaning that not all growing plants form vegetation. For instance, a sown cornfield or flower bed in a garden forms no vegetation, but the weeds surrounding such plants do form vegetation. A pine plantation will turn into vegetation after a few years of spontaneous growth of the pine trees. The complexities of vegetation arise from the great variation in altitude, temperature, humidity and rainfall (Woldu 1999).

The vegetation of Ethiopia is complicated. There is a variation from region to region; some regions of the country including in southern and southwestern parts of the countries are relatively richer in biodiversity than the other parts of the countries. Vegetation types in Ethiopia are also highly diverse, including Afroalphine and Sub Afroalphine, Dry evergreen montane forest and grassland, Moist evergreen montane forest, Evergreen scrub, Combretum Terminalia (broad-leaved) deciduous woodland, Acacia-Commiphora (small-leaved) deciduous woodland, Lowland semi-evergreen forest, The desert and semi-desert scrubland, and Riparian and swamp vegetation (Friis and Demissew 2001).

Ethiopia is also a very important center of crop genetic diversity and for this reason, it is one of the twelve Vavilovian centers (Vavilov 1951; Harlan 1969). It has a very high genetic diversity in four of the world's widely grown food crops (i.e., wheat, barley, sorghum and peas), in three of the world's most important industrial crops (i.e., linseed, cotton, castor bean), in the world's most important cash crop (coffee), and in food crops of regional and local importance (i.e., teff, finger millet, nug, sesame, enset) (EPA 1997).

However, the vegetation resources, including forests are being devastated at an alarming rate, due to a number of causes. The primary causes for the devastation of natural forests are agriculture (the expansion and the conversion of natural vegetation to farmland) and overexploitation for various purposes such as fuelwood, cultivation purpose, charcoal production, construction material and timber, uncontrolled utilization of natural founts (over-consumption). Additionally, forest fires, land degradation, habitat loss, drying of water bodies, soil erosion and fragmentation, invasive species, and wetland destruction (drying of water bodies) lead to the decline of forest and forest resources. All are accelerated by rapid human population growth which is at a rate of about 3%/yr. Bad management of stakeholders such as Zone, Woreda and Kebele rural and agricultural organizations also leads to the decline of natural high forests. If this situation continues unchecked, the natural forest will be gone in a few decades.

Deforestation and land degradation lead to ecological and socio-economic crises in Ethiopia (Lisanework 1987). The current rate of deforestation is 15000-20000 hectares per year (EFAP 1994). In case of the above factors, Ethiopia‘s forest area reduced from 16% in the 1950s and to 3.1% by 1982 (UNEP 1992). According to Yirdaw (1996), the annual loss of the highland montane forest areas of Ethiopia has been estimated between 160,000 and 200,000 ha.

Because of the rapid deforestation, forests plant and animal species that are important both at national and global levels are in the state of endangered now. This is mainly attributed to lack of proper conservation strategies and practices of forest and forest resources (Kelbessa et al. 1992). As the plant and animal species are lost from the area, the indigenous knowledge and associated practices will also be obscured and finally will be gone forever. Consequently, the danger certainly poses a major threat to the well-being of the population that depends on the biological resources of this ecosystem (Beyene 2010).

Most of the remaining natural forests in Ethiopia are found in the southern and south-western parts of the country, and the forests have virtually disappeared from the rest of the country except a few scattered and relatively small areas of forest cover that remained in the northern, central and eastern parts of the country (Gebre Egziabher 1986). Generally, the remaining forests are only small remnant patches mostly confined to inaccessible areas (e.g., mountain tops and steep slopes) and sacred places (e.g., churches, monasteries, and mosques) (Wassie et al. 2002). With the prevailing alarming rate of deforestation and other factors described above, the remaining natural forests could disappear within a few decades, unless appropriate and immediate measures are taken (Zegeye et al. 2010).

In Ethiopia, many ecosystems or habitats being important for biodiversity conservation are excluded from the country’s system of protected areas. Hillman (1993) described that some protected areas at different levels have been built by the government with a total extent of 193,600 Km^2 of land. The Wildlife Conservation Areas are divided into two main categories, namely Principal Wildlife Conservation Areas, which include nine National Parks and four Wildlife Sanctuaries, and Secondary Wildlife Conservation Areas (WCA) comprising eight Wildlife Reserves and eighteen Controlled Hunting Areas (CHA). But up to now, there is no formal protected area that has been built to conserve an ecosystem or habitat important for plant species although Ethiopia has high plant diversity (Tadesse 1991).

Various studies have been conducted in different parts of Ethiopia on the themes of population dynamics and regeneration ecology of forests (Demissew 1988; Alelign et al. 2007; Beyene 2010; Getaneh 2012). The outcomes of these works give relevant information on the rejuvenation status of numerous trees and bush species which are very important to perform suitable conservation and management measures. But up to now, there is no study carried out on the floristic composition and vegetative structure of Ylat Forest found in Amhara region North Wollo Zone Meket Woreda.

The objectives of this research were (i) to document the floristic composition of woody plant species of Ylat Forest, Meket Woreda, Northeastern Ethiopia, (ii) to describe the vegetative structure of the forest, and (iii) to evaluate the natural regeneration status of woody plant species of the forest.

MATERIALS AND METHODS

Description of the study area

Location and geographical features of the district

The study was carried out in October 2008 in the Ylat Forest in Meket Woreda, border of Boya and Kolla Boya Kebele. Meket Woreda is one of the twelve districts of North Wollo Zone Amhara regional state located at a distance of about 657 km from Addis Ababa, North East Ethiopia (Meket Woreda Communication Office) (Figure 1).

As the information gained from Meket Woreda Agricultural and Rural Office, the capital of the district is Filakit (found at 11º 35' 55" -12º 2' 30" N and 38º 32' 35" - 39º16'40" E) located on the main highway about 137 km west from Woldiya, the capital of North Wollo zone. The district is bordered on the North by Bugna, on the East by Gubalafto and Gidan, on the West by Gaynt and on the South by Wadla Woreda. The ranges altitude of the study area is 1699-3502 meters above sea level having 47 kebeles in which out of those 6 are urban kebeles.

