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Woody Species Composition, Diversity and Vegetation Structure of Dry Afromontane Forest, Ethiopia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This study was conducted in wanzaye natural forest, South Gondar, Ethiopia. The main objective of the study was to determine the species composition, diversity and vegetation structure analysis of wanzaye natural forest. A total of 75 quadrants or plots were used. Each sample plot covered an area of 400 m2 (20m x 20 m). For trees/ shrubs, all woody species with diameter at breast height (DBH) ≥2.5 cm and height ≥2 m were recorded in all plots. For the regeneration purpose, trees/shrubs species with diameter < 2.5 cm and height < 2 m also recorded. Diversity and richness were calculated using the Shannon- Wiener diversity index. All Woody species population was examined by estimating Frequency, relative Frequency, density, relative density and Dominance (basal area). Basal area was calculated using the cross-sectional area of a tree trunk measured at diameter at breast height (DBH, 1.3 m height) Excel and STATISTICA version 10 software were used to analyse vegetation data. The result indicated that a total of 49 woody species belongs to 29 families were identified. The total basal area was 23.3 m^2 ha^{-1}. Number of individuals with (DBH) ≥2.5cm and height ≥2 m was 482 trees ha^{-1} and for the regeneration it was (2916 individuals ha^{-1}). Based on Importance Value Index (IVI) *Ficus sycomorus* (56%) followed by *Dodonaea viscosa* (31%) and *Croton macrostachys* (19%) was recorded. The overall diameter frequency distribution of woody species show inverse J- shape.

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Keywords: Basal area; importance value index; regeneration; population structure; species area curve.

1. INTRODUCTION

1.1 Background and Justification

Ethiopia is located in the horn of Africa [1]. It is one of the biggest countries in sub- Saharan African with a land area of about one hundred ten million hectares [1,2]. The country is rich in flora and fauna as the result of this; it is the fifth largest flora in tropical Africa [3]. The differences in altitude and latitude have resulted in a wide variation in climates (rainfall, humidity, temperature and exposure to wind). Therefore, the flora is very heterogeneous and it is estimated to be six to seven thousand, of which Twelve percent are only found in Ethiopia [4,5,6]. According to Convention on biological diversity country report (2009), indicated that the Biodiversity conservation status in Ethiopia is decline because of different factors. Inappropriate use of natural resources, deforestation of the natural vegetation, invasive species, illegal trafficking of wild animal and climate change are the major factors that affects the biodiversity of the country [5]. Now a day's different research and literatures recognised that forests in Ethiopia are currently threatened by different factors such as population growth, agricultural expansion land, the demand for increasing amounts of construction material, for timber, fuel wood and charcoal are increasingly affecting the natural forests in both quality and quantity [7]. Agricultural expansion is a one of feature in almost all studies related on deforestation. On the other hand, to fulfill the gap for agricultural production and increasing yields, it needs more than millions of hectares of forest will be deforested. [8]. Degradation is higher especially in the northern highlands, in which more than 90% of Country population, about 93% of the cultivated land, around 75% of the country's livestock and 90% of the country's economic activity, Due to high population and livestock pressure in the highland areas, forests are remains in patches around churches and remote areas [1,9,10]. Some degradation is happened because of natural disasters such as landscape feature and heavy rainfall [11]. Awareness creation by the local people plays a crucial role for the sustainable utilisation and conservation of forest resources but it is so far been insufficient [12].

This research was particularly conducted in wanzaye natural forest, South Gondar Administrative Zone of Amhara Regional State, Ethiopia. Wanzaye natural forest is categorised under Dry Mountain Forests ranging an altitude between 1500- 2700 m a.s.l, and long dry season four to eight months with variable rain, which is highly fragmented biome consists of a complex type vegetation on isolated highland areas of the country [13,14,15,5,10,16]. Dry mountain Forest is dominated by species such as *Olea europea, Albezia gummifera*, *Ficus spec, Celtis Kraussina, Rosa abyssinica, Mimusops kummel*, *Ekebergia capensis Euphorbia* species and Croton *macrostachyus,* whereas the area is known by its species richness even if it is now under human land use pressure [13,17]. There are different studies on Dry Montane remnant forest of the country focused on species diversity including [18,3,19,20,6,21,22,23,24,25]. So those studies play a great role for the conservation and management of the forest resources. Like other forests in the Country, wanzaye natural forest also expose to illegal logging and encroachment of forestlands. Indigenous tree species are also becoming severely affected in the area. There is no scientific study about the woody composition, diversity and vegetation structure of the wanzaye natural forest. Therefore, to overcome the above-mentioned problems and to use the forest in a sustainable way, forest management is very important. So, to develop more effective approaches for conservation and sustainable utilisation of the forest resources, information on composition, diversity and population structure is a baseline. This information is crucial for future conservation and management of the forest. Therefore, the general objective of the study was to assess woody tree species composition, diversity and Vegetation Structure Analysis of wanzaye natural forest, South Gondar, Ethiopia. The specific objectives were to determine woody species composition, to evaluate diversity of woody species, to analyse the woody vegetation structure and to provide a woody species list for possible Conservation Program.

2. MATERIALS AND METHODS

2.1 Study Area

This research was conducted in wanzaye natural forest, South Gondar administration zone of Amhara Regional state, Ethiopia. It is one of the most degraded areas in the state [10]. Dera district is located 37^0 25' 45" - 37^0 54' 10" E

longitude and 11^0 23' 15"- 11^0 53' 30" N latitude [26]. It has a land area of 1,497 square kilometers, which is subdivided into twenty-nine rural and three urban kebeles [27]. Wanzaye Forest consists of an area of 276 ha of natural forest therefore, this research focused on the natural forest ecosystem.