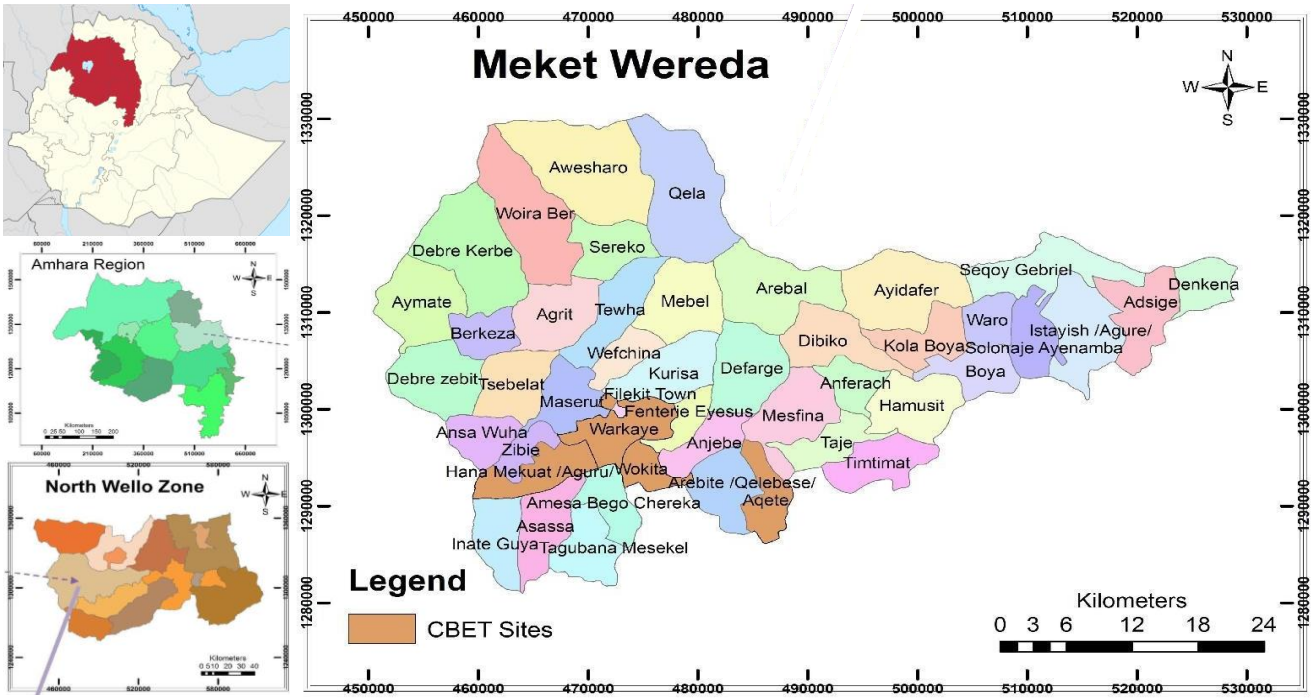

Figure 1. Map of the study area in Ylat Forest, Meket Woreda, North Wello, Amhara, Northeastern Ethiopia

Climate

The data from the head of the Meket Woreda Agricultural Office Ato Anteneh Alemie show that the study area is generally characterized by diverse agro-climatic zones; most of which are the "Kolla" and "Woyna dega" climates that are comparable to cold arid and warm to cool Sub-humid (semi-cold, semi hot-arid) climatic types respectively.

The mean minimum and maximum temperatures are 18 and 27.8ºc. In the district area, low temperature is recorded during July to 15 October, but sometimes in January, and is recorded when rain falls during autumn season. The high temperature is recorded from 15 February to 15June. The mean annual rainfall ranges from 900mm-1400mm. High rainfall is from June to August and low rainfall is during autumn season from March to May.

Topography and soil

The study area is generally characterized by rough topography. It consists of mountains and gorges. The district falls at an altitudinal range of 1699-3502 m.a.s.l. The major soil type and their spatial coverage in the district are Camisol (58.03%). Other soil types are also found in the study area including Litosol (12%), Roaksol (15.47%), Ntosol (6.12%) and Vertisol (15.47%).

Vegetation

The vegetation type of the Ylat Forest is indicated by patches of scattered plants like *Acacia albida*, *Dodonaea angustifolia*, *Bersama abyssinica*, *Mayte*nus *arbustifolia*, *Croton macrostachyus*, *Olea europaea*, *Myrsine africana*, *Juniperus procera*, and *Myrica salicifolia*. Previously, the forest-covered an area of about 102 km^2, but the forest had been declining due to various reasons such as agriculture expansion and cultivation, fuelwood, timber production, etc. Nowadays, the Ylat Forest is protected and it is the only forest conserved in the Meket Woreda.

Human population and social condition

According to the data obtained from Woreda information office, the total population of the observed district Meket Woreda was 273,000, among those 137,256 were males and 134,744 were females. All people in this area speak Amharic language (100%) and they belong to Amhara ethnic group. The two common religions embraced by these people are Orthodox (94.35%), Islam (4.95%), and 0.7% people embrace other types of religion.

The livelihood of the local people is predominantly based on subsistence agriculture. Agriculture activity is characterized by mixed cropping practices with the main principal crops of bean, pea, maize, teff, sorghum, barley, wheat and nug, and the cash crops including lentil and garlic (Meket Woreda Agricultural and Rural Development Office).

Wildlife

The information from kebele agricultural officer describes that the study area is generally poor in wildlife due to deforestation and high human interference. However, different kinds of wild animals are found, such as mammals (e.g., apes, monkeys, antelopes, common fox, leopards, rabbit, Ethiopian tiger, and hyena) and birds (e.g., jigra).

Methodology for data collection

Preliminary survey

To obtain vegetation patterns of the study area and to identify representative sampling sites about the forest, preliminary survey of Ylat Forest was conducted in October 2008. According to Panwar and Bhardwaji (2005), it is important to know the size of the vegetation as well as the number of plots to be laid out per hectare before data collection. In this case, 20 m x 20 m (400 m^2) plots were laid on the study area to collect the vegetation data. The data were collected from November to December 2008.

Sampling design (vegetation data collection)

A systematic sampling design was employed to collect vegetation data using line transect method described by Bullock (1996). In this method, parallel line transects were laid across the forests in west-east direction determined using compass. For each of the sampling sites, five transect lines each having 54 main plots were used to sample vegetation data. The first sampling point was established systematically which is 200 m away from each other. Plots having equal sizes of 20 m x 20 m (400 m^2) were laid out to collect the data on woody species. The distance between main plots was 200 m along each of the transect lines. The plot was made by using two measuring tapes bisecting at right angles in each center locating the four corners of the plot, and the square plot was fenced with a rope made from sack. The latitude, longitude and altitude were taken from the center of each main plot using a GPS (Global Positioning System). In each quadrat, all woody plant species with a DBH of ≥ 2.5 cm were measured and recorded.

In each quadrat, all the plant species were recorded. Data on Diameter at Breast Height (DBH) / Diameter at Shrub Height (DSH) of the trees or shrubs, number of stems, coverage of each tree/shrub and coverage of herbaceous composition were collected from total of 54 quadrats of 20 x 20m (400m^2). Diameters at Breast Height (DBH) ≥ 2.5 cm of trees and shrubs were measured by using diameter tape following the methods described by Cunningham (2001). Individuals of trees and shrubs with DBH < 2.5cm were counted as seedlings. New woody plant species occurring outside the sampling plots (quadrats) were also recorded to prepare a complete checklist of plants in the area. Diameter was measured for all individual trees and shrubs having DBH (Diameter at Breast Height) using a conventional tape-meter. Diameter of small and big trees was measured by using a caliper and diameter tape, respectively.

Specimens of all plant species were collected, stored and identified at the National Herbarium using Flora of Ethiopia and Eritrea.

Methods of data analysis

Structural data analysis

Density, frequency, diameter at breast height (DBH), dominance, importance value index (IVI) and basal area were analyzed to describe vegetation structure in all 54 sample plots.

Density is defined as the number of plants of a certain species per unit area. It is closely related to abundance but more useful in estimating the importance of a species. The counting is usually done in small plots placed several times into vegetation communities under study and the sum of individuals per species is calculated in terms of species density per convenient area unit such as a hectare (Mueller - Dombois and Ellenberg 1974).

$$D = \frac{\text{Number of above-ground stems of a species countered}}{\text{Sampled area in hectare(ha)}}$$

The relative density of the species is calculated by using the following formula.

$$RD = \frac{\text{Number of individual tree species}}{\text{Total number of individuals}} \times 100$$

Frequency is defined as the chance of finding a species in a particular study sample. According to Goldsmith et al. (1986), frequency is obtained by using quadrants and expressed as the number of quadrants occupied by a given species per number thrown or more often, as percentage. Higher frequency means higher importance of the plant in the community.

$$F = \frac{\text{Number of plots in which species occurred}}{\text{Total number of plots}} \times 100$$

The importance of a species within the frequency can be obtained by comparing the frequency of occurrences to the entire tree species present, and it is called the relative frequency and the formula is as follows:

$$RF = \frac{\text{Frequency of one species}}{\text{Total frequency}} \times 100$$

Dominance is the degree of coverage of species as an expression of the space at ground level (Mueller-Dombois and Ellenberg 1974). Dominance is measured in terms of cover or basal area. It is the mean basal area per tree times the number of tree species.

$$\text{Basal area} = \sum \pi (d/2)^2$$

Where:
d is diameter at breast-height and $\pi = 3.14$

Diameter at Breast Height (DBH) is carried out at about 1.3 m height from the ground using a measuring tape. It is easy, quick, inexpensive and relatively accurate. There is a direct relationship between DBH and basal area (Beyene 2010). Basal area is the area outline of a plant near ground surface. It is the cross-sectional area of tree stems at DBH.

Relative dominance is the ratio of dominance of individual tree species per dominance of all tree species. It will be calculated by the following formula:

$$RDO = \frac{\text{Dominance of individual tree species}}{\text{Dominance of all species}} \times 100$$

Importance Value Index (IVI) is used to calculate the significance of a plant species. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Kent and Coker 1992). As Lamprecht (1989) indicates that, it is useful to compare the ecological significance of species.

IVI = Relative density + Relative frequency + Relative dominance

Plant diversity analysis of plant species

The diversity of woody species (species richness and evenness) are determined using the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) (Krebs 1999 and Barnes et al. (1998). Especially for Shannon-Wiener Diversity Index (H'), in addition to counting for species richness and evenness, it is not affected by sample size and it used to measure the degree of uncertainty, i.e., if the diversity is high in a given habitat, the certainty of observing a particular species is low (Kent and Coker 1992; Krebs 1999). Shannon-Wiener Equitability index (H') (the relative equitability or evenness) of the species in each cluster was calculated using Microsoft Excel. The species evenness that measures the equity of species in a samples area is represented by 0 and 1, which are equally abundant (Whittaker 1972). As Molles (2007) described that, it can be zero which is the value for a community with a single species and takes a maximum value of lnS for a given number of species (S), when the same number of individuals represents all species also increases as species richness and evenness increases.

Both the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) are expressed as follows,

$$H' = \sum_{i=1}^{s} Pi \ln pi$$

Where,

H' is the Shannon-Wiener Diversity Index,

$\sum$ is sum of species from species 1 to species S,

Pi is the proportion of individual's abundance of the i^{th} species, S is number of species encountered

ln is natural logarithm in base e.

$$J = \frac{H'}{H'max} \times 100$$

Where:

H' max= ln S

H' is Shannon diversity index

lnS is the natural logarithm of the total number of species in each community

S is number of species in each community

RESULTS AND DISCUSSION

Floristic composition

In this study, 60 species of vascular plants representing 56 genera and 41 families were identified and recorded (Table S1). Out of the 60 identified plant species, 51.67% (31 species) were shrubs, 21.67% (13 species) were trees, 10% (6 species) were lianas and 16.66% (10 species) were herbs (Figure 2).

Out of the total families, 8.33% were Lamiaceae, 5% were Fabaceae, Rosaceae, Solanaceae, and Euphorbiaceae and 3.33% were Sapindaceae, Aloaceae, Ranunculaceae, Poaceae, Oleaceae, Polygonaceae, and Cucurbitaceae (Table 1).

Woody species

A total of 31 species belonging to 23 families and 31 genera with ≥ 2.5cm DBH of woody species individuals were recorded from 54 sample plots (2.16 ha). The highest number of species were Rosaceae, Solanaceae, Lamiaceae, and Fabaceae, followed by Euphorbiaceae and Sapindaceae. In total, 1227.77 individuals of woody plant species were recorded with *M. africana* as the highest of all woody species with 15.27% (Table S2).

Myrsine africana, Erica arborea and *Dodonaea angustifolia* were the dominant species consecutively. *M. salicifolia, Dombeya torrida, Capparis tomentosa, Millettia ferruginea* and *Euphorbia tirucalli were* some of the rare species within the plot. *E. arborea* and *Allophyllus abyssinicus* were the most common (most frequent) species in the sample plots in Ylat Forest.

Vegetation structure

Woody species density and DBH (Diameter at Breast Height)

The numbers of individuals which have DBH ≥ 2.5cm were 1227.77. *Myrsine aficana* had 15.27% of the total density followed by *E. arborea* (14.4%) and *Dodonaea angustifolia* (6.79%) (Table S2). These three woody species were the most dominant species. The least abundant species recorded were *M. salicifolia* (0.72%), *Dombeya torrida* (0.75%), *Capparis tomentosa,* and *Euphorbia trucalli* (0.9%) and *M. ferruginea* (1.02%). The mean density of woody species of the study vegetation was higher than Achera forest (1034.17 individuals per hectare) (Getaneh 2012).

Table 2 shows that 97.15% of woody species individuals were in ≤ 10cm DBH classes and about 2.85% were within 10 < 20cm DBH classes. An increase in DBH causes significant decrease in number of individuals. The Ylat Forest is composed of high proportion of small-sized woody species. *Opuntia ficus-indica* was the largest woody species with an average DBH 65.08 cm (Table 3 and Table S3).