2.2 Sampling and Sampling Design

Different field equipments were used during field work such as for tree (Diameter and height) measurements such as caliper, meter tapes, hypsometer. Trees were marked using different color chalk to easily identify counted and measured trees. GPS, compass with 360-degree scale (suunto), and tally sheet were used. A reconnaissance survey was conducted to collect basic information such as site condition and area of the forest to determine the sampling size. A systematic sampling method were used in a homogenous vegetation stands along an altitudinal gradient [28]. All woody plants species diameters ≥ 2.5 cm and ≥ 2m height were measured based on Didita [6]. A total of 75 quadrants were taken for wanzaye natural forest. Each plot measuring 20 x 20 m =400 m^2 based on Gering [29]. Sample plots established at 50 m interval along a serious of transects and distance between transects were 30 m and within each plot were 30m. Diameter was determined by using calipers, but for those trees which has big diameter, measurement was done using tape meter. For regeneration, Trees which have < 2.5 cm DBH or height < 2m are counted in each compartment. Tree height was measured using a suunto-clinometer. Altitude and longitude of each sample plots were measured using GPS (Geographical Position System) [30,23].

2.3 Data Collection

All Woody species in each quadrant were recorded. The plant specimen with their local name collected and identification were performed in the National Herbarium, Addis Ababa University. Identification of woody species was performed by referring the publication volume of flora and Ethiopian and Eritrea according to Edwards, Bekele [31,32]. Seedlings of each tree species were counted to estimate the regeneration status of Wanzaye natural forest.

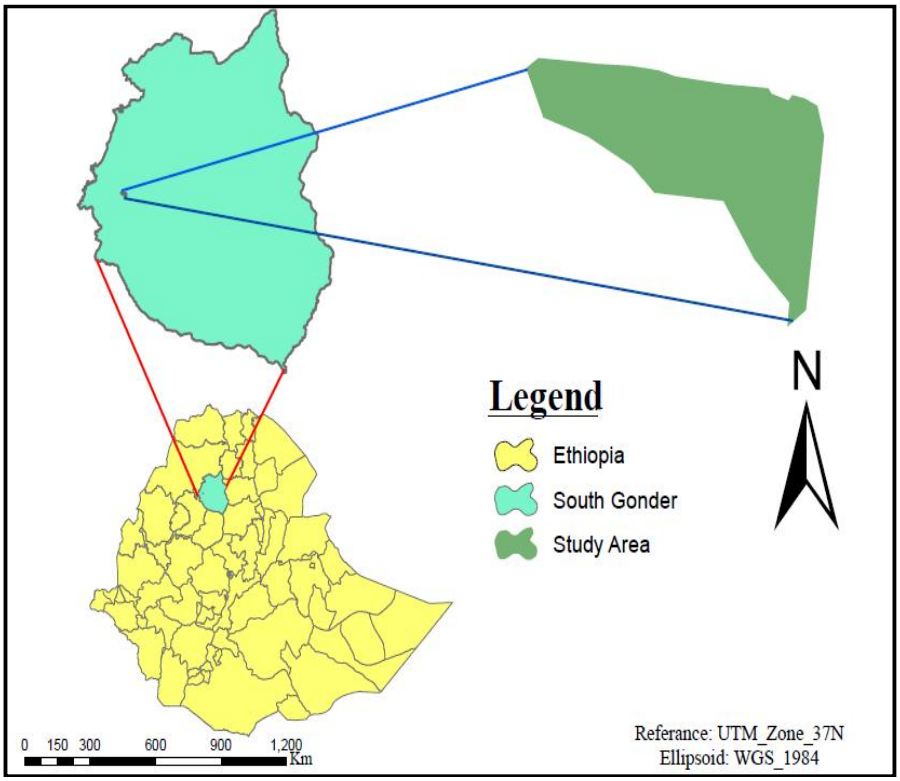

Fig. 1. Location of the study area, Wanzaye Natural Forest, Dera District, South Gondar, Ethiopia

2.4 Ecological Diversity Indices

Wanzaye natural forest species diversity and richness were calculated using the Shannon-Wiener diversity index Fisaha, Kebede [33,29].

$$H' = -\sum_{i=1}^{k} pi \ln pi \quad (1)$$

Where,

H = Shannon diversity index,
Pi = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of a total cover
K = the number of species,
ln = logbasen
Evenness or Equitability can be calculated based on Peet [33].

$$\text{Evenness} = (D - D_{min}) / (D_{max} - D_{min}) \quad (2)$$

$$\text{Evenness} = (D/D_{max}) \quad (3)$$

Where,

D = a heterogeneity value for the sampled population,
D_{min} = the minimum values possible for the given species number and
D_{max} = the maximum values possible for a given species number

But for this study purpose, the most common and widely used methods for Evenness were based on (Pielou [34] as follows

$$J = H'/H'_{max} \quad (4)$$

Where,

J= Evenness,
H'= Shannon-Wiener diversity index and
H'_{max} = lns where s is the number of species

Simpson's Index (D)

According to Gering [29], the value of Simpson's Index is always less than one and it is the chance that two similar species to be selected from the sample.

It is calculated as follow

$$1 - \sum pi^2 \quad (5)$$

Important Value Index (IVI)

All woody species population was examined by estimating Frequency, relative Frequency, density, relative density and Dominance (basal area). Important Value Index (IVI) measure to asses and compare the overall significant it considers several properties of the species and those species which have a higher Importance Value Index shows the dominant tree in the study area and it calculated as follows based on Lamprecht, Kent M,Coker, Tauseef [28,35,36].