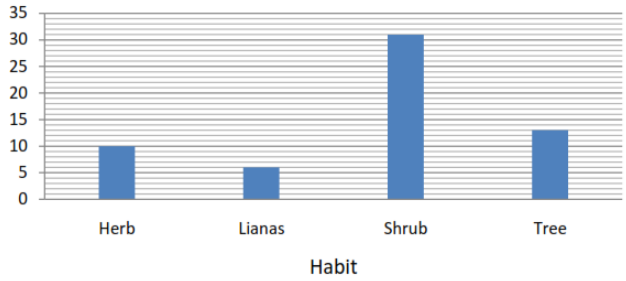

Figure 2. The plant habit (growth forms) in Ylat Forest, Meket Woreda, Northeastern Ethiopia. Note: Herbaceous includes herbs and grasses while woody species includes lianas, shrubs and trees

Table 1. Plant families with their genera and species distribution in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Family	No. of Genera	% of Genera	No. of Species	% of Species
Lamiaceae	2	3.57	5	8.33
Fabaceae	3	5.36	3	5
Rosaceae	3	5.36	3	5
Euphorbiaceae	3	5.36	3	5
Solanaceae	3	5.36	3	5
Aloaceae	1	1.79	2	3.33
Ranunculaceae	2	3.57	2	3.33
Sapindaceae	2	3.57	2	3.33
Poaceae	2	3.57	2	3.33
Cucurbitaceae	2	3.57	2	3.33
Polygonaceae	2	3.57	2	3.33
Oleaceae	2	3.57	2	3.33
Acanthaceae	1	1.79	1	1.67
Loganiaceae	1	1.79	1	1.67
Capparidaceae	1	1.79	1	1.67
Apocynaceae	1	1.79	1	1.67
Sterculiaceae	1	1.79	1	1.67
Flacourtiaceae	1	1.79	1	1.67
Ericaceae	1	1.79	1	1.67
Myricaceae	1	1.79	1	1.67
Eubenaceae	1	1.79	1	1.67
Melianthaceae	1	1.79	1	1.67
Apiaceae	1	1.79	1	1.67
Balsamaminaceae	1	1.79	1	1.67
Cupressaceae	1	1.79	1	1.67
Malvaceae	1	1.79	1	1.67
Celasteraceae	1	1.79	1	1.67
Myrsinaceae	1	1.79	1	1.67
Asparagaceae	1	1.79	1	1.67
Convolvulaceae	1	1.79	1	1.67
Cactaceae	1	1.79	1	1.67
Santalaceae	1	1.79	1	1.67
Phytolaccaceae	1	1.79	1	1.67
Anacardiaceae	1	1.79	1	1.67
Salicaceae	1	1.79	1	1.67
Urticaceae	1	1.79	1	1.67
Scophulariaceae	1	1.79	1	1.67
Asteraceae	1	1.79	1	1.67
Guttiferaceae	1	1.79	1	1.67
Geraniaceae	1	1.79	1	1.67
Myrtaceae	1	1.79	1	1.67
Total	56	100	60	100

Table 2. Distribution of woody species in DBH classes

DBH (cm)	Density/ha	%
≤10	1192.77	97.15
10<20	35	2.85
20<30	0	0
30<40	0	0
>40	0	0

Table 3. Dominant woody species with their percentage basal area of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Species	Density	Average DBH (cm)	BA/ha	Percentage
Opuntia ficus-indica	16.2	65.08	0.154	15.465
Acacia albida	60.65	64.09	0.149	14.98
Juniperus procera	59.26	62.23	0.141	14.14
Allophylus abyssincus	69.44	55.11	0.11	11
Erica arborea	176.39	49.97	0.091	9.12

Basal area

The total basal area of woody species was 1 m^2/ha (Table S4). *Opuntia ficus- indica* (15.465%), *Acacia albida* (14.98%) and *J. procera* (14.14%) were some of the highest basal area woody species. According to Dawins (1959; cited in Lamprecht 1989) the normal area of virgin tropical forest in Africa is 23-37m^2/ha. Based on the report, the basal area of Ylat Forest is low indicating the woody species are thin and scattered.

Opuntia ficus-indica has low density but highest basal area because of its high value of DBH while *E. arborea* has high density but low value of basal area because of its low value of DBH.

Frequency

The most frequent woody species in Ylat Forest were *E. arborea (*12.79%), *Allophylus abyssinicus (*12.02%) and *M. africana (*10.857%). The less frequent woody species were *E. tirucalli, Opuntia ficus-indica, Hagenia abyssinica, M. salicifolia* and *Withania semnifera* (Table S2).

Frequency indicates an approximate homogeneity and heterogeneity of species. Lamprecht (1989) pointed out that the high value in higher frequency and low value in lower frequency classes indicate constant or similar species composition whereas high value in lower frequency classes and low values in higher frequency indicates high degree of floristic heterogeneity. For convenience, the Ylat Forest woody species had been classified into four frequency classes (Table 4).

In the table, the result showed that there was high value in lower frequency classes and low values in higher frequency. This indicated that Ylat Forest had heterogeneous species composition. A similar result was also gotten from South Wollo zone, Yogof forest (Mohammed and Abraha 2013).

Table 4. Classification of Ylat Forest woody species, Meket Woreda, Northeastern Ethiopia

	Class frequency	Species frequency
A	31-40	2
B	21-30	3
C	11-20	6
D	1-10	22

Table 5. IVI of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	IVI
Erica arborea	36.31
Allophylus abyssinicus	28.65
Myrsine africana	27.61
Juniperus procera	27.49
Acacia albida	24.57
Eucalyptus globulus	20.02
Euclea racemosa subsp. *schimperi*	20.02
Opuntia ficus- indica	17.175
Dodonaea angustifolia	13.05
Hypericum revolutum	13.02
Discopodium penninervium	12.69
Otostegia tomentosa	7.14
Olea europaea subsp. *cuspidata*	6.82
Rhus retinorrhoea	6.19
Prunus Africana	4.71
Croton macrostachyus	4.23
Clerodendrum alatum	4.07
Salix subserrata	4.04
Capparis tomentosa	3.87
Carissa spinarum	3.52
Rosa abyssinica	3.52
Dombeya torrida	3.5
Withania somnifera	3.49
Clerodendrum myricoides	3.27
Dovyalis abyssinica	3.06
Osyris quadripartita	2.96
Millettia ferruginea	2.82
Calpurnia aurea	2.69
Hagenia abyssinica	1.74
Euphorbia tirucalli	1.5
Myrica salicifilia	1.285

Importance value index

McIntosh (1967) pointed out Important Value Index gives a more realistic figure of dominance from the structure standpoints. Lamprecht (1989) also noted that the IVI is useful to compare the ecological significance of species.

The result of IVI showed that *E. arborea* (12.09%), *A. abyssinicus* (9.59%), *M. africana* (9.2%), *J. procera* (9.17%), and Acacia *albida* (8.19) were plant species with the highest importance value index, while *M. salicifolia* (0.43%), *E. tirucalli* (0.5%), *H. abyssinica* (0.58%), *Calpurnia aurea* (0.9%) and *M. ferruginea* (0.96%) were species with the lowest importance value index.

The five most dominant woody species of Ylat Forest had 48.24% of the total importance value index (Table S5 and Table 5). Those dominant species were *E. arborea*, *A. abyssinicus*, *J. procera*, *M. africana* and *Acacia albida*. This result shows that much of IVI was attributed to few species. About 57.57% of woody species had IVI value less than 5 indicating the requirement for conservation management.

Species population structure

Dissimilar scheme of species population structure can indicate variation in population dynamics. The schemes are based on various size classes (DBH) and density. On the other hand, the variation could arise from inherent characters, interventions of human and livestock.

The six most significant values of woody species representing 33 species in Ylat Forest whose IVI value > 18 are illustrated in Figure 3. The population structure of *E. arborea*, *A. abyssinicus*, *J. procera*, *M. africana*, *Acacia albida*, and *Eucalyptus globulus* shows an inverted J curve population high number of individuals in the first DBH class by a progressive decrease in the number of individuals with increasing DBH. This scheme indicates good rejuvenation and recruitment. This successful regeneration might be associated with its environmental adaptation. As diameter increases, the density of this species also increases.

Regeneration status of the Ylat Forest

The counting of the composition and the density of seedlings and saplings of woody species were done in Ylat Forest. The number and type of seedlings and saplings in any vegetation cover shows the regeneration status of that vegetation cover. Accordingly, a total of 1339.83 seedlings/ha, 1319.45 saplings/ha and 1227.77 mature individuals/ha were recorded. From the analysis of seedlings and saplings data, the density of tree was 604.74/ha and shrub seedlings were 735.09/ha. Similarly, the densities of trees and shrub species saplings were 627.32/ha and 692.13/ha respectively (Figure 4).

The ratio of seedlings to mature individuals of woody species in Ylat Forest was 1.09:1, the ratio of seedlings to saplings was 1.02:1 and sapling to mature individuals was 1.07:1. This result shows the presence of more seedlings than saplings and saplings than mature woody species, which indicates successful regeneration of forest species.

The woody species in the study area were categorized into two groups based on the number of seedlings and saplings encountered during the study (Table 6). From this study, *E. arborea*, *J. procera*, *M. africana* and *Acacia albida* had highest number of saplings/ha. *E. arborea*, *M. africana*, *Dodonaea angustifolia* and *Discopodium penninervium* had the highest number of seedlings/ha in the study area (Table S6). The composition, distribution and density of seedlings and saplings indicate the future status of the vegetation cover. Woody species in category "B" needs priority of conservation.

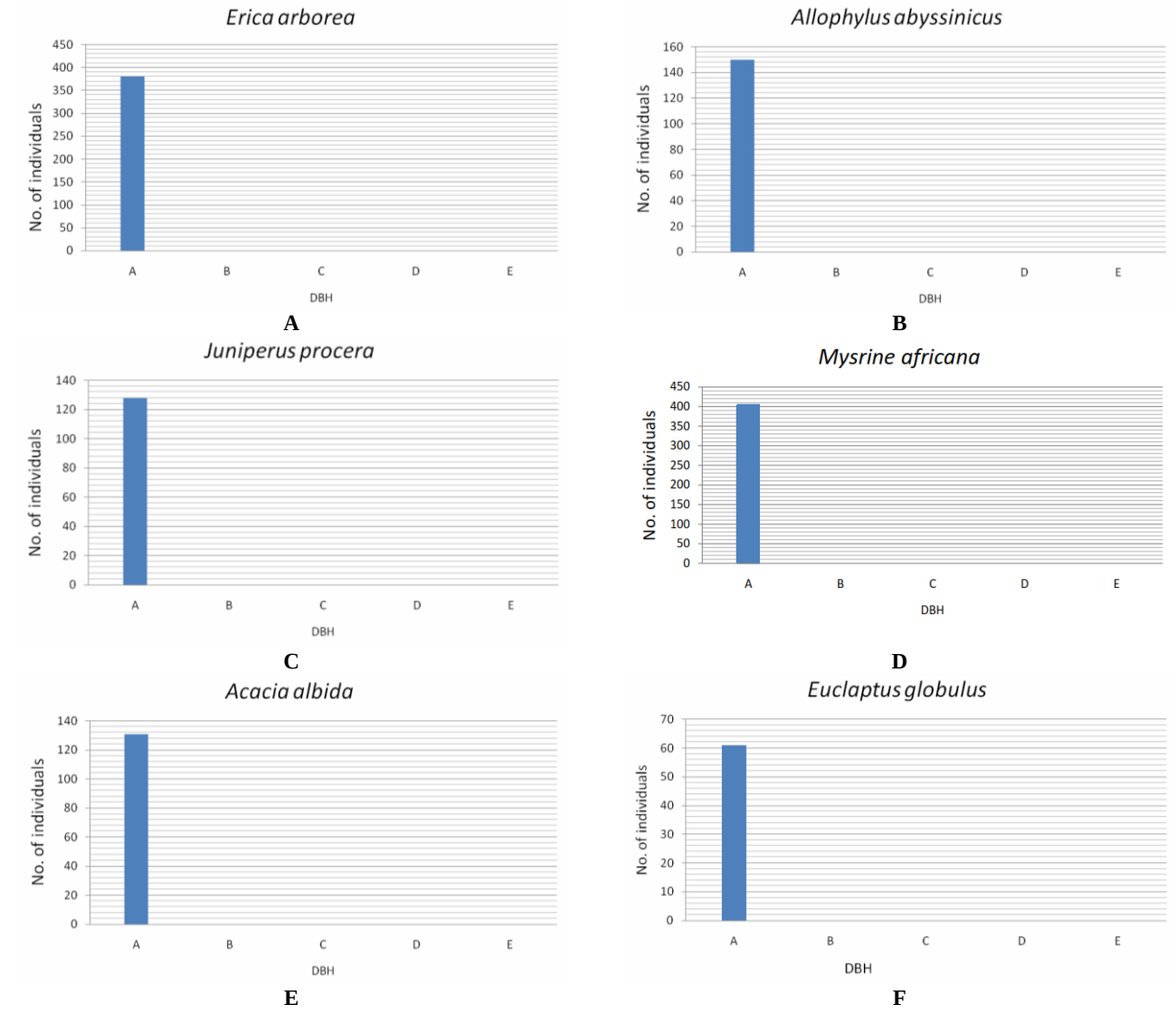

Figure 3. Population structure of six most important woody species in Ylat Forest, Meket Woreda, Northeastern Ethiopia. DBH A: 2.5-10cm, B: 10.1-20cm, C: 20.1-30cm, D: 30.1- 40cm, E: > 40cm