IVI = Relative density + relative dominance (basal area) + relative frequency (6)

But Relative density = (Density of each species/ Total Density) *100 (7)

Relative dominance or basal area = (basal area of each species/Total basal area) *100 (8)

Relative frequency =(Frequency of each species/ Total Frequency of species)* 100 (9)

Relative density defined as the number of all individuals of a species/ the total number of all individuals (DBH≥ 2 cm) times 100; whereas relative dominance (basal area) is defined as the basal area of the species /total basal area times 100 (DBH≥ 2.5 cm) and relative frequency is the number of plots, where a species occurs/the total occurrence of all species in all of the plot's times 100. Basal area was calculated using the cross-sectional area of a tree trunk measured at diameter at breast height (DBH, 1.3 m height) Didita [6].

$$\text{Basal area} = \Pi d^2/4$$

Where,

Π= 3.14, d= Diameter at breast height in cm

Analysis of data was carried out using quantitative methods. Species richness and diversity analysis were done using Shannon-Wiener diversity index and Simpson's Index. STATISTICAL version 10.0 software at a significant level of 5% was performed to analyse differences of species along altitudinal gradients and Diameter- Height curve. STATISTICAL Version 10 was used to draw histograms for diameter and height distribution of woody species. Excel 2007 was also performed to see the mean diameter and mean height of the stand.

3. RESULTS AND DISCUSSION

3.1 Stand Diversity

3.1.1 Species - area curve

Species area curve shows that the relationship between the area and the number of species found within that area it is very important to determine the sufficiency of the sample plot [29]. The species area curve developed from 75 sample plots which covering an area of 3 ha. In the case of wanzaye natural forest, the pattern of curve increases the number of species with increasing areas up to 27000 m^2 for the regeneration status and up to 28000 m^2 for woody species (dbh ≥ 2.5 cm) since species diversity will increases with the increasing of area [37]. But after 27,000 m^2 the species area curve seems constant. Therefore, generally it can be concluded that sample plots were sufficient and it can give information about the composition, diversity and dominant tree species in the study area.

3.1.2 Woody species composition

For this study purpose, a total of 75 quadrants or sample plots were used and each sample plot contains an area of 400 m^2 (20 x 20 m). A total 49 woody species and 29 families were identified. The total density of wanzaye natural forest was (482 individuals ha^{-1}) was higher than the remnant moist Afromontane forest of Wondo Genet (379 individual's ha^{-1}) [23]. But when it compared with others Afro montane forests of the country, the density of Wanzaye natural forest was less than Wof Washa Natural Forest (698 individuals ha^{-1}) [30]. Boda Dry evergreen Montane Forest (682 individuals ha^{-1}) [16] and Bale National Park, Boditi Forest (498 individuals ha^{-1}) [20].

Wanzaye natural forest, the species with the highest Importance Value Index (IVI) were *Ficus sycomorus* (56) and followed by *Dodonaea viscosa* (31), *Croton macrostachyus (*19), *Senna multiglandulosa (*14), *Carissa spinarum* (13) *and Syzygium guineense (*12) occupied the higher importance value index (IVI) and those species with higher IVI considered as more significant than species with low IVI [38].

Based on families, Fabaceae was the dominant family by consists of 9 species (31%), followed by Maraceae 4 (14%), Apocynaceae 3 (10%) and the rest families share 45% from a total family of the study area.

Fabaceae were the dominant family and similar results reported with studies conducted in Dry Afromontane forest [39,6,40,22,41,42].

3.1.3 Ecological diversity indices of trees

If, the species distributed evenly, the diversity considered as higher but only few species dominates the area, the diversity considered as low [34]. Wanzaye natural forest was rich in species composition with 49 woody species and 29 families. Species richness indicated that the assets of species in the community [33]. Similar result was reported in Zengena Forest [41]. The species richness was higher compared with other

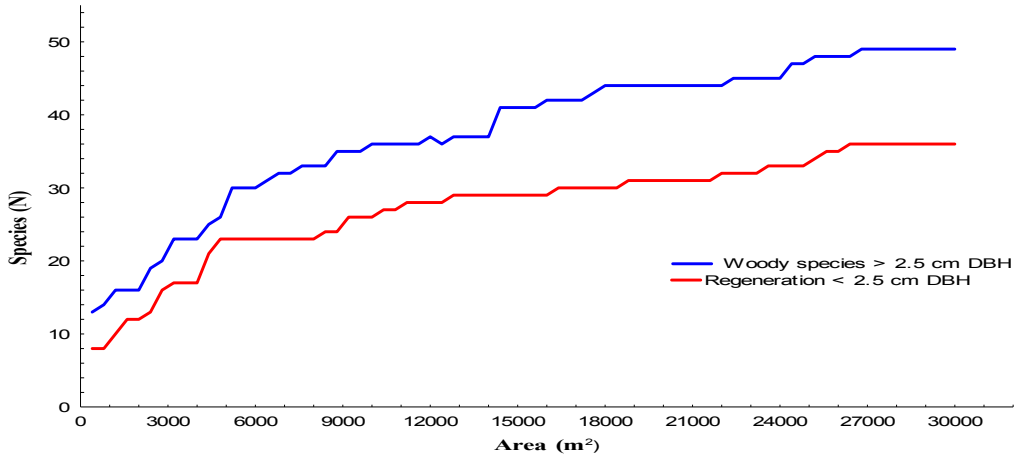

Fig. 2. Species-area curve of all trees and regenerations of Wanzaye Natural Forest, South Gondar, Ethiopia