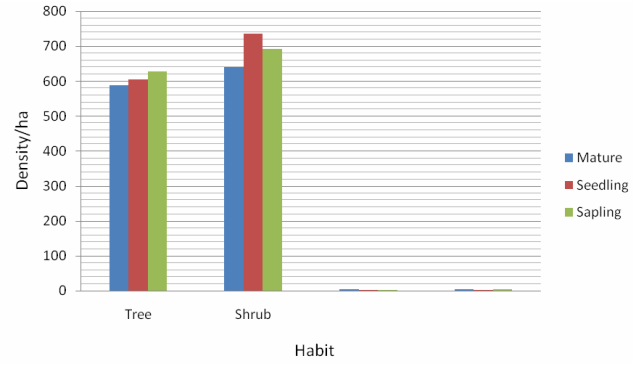

Figure 4. Seedling and sapling distribution of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Species diversity and evenness

The diversity and evenness of woody species in Ylat Forest are relatively high. It is indicated by the Shannon-Wiener diversity index of 2.94 and evenness index of 0.84. According to Kent and Coker (1992), Shannon-Wiener index value varies between 1.5 and 3.5 and to exceed 4 is rare. Thus, the result of the present study showed that the Ylat Forest has a balanced species distribution, indicated by the relatively high value of Shannon-Wiener diversity index (H'=2.94), which is more diverse than of Menagesha Suba State forest (H'=2.57) (Beche 2011).

Table 6. The regeneration status of different woody plant species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Group	Species
A	*Acacia albida*
	Allophylus abyssinicus
	Calpurnia aurea
	Capparis tomentosa
	Carrisa spinarum
	Clerodendrum alatum
	Clerodendrum myricoides
	Croton macrostachus
	Discopodium penninervium
	Dodonaea angustifolia
	Dovyalis abyssinica
	Erica arborea
	Eucalyptus globulus
	Euclea racemosa subsp. *schimperi*
	Euphorbia tirucalli
	Hagenia abyssinica
	Hypericum revolutum
	Juniperus procera
	Millettia ferruginea
	Myrica salicifolia
	Myrsine africana
	Olea europaea subsp. *cuspidata*
	Opuntia ficus-indica
	Osyris quadripartita
	Prunus africana
	Rhus retinorrhoea
	Rosa abyssinica
	Salix subserata
	Withania somnifera
B	*Dombeya torrida*
	Otostegia tomentosa

Note: Group "A" = species with ≥ 1 seedlings and saplings and Group "B" =species no seedlings and saplings at all.

The presence of higher species diversity was indicated by the analysis of floristic composition, vegetative structure and regeneration data on Ylat Forest between altitudinal gradients of 1699-3502 m. The counting activity found a total of 60 species belonging to 41 families and 56 genera. The collection activity in Ylat Forest yielded 1227.77 individual ha^{-1} woody plant species. And it is also found that there was high value of woody plant species in first frequency classes, low value in the next frequency classes, a simple decline in the last frequency class. Therefore, this indicated that the Ylat Forest had heterogeneous species composition. From the overall distribution DBH classes, in Ylat Forest, high contribution of woody plant species in the lower Diameter Basal Height classes and lower plant contribution in the higher classes or as the DBH class size increases, the number of individuals gradually decrease which stimulates an ordinary inverted J-shaped distribution. It brings to an indication that small-sized individuals dominate the forest and allegedly due to selective cutting of large tree individuals for agriculture (farm implements), charcoal production and building houses (construction purpose). Yet, the forest remains in the status of good regeneration with high recruitment potential. The data analysis on the structure of woody plant species of Ylat Forest revealed that the density of seedling (1339.83 individual ha^{-1}) and sapling (1319.45 individual ha^{-1}) were relatively higher than the value on the mature (1227.77 individual ha^{-1}). Although, the seedling and sapling individuals died before reaching maturity due to the different factors, but this still brought up a good status of the vegetation cover in the future and a priority for conservation should be given.

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Table S1. Plant species, family and growth habits recorded from Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	Family	Habit
Acacia albida Del.	Fabaceae	Tree
Acanthus sennii Chiov.	Acanthaceae	Shrub
Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	Tree
Aloe berhana Reynolds	Aloaceae	Herb
Aloe pulcherrima Gilbret and Sebsebe	Aloaceae	Shrub
Anthoxanthum aethopicum I. Hedberg	Poaceae	Herb
Asparagus africanus Lam.	Asparagaceae	Shrub
Bersama abyssinica Fresen.	Melianthaceae	Shrub
Buddleja polystachya Fresen.	Loganiaceae	Shrub
Calpurnia aurea (Ait.) Benth.	Fabaceae	Shrub
Capparis tomentosa Lam	Capparidaceae	Shrub
Carissa spinarum L.	Apocynaceae	Shrub
Clematis simensis Fresen.	Ranunculaceae	Lianas
Clerodendrun alatum Gürke	Lamiaceae	Shrub
Clerodendrum myricoides (Hochst.) Vatke	Lamiaceae	Shrub
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae	Shrub
Croton macrostachyus Del.	Euphorbiaceae	Tree
Cucumis ficifolius A.Rich.	Cucurbitaceae	Herb
Discopodium penninervium Hochst.	Solanaceae	Shrub
Dodonaea angustifolia L.f.	Sapindaceae	Shrub
Dombeya torrida (J.F.Gmel.) P. Bamps	Sterculiaceae	Tree
Dovyalis abyssinica (A.Rich.) Warb.	Flacourtiaceae	Shrub
Erica arborea L.	Ericaceae	Shrub
Euclaptus globulus Labill	Myrtaceae	Tree
Euclea racemosa Murr. Subsp. *schimperi* (A.DC.) White	Eubenaceae	Shrub
Euphorbia tirucalli L.	Euphorbiaceae	Tree
Ferula communis L.	Apiaceae	Herb
Geranium arabicum Forssk.	Geraniaceae	Herb
Hagenia abyssinica (Brace) J.F. Gmel.	Rosaceae	Tree
Hibiscus crassinervius Hochst. ex A. Rich	Malvaceae	Shrub
Hypericum revolutum Vahl	Guttiferaceae	Tree
Hyparrhenia variabilis Stapf	Poaceae	Herb
Impatiens rothii Hook.f.	Balsaminaceae	Herb
Inula confertiflora A. Rich.	Asteraceae	Shrub
Ipomoea tenuirostris Choisy	Convolvulaceae	Lianas
Jasminum grandiflorum L.	Oleaceae	Lianas
Juniperus procera Hochst.ex Endl.	Cupressaceae	Tree
Maytenus arbitufolia (A. Rich) Wilczek	Celastraceae	Shrub
Millettia ferruginea (Hochst.) Bak.	Fabaceae	Shrub
Myrica salicifolia A. Rich.	Myricaceae	Shrub
Myrsine africana L.	Myrsinaceae	Tree
Olea europaea L. subsp. *cuspidata* (Wall. ex G.Don) Cif.	Oleaceae	Tree
Opuntia ficus-indica (L) Miller	Cactaceae	Shrub
Osyris quadripartita Decn.	Santalaceae	Tree`
Otostegia integrifolia Benth.	Lamiaceae	Shrub
Otostegia tomentosa A. Rich.	Lamiaceae	Shrub
Otostegia tomentosa A. Rich subsp ambigens (Chiov.) Sebald	Lamiaceae	Shrub
Phytolacca dodecandra L He rit.	Phytolaccaeae	Lianas
Prunus africana (Hook. f.) Kalkm.	Rosaceae	Tree
Rhus retinorrhoea Oliv.	Anacardiaceae	Shrub
Rosa abyssinica Lindley	Rosaceae	Shrub
Rumex nepalensis Spreng.	Polygonaceae	Herb
Rumex nervosus Vahl	Polygonaceae	Shrub
Salix subserrata Willd.	Salicaceae	Shrub
Solanum marginatum L.f.	Solanaceae	Shrub
Thalictrum rhynchocarpum Dill. & A. Rich.	Ranunculaceae	Herb
Urera hypselodendron (A. Rich) Wedd.	Urticaceae	Lianas
Verbasicum sinaiticum Benth.	Scrophulariaceae	Herb
Withania somnifera (L.) Dunal	Solanaceae	Shrub
Zehnera scabra (Linn. f.) Sond.	Cucurbitaceae	Lianas