Table 1. The most common woody tree species ranked by their importance value index of with diameter at breast Height (dbh) at ≥ 2.5 cm in Wanzaye Natural Forest, South Gondar, Ethiopia

Rank	Species	Abundance (N ha^{-1})	Dominance (m^2 ha^{-1})	Frequency (%)	IVI
1	*Ficus sycomorus*	17	12.9	3	56
2	*Dodonaea viscosa*	90	0.5	62	31
3	*Croton macrostachyus*	41	0.8	46	19
4	*Senna multiglandulosa*	28	0.2	46	14
5	*Carissa spinarum*	29	0.2	38	13
6	*Syzygium guineense*	27	0.5	25	12
7	*Terminalia Schimperiana*	26	0.3	29	11
8	*Flueggea virosa*	26	0.1	34	11
9	*Rhus glutinosa*	16	0.2	37	10
10	*Grewia ferruginea*	15	0.1	25	8
Others 11- 49		167	7.5		115
Total		**482**	**23.3**		**300**

Remark: IVI = Importance Value Index

Table 2. Family of the dominant woody species with diameter at breast Height (dbh) at ≥ 2.5 cm in Wanzaye Natural Forest, South Gondar, Ethiopia

No	Family	No. of Species	No. of Individuals
1	*Fabaceae*	9	169
2	*Moraceae*	4	31
3	*Apocynaceae*	3	129
4	*Euphorbiaceae*	3	120
5	*Anacardiaceae*	2	57
6	*Combretaceae*	2	75
7	*Oleaceae*	2	31
8	*Rubiaceae*	2	26
9	*Sapindaceae*	2	298
10	*Sapotaceae*	1	8
	Others 11-29	19	494
	Total	**29**	**1438**

Table 3. The most common families ranked by their Importance Value Index with diameter at breast Height (dbh) at ≥ 2.5 cm in Wanzaye Natural Forest, South Gondar, Ethiopia

Rank	Family name	Abundance (N ha^{-1})	Dominance (m^2 ha^{-1})	Frequency (%)	IVI
1	Moraceae	11	15.5	18	71.8
2	Sapindaceae	99	0.9	82	37.1
3	Euphorbiaceae	70	0.9	86	32.2
4	Fabaceae	57	0.9	85	29.2
5	Apocynaceae	44	0.4	56	19.7
6	Combretaceae	28	0.3	31	12.0
7	Anacardiaceae	17	0.4	42	11.8
8	Myrtaceae	28	0.4	25	11.8
9	Tiliaceae	15	0.1	25	7.7
10	Ebenaceae	22	0.07	16	7.4
	Others 11- 29	91	3.4		59.23
	Total	**482**	**23.3**		**300**

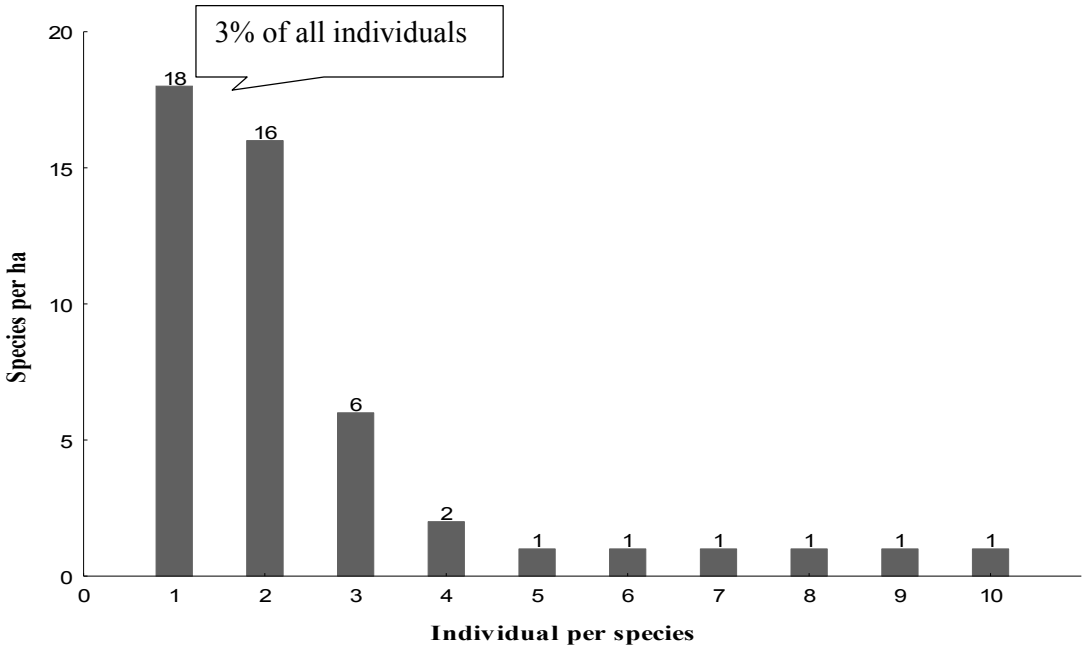

Fig. 3. Species frequency diagram of Wanzaye Natural Forest, South Gondar, Ethiopia

dry Afro montane forests reported by [43] (15 woody species); [44] (33 woody species); [45] (42 woody species); [46] (36 woody species) at Munessa-Shashemene Forest and [18] (40 and 41 species) at Gera and Menagesha Forest respectively but it was less than Wof Washa natural forest (62 woody species) [30]; Woody vegetation in degraded dry land hillside (58 woody species) [39]; Native woody species under plantation forests in the highlands of Ethiopia (55 woody species) [47]; Fragmented Afromontane forest (220 plant species) [17]; Church Forests (168 woody species) [10]; Jibat Forest (53 tree and shrub species) [48] and Hugumburda forest (79 species) [49].

Wanzaye Natural Forest tree species were categorised under four frequency classes. Frequency means that the ratio of quadrants that the species found [23]. Species were classified in to five frequency classes. High value in frequency class I (absolute frequency 1-20%) and class II (absolute frequency 21-40%) and it gradually decreases in class III (absolute frequency 41-60%) and class IV (61-80%). The result indicated that more than 93 % of the species found in class I and class II which means that High value in the lower frequency classes indicated that high floristic heterogeneity occurred [24]. From a total species, (35 species, 71%) represented in class I, whereas (11 species, 22%) in class II and the rest (2 species, 4% and 1 species 2 %) represented in class III and class IV respectively. This result shows that high heterogeneity in species.

SHANNON Index (H')

Wanzaye natural forest species diversity and richness were calculated using the Shannon-Wiener diversity index (See Equation 1) [33,29] whereas for Evenness or equitability calculation, the most common and widely used methods based on Pielou [34] and for Simpson's Index Gering [29]. Shannon - Wiener diversity and evenness index woody species was 3.15 and 0.81 respectively which means woody diversity and evenness was high with compare to ice lands of lake Ziway 2,60 and 0.62 respectively [21]. The Shannon divesrity and Evenness index of wanzaye natural forest was higher due to large number of rare species [17].

3.1.4 Basal area

The basal area distribution is very important criteria for determining and classifying forest type based on the maturation of the stand [50]. Total Woody species basal area of the study area was 23.3m^2 ha^{-1}. More than 74 % of the basal area was shared by four species, *Ficus sycomorus* 12.9 m^2 ha^{-1} (55%), *Ficus vasta* 1.72 m^2 ha^{-1}

(7%), *Stereospermum kunthianum* 1.35m^2 ha^{-1} (6%) and *Cordia africana* 1.1m^2 ha^{-1} (5%) whereas the rest species share 6.23m^2 ha^{-1} (26%) from a total basal area. The lower basal area was *Celtis africana* (0.002m^3 ha^{-1}). Species such as *Dodonaea viscosa, Senna multiglandulosa* and *Carissa spinarum* have high density but their basal area was low, this was due to the nature of plant species which cannot be grow to a high basal area [51]. Generally, the basal area of Wanzaye natural forest was very low even when it compared to the mean basal area of tropical forest 35m^2ha^{-1} [52]. A similar results were reported from Bale Mountain National park, Boditi Forest, 23 m^2 ha^{-1} [20] but when it compared with other forests of the country, it was higher than wood land and Riverine vegetation of Sire Beggo in Golocha district (19.3 m^2 ha^{-1}) [24]; Zengena Forest (22.3 m^2 ha^{-1}) [41] and Hugumburda forest (9.23 m^2 ha^{-1}) [49].

The basal area of wanzaye natural forest (23.3m^2 ha^{-1}) was less than that of Boda Dry Evergreen Montane Forest (114.6 m^2 ha^{-1}) [16]; Belete moist evergreen montane forest (103.5 m^2 ha^{-1}) [25]; Tara Gedam and Abebaye Forest, 115.4 m^2 $ha^{-1}$and 49.5 m^2 ha^{-1} respectively [21].

3.2 Stand Structure

3.2.1 Diameter distribution

Diameter distribution plays a significant role in forest science and used to determine the optimum selective cutting that improves the stand structure [53,54]. The diameter distribution of the study area showed that an inverted -J shaped which means that high number of individuals in the lower diameter class and very few numbers of individuals in the high diameter classes. On the other hand, the diameter of the

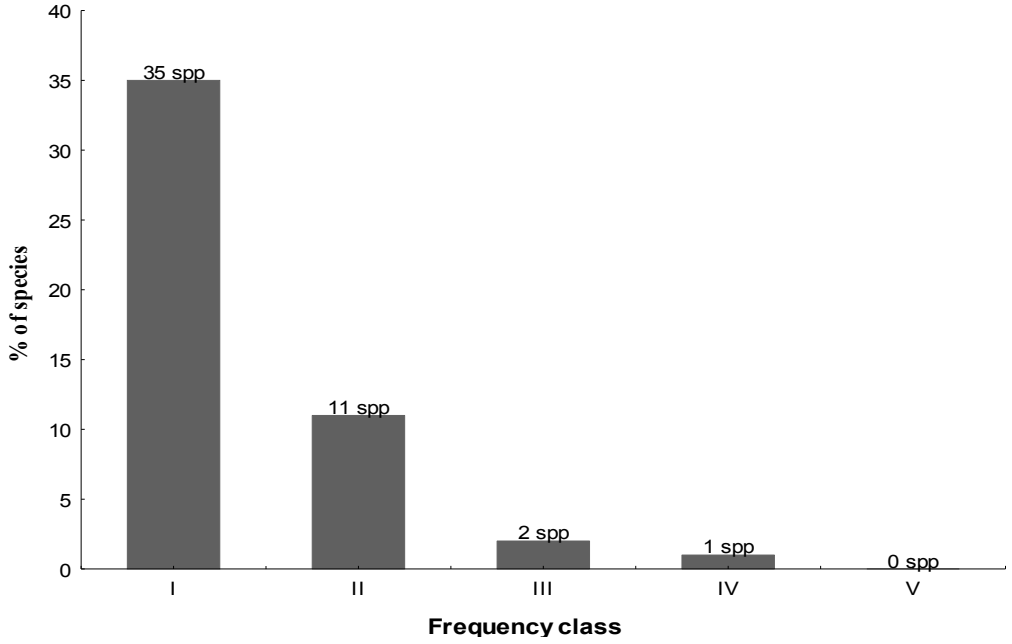

Fig. 4. Frequency diagram of Wanzaye Natural Forest, South Gondar, Ethiopia. Frequency classes: I= 1-20%; II= 21-40%; III=41-60%; IV= 61-80%; V= 81-100%