Table S2. Woody species, number of stems, density and frequency of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	No. of stems	Density	Density/ha (%)	r. density	Freq.	r. freq (%)
Acacia albida	131	60.65	4.94	4.94	12	4.65
Allophylus abyssinicus	150	69.44	5.65	5.65	31	12
Calpurnia aurea	35	16.2	1.32	1.32	3	1.16
Capparis tomentosa	24	11.11	0.9	0.9	2	0.78
Carissa spinarum	48	22.22	1.81	1.81	3	1.16
Clerodendrum alatum	66	30.56	2.49	2.49	2	0.78
Clerodendrum myricoides	45	20.83	1.69	1.69	2	0.78
Croton macrostachyus	30	13.89	1.13	1.13	2	0.78
Discopodium penninervium	144	66.67	5.43	5.43	12	4.65
Dodonaea angustifolia	180	83.33	6.79	6.79	10	3.89
Dombeya torrida	20	9.26	0.75	0.75	6	2.33
Dovyalis abyssinica	34	15.741	1.28	1.28	3	1.16
Erica arborea	381	176.39	14.4	14.4	33	12.79
Eucalyptus globulus	61	28.24	2.3	2.3	25	9.7
Euclea racemosa subsp. *schimperi*	51	23.61	1.92	1.92	2	0.78
Euphorbia tirucalli	24	11.11	0.9	0.9	1	0.39
Hagenia abyssinica	28	12.963	1.06	1.06	1	0.39
Hypericum revolutum	141	65.28	5.32	5.32	9	3.49
Juniperus procera	128	59.26	4.83	4.83	22	8.52
Milettia ferruginea	27	12.5	1.02	1.02	4	1.55
Myrica salicifolia	19	8.796	0.72	0.72	1	0.39
Myrsine africana	405	187.5	15.27	15.27	28	10.85
Olea europaea subsp. *cuspidata*	44	20.37	1.66	1.66	13	4.04
Opuntia ficus-indica	35	16.2	1.32	1.32	1	0.39
Osyris quadripartita	47	21.76	1.77	1.77	2	0.78
Otostegia tomentosa	96	44.44	3.62	3.62	8	3.1
Prunus africana	37	17.3	1.41	1.41	5	1.93
Rhus retinorrhoea	89	41.204	3.36	3.36	6	2.3
Rosa abyssinica	42	19.44	1.58	1.58	4	1.55
Salix subserrata	57	26.39	2.15	2.15	4	1.55
Withania somnifera	33	15.28	1.24	1.24	1	0.39
Total	2652	1227.77	100		100	258

Table S3. DBH range of woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	Diameter at Breast Height (cm)			
	1-10	11-20	21-30	>40
Acacia albida	131	0	0	0
Allophylus abyssinicus	150	0	0	0
Calpurnia aurea	35	0	0	0
Capparis tomentosa	24	0	0	0
Carissa spinarum	48	0	0	0
Clerodendrum alatum	66	0	0	0
Clerodendrum myricoides	45	0	0	0
Croton macrostachyus	30	0	0	0
Discopodium penninervium	144	0	0	0
Dodonaea angustifolia	180	0	0	0
Dombeya torrida	20	0	0	0
Dovyalis abyssinica	34	0	0	0
Erica arborea	381	0	0	0
Eucalyptus globulus	61	0	0	0
Euclea racemosa subsp. *schimperi*	51	0	0	0
Euphorbia tirucalli	24	0	0	0
Hagenia abyssinica	28	0	0	0
Hypericum revolutum	141	0	0	0
Juniperus procera	128	0	0	0

Millettia ferroginia	27	0	0	0
Myrica salicifolia	19	0	0	0
Myrsine africana	405	0	0	0
Olea europaea subsp. *cuspidata*	44	0	0	0
Opuntia ficus-indica	0	35	0	0
Osyris quadripartita	47	0	0	0
Otostegia tomentosa	96	0	0	0
Prunus africana	37	0	0	0
Rhus retinorrhoea	89	0	0	0
Rosa abyssinica	42	0	0	0
Salix subserrata	57	0	0	0
Withania somnifera	33	0	0	0
Total	2617	35	0	0

Table S5. Importance Value Index (IVI) of each woody species of Ylat Forest, Meket Woreda, Northeastern Ethiopia resulted from the sum of relative density, relative frequency and relative dominance