Table 4. Shannon Index and Simpson's Index, of Wanzaye Natural Forest, South Gondar, Ethiopia

Land use	No. of Trees/ha	No. of Species	Shannon Index (H')	Simpson's index		Evenness (J)
				D	1-D	
Wanzaye Natural Forest, Dera District, South Gondar	482	49	3.15	0.07	0.93	81

trees increases with decreasing of the number of individuals. This is a general pattern of normal distribution [6]. Based on result shown in the diameter frequency distribution graph, 49 % Diameter at breast height, DBH class 2 - 6.9 cm followed by 35 % DBH class 7 - 11.9 cm and the rest shares only 16 % from a total diameter frequency distribution. This means that the study area were dominanted by low sized trees or shrubs species such as *Dodonia viscosa, Croton macrostachyus, Carissa spinarum and Senna multiglandulosa.* Generally, this pattern of diameter distribution indicated that good regeneration status of the forest [18]. On the other hand, According to Dera Woreda Agricultural office annual report, there was illegal cutting of tree for different purposes such as timber, construction and fuel wood. Therefore, this selective cutting of a forest leads to decreasing in the number of trees in the higher diameter class [21,23]. Similar type of diameter distribution results was reported by [20,6,21,41, 42,24,23,51].

3.2.2 Stand height

Like diameter distribution, the height distributions of the study area were performed. The Height distribution showed that an inverse -J shaped curve which means that high number of individuals in the lower height class and very few numbers of individuals in the high height classes. On the other hand, the height of the trees increases with decreasing of the number of individuals. The result indicated that 58 % of individuals trees found under height class 2 - 4 m and followed by 28 % individuals under height class 4- 6 m whereas the rest shares only 14 % from a total height frequency distribution.

3.2.3 Species population structure

Investigation of diameter at breast height (DBH) and Height distribution gives evidence for the regeneration status of the natural forest [45]. Change in population structure can affect the composition [55] because it can indicate the Silvicultural characteristics of a species [23]. The diameter and height distribution of all individuals showed inverted J-shape distribution which means that the majority of the species had highest number of individuals at lower diameter and height classes. However, this pattern cannot indicate the general trend of a given species. Therefore, Analysis of each species structure provides more realistic information and used for conservation measures. Based on this, six species were selected based on their Importance Value Index (IVI) to determine the population structure of the study area. *Ficus Sycomorus* with IVI (56%), *Dodonaea viscosa* (31%), *Croton macrostachyus* (19%), *Senna multiglandulosa* (14%), *Carissa spinarum* (13%) and Syzygium guineense (12%). Species with highest basal area leads to high relative dominance which contributed to the highest Importance Value Index (IVI). Therefore, Wanzaye Natural Forest species population structures were classified into four population distribution patterns. Inverse J-Shape, Bell- Shape, Broken J- shape and Irregular shape.

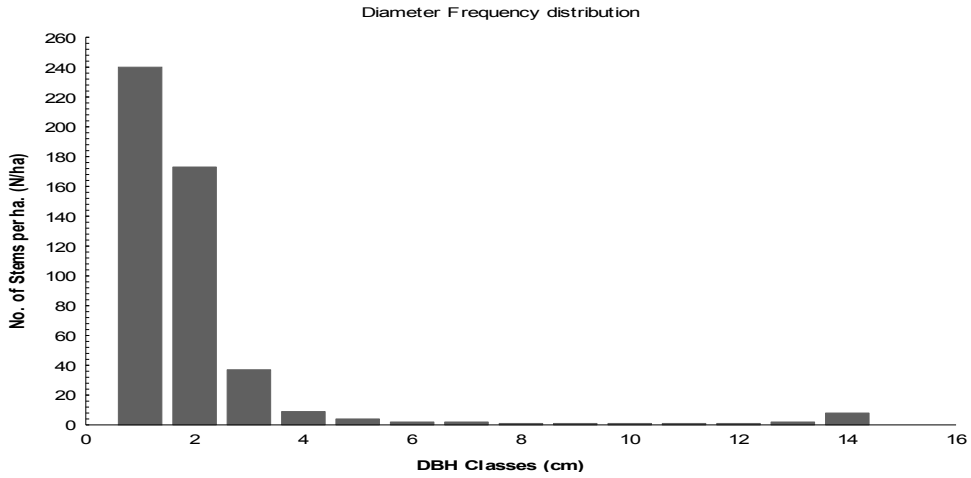

Fig. 5. Diameter frequency distribution of Woody species of Wanzaye Natural Forest. DBH classes (1= 2 - 6.9 cm; 2 = 7 - 11.9 cm; 3 = 12 - 16.9 cm; 4= 17 - 21.9 cm; 5 = 22- 26.9 cm; 6 = 27 - 31.9 cm; 7 = 32 - 36.9 cm; 8 = 37- 41.9 cm; 9 = 42 - 46.9 cm; 10 = 47 - 51.9 cm; 11 = 52 - 56.9 cm; 12 = 57- 61.9 cm; 13 = 62 - 66.9; 14 = >67 cm

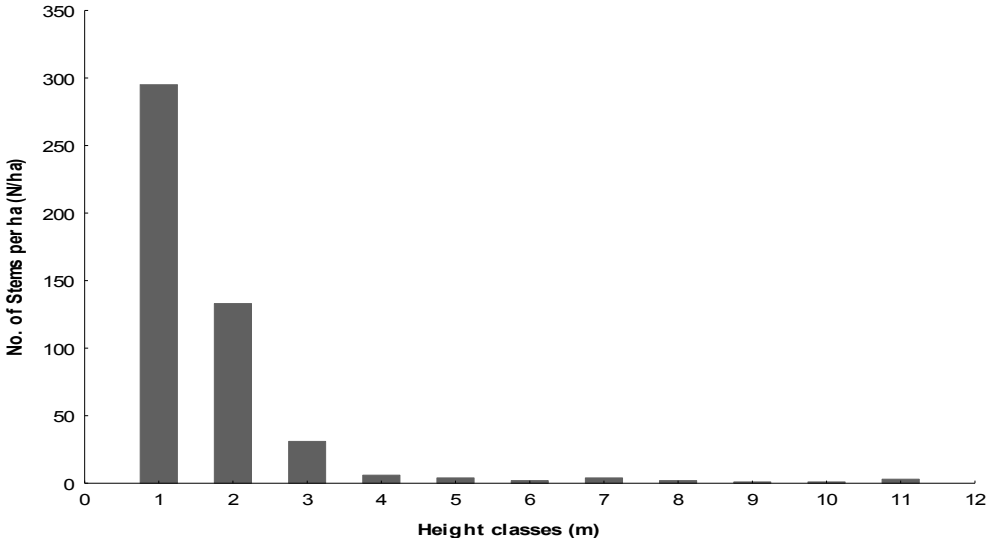

Fig. 6. Height frequency distribution of Woody species of Wanzye Natural Forest. Height classes (1= 2 - 4 m; 2 = 4 - 6 m; 3 = 6 - 8 m; 4= 8 - 10 m; 5 = 10 - 12 m; 6 = 12 - 14 m; 7 = 14 - 16 m; 8 = 16 - 18 m. 9 = 18 - 20 m; 10 = 20 - 22 m; 11 = ≥ 22

Inverse J- Shape:- Tree species like *Senna multiglandulosa and Carissa Spinarum* respectively showed Inverse J- shaped distribution, which indicated a Good regeneration status [18,20,6]. Inverse J-Shape characterised by its shade tolerant species [50], which have high number of seedling and sampling growth stage [19]. High number of individuals in the lower diameter class and gradual it decreases with the increasing of diameter classes. Similar result also reported by [20] at Bale National Park, Dry Afromontane forest.

Bell- Shaped: - Whereas species such as *Syzygium guineense*, showed Bell- shaped which means that high number of individuals in the middle class and low number of individuals in both lower and higher diameter classes which indicated poor reproduction [23]. Similar result also reported by [25] from Belete Moist Evergreen Montane forest. This pattern of species distribution indicated that light-demanding trees [50].

Broken J- shaped: - Species like *Ficus Sycomorus* showed broken J-shaped which indicated that High number individuals in the highest diameter class (especially 14 class) and Gradually decrease individuals in lower diameter class even miss individuals in classes (2, 4, 6, 8, 10, 11, 12) which mean that poor regeneration status [21]. Therefore, some conservation measures should be taken.

Irregular shaped: - *Croton macrostachyus*, diameter distribution Indicated that absence of some individuals in the middle class. Number of individuals increased until class two then decreases in third class and absence of individuals in 4^{th}, 5^{th} classes. It was Similar with Belete Moist Evergreen Montane forest structure also reported by Gebrehiwot and Hundera [25].

Like diameter distribution, height distributions of wanzaye natural forest were assessed based on the selected six species. The species population structure based on height classified into three distribution patterns. *Dodonaea viscosa, Senna multiglandulosa, Syzygium guineense and Carissa spinarum* classified under Inverse J-shape. This indicated that high number of individuals in the lower height class showed that different height distribution pattern of Wanzaye natural forest. The second type of height distribution were broken inverse J- shaped species such as *Croton macrostachys showed* Absence of individuals in the 5^{th} class of height distribution pattern. Species such as *Ficus Sycomorus* showed a Bell-shape height distribution. This showed that high number of individuals in the middle class and gradually decreases in both sides of lower and higher height classes.