Scientific name	**r. density**	**r. freq**	**r. dom**	**IVI**
Acacia albida	4.94	4.65	14.98	24.57
Allophylus abyssinicus	5.65	12	11	28.65
Calpurnia aurea	1.32	1.16	0.21	2.69
Capparis tomentosa	0.9	0.78	2.19	3.87
Carissa spinarum	1.81	1.16	0.55	3.52
Clerodendrum alatum	2.49	0.78	0.8	4.07
Clerodendrum myricoides	1.69	0.78	0.42	3.27
Croton macrostachyus	1.13	0.78	2.32	4.23
Discopodium penninervium	5.43	4.65	2.61	12.69
Dodonaea angustifolia	6.79	3.89	2.37	13.05
Dombeya torrida	0.75	2.33	0.417	3.5
Dovyalis abyssinica	1.28	1.16	0.617	3.06
Erica arborea	14.4	12.79	9.12	36.31
Eucalyptus globulus	2.3	9.7	8.02	20.02
Euclea racemosa subsp.. *schimperi*	1.92	0.78	1.53	4.23
Euphorbia tirucalli	0.9	0.39	0.21	1.5
Hagenia abyssinica	1.06	0.39	0.29	1.74
Hypericum revolutum	5.32	3.49	4.21	13.02
Juniperus procera	4.83	8.52	14.14	27.49
Milltettia ferruginea	1.02	1.55	0.25	2.82
Myrica salicifolia	0.72	0.39	0.175	1.285
Myrsine africina	15.27	10.85	1.49	27.61
Olea europaea subsp. *cuspidata*	1.66	4.04	1.12	6.82
Opuntia ficus-indica	1.32	0.39	15.465	17.175
Osyris quadripartita	1.77	0.78	0.41	2.96
Otostegia tomentosa	3.62	3.1	0.42	7.14
Prunus africana	1.41	1.93	1.37	4.71
Rhus retinorrhoea	3.36	2.3	0.53	6.19
Rosa abyssinica	1.58	1.55	0.39	3.52
Salix subserrata	2.15	1.55	0.34	4.04
Withania somnifera	1.24	0.39	1.86	3.49
Total	100	100	100	300

Table S4. Basal Area (BA) and dominance of woody species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	BA	BA/ha	BA%	Mean BA	total no.	Dominancy	r. dominancy
Acacia albida	0.322	0.1491	14.98	0.002458	131	0.322	14.98
Allophylus abyssinicus	0.2384	0.1104	11	0.001589	150	0.2384	11
Calpurnia aurea	0.0045	0.002083	0.21	0.00012857	35	0.0045	0.21
Capparis tomentosa	0.04712	0.0218	2.19	0.0001963	24	0.04712	2.19
Carissa spinarum	0.011934	0.005525	0.55	0.00024862	48	0.011934	0.55
Clerodendrum alatum	0.0172	0.007963	0.8	0.0002606	66	0.0172	0.8
Clerodendrum myricoides	0.00894	0.0041375	0.42	0.000199	45	0.00894	0.42
Croton macrostachyus	0.0499	0.0231	2.32	0.001663	30	0.0499	2.32
Discopodium penninervium	0.05621	0.02602	2.61	0.0003903	144	0.05621	2.61
Dodonaea angustifolia	0.051	0.02361	2.37	0.000283	180	0.051	2.37
Dombeya torrida	0.00897	0.00415	0.417	0.0305	20	0.00897	0.417
Dovyalis abyssinica	0.013267	0.006142	0.617	0.0003902	34	0.013267	0.617
Erica arborea	0.1961	0.091	9.12	0.000515	381	0.1961	9.12
Eucalyptus globulus	0.1724	0.0798	8.02	0.00283	61	0.1724	8.02
Euclea racemosa subsp. *schimperi*	0.033	0.01528	1.53	0.000647	51	0.033	1.53
Euphorbia tirucalli	0.0046	0.00212	0.21	0.00019166	24	0.0046	0.21
Hagenia abyssinica	0.0062	0.00285	0.29	0.0002214	28	0.0062	0.29
Hypericum revolutum	0.09054	0.042	4.21	0.000642	141	0.09054	4.21
Juniperus procera	0.304	0.141	14.14	0.002375	128	0.304	14.14
Millettia ferroginia	0.0054	0.002481	0.25	0.0002	27	0.0054	0.25
Myrica salicifolia	0.00377	0.00175	0.175	0.0001984	19	0.00377	0.175
Mysrine africina	0.032	0.0148	1.49	0.000079	405	0.032	1.49
Olea europaea subsp. cuspidata	0.024	0.012	1.12	0.000535	44	0.024	1.12
Opuntia ficus-indica	0.3325	0.15394	15.465	0.0095	35	0.3325	15.465
Osyris quadripartita	0.0089	0.004157	0.41	0.0001911	47	0.0089	0.41
Otostegia tomentosa	0.009122	0.004223	0.42	0.000095	96	0.009122	0.42
Prunus africana	0.0294	0.0136	1.37	0.000795	37	0.0294	1.37
Rhus retinorrhoea	0.01145	0.0053	0.53	0.00012865	89	0.01145	0.53
Rosa abyssinica	0.00834	0.00386	0.39	0.0001985	42	0.00834	0.39
Salix subserrata	0.00722	0.003343	0.34	0.000127	57	0.00722	0.34
Withania somnifera	0.04	0.02016	1.86	0.00133	33	0.04	1.86
Total	2.15	1	100		0.0587	2652	2.15

Table S6. The regeneration status of woody plant species in Ylat Forest, Meket Woreda, Northeastern Ethiopia

Scientific name	**Seedlings/ha**	**Saplings/ ha**
Acacia albida	66.203	67.13
Allophylus abyssinicus	49.17	27.315
Calpurnia aurea	28.241	35.19
Capparis tomentosa	32.41	50.463
Carissa spinarum	17.593	58.33
Clerodendrum alatum	30.55	27.3
Clerodendrum myricoides	29.17	28.704
Croton macrostachyus	31.02	34.26
Discopodium penninervium	73.61	14.352
Dodonaea angustifolia	75.463	60.65
Dombeya torrida	0	0
Dovyalis abyssinica	45.83	43.52
Erica arborea	185.65	157.41
Eucalyptus globulus	30.0926	25
Euclea racemosa subsp. *schimperi*	13.426	18.06
Euphorbia tirucalli	63.89	65.74
Hagenia abyssinica	30.093	31.944
Hypericum revolutum	47.69	57.87
Juniperus procera	53.24	75.93
Millettia ferruginea	12.5	9.722
Myrica salicifolia	43.43	61.574
Myrsine africina	79.17	71.2963
Olea europaea subsp. *cuspidata*	43.06	42.13
Opuntia ficus-indica	68.06	61.57
Osyris quadripartita	34.26	37.5
Otostegia tomentosa	0	0
Prunus africana	44.44	40.741
Rhus retinorrhoea	46.759	45.37
Rosa abyssinica	18.98	19.91
Salix subserrata	24.074	22.685
Withania somnifera	21.76	27.78
Total	1339.83	1319.45