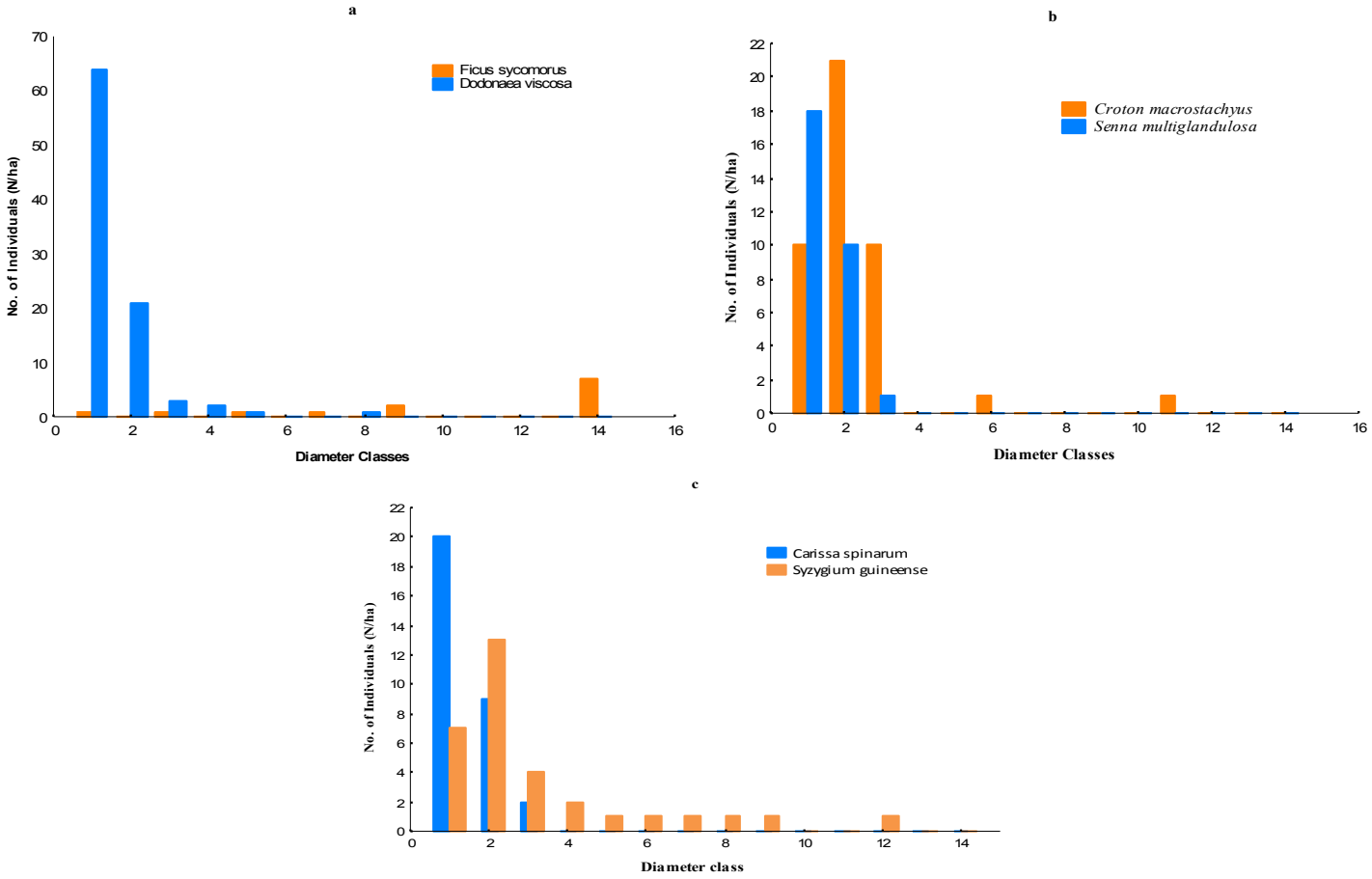

Fig. 7. Diameter frequency distribution of Woody species of Wanzaye Natural Forest. DBH (1= 2 - 6.9 cm; 2 = 7 - 11.9 cm; 3 = 12 - 16.9 cm; 4= 17 - 21.9 cm; 5 = 22- 26.9 cm; 6 = 27 - 31.9 cm; 7 = 32 - 36.9 cm; 8 = 37- 41.9 cm; 9 = 42 - 46.9 cm; 10 = 47 - 51.9 cm; 11 = 52 - 56.9 cm; 12 = 57- 61.9 cm; 13 = 62 - 66.9; 14 = >67 cm)

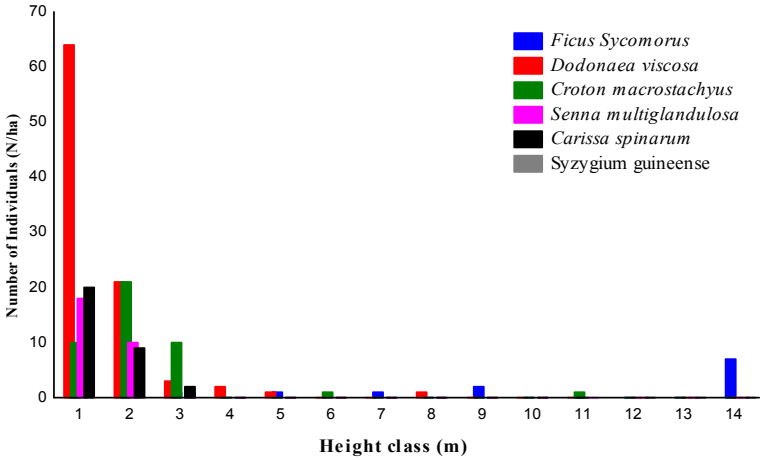

Fig. 8. Height frequency distribution of Woody species of Wanzaye Natural Forest. Height classes (1= 2 - 4 m; 2 = 4 - 6 m; 3 = 6 - 8 m; 4= 8 - 10 m; 5 = 10 - 12 m; 6 = 12 - 14 m; 7 = 14 - 16 m; 8 = 16 - 18 m. 9 = 18 - 20 m; 10 = 20 - 22 m; 11 = ≥ 22 m

3.3 Natural Regeneration

3.3.1 Abundance and frequency of natural regeneration

Tropical dry montane forests are the most vulnerable terrestrial ecosystem [56]. In this study, seedling with diameter at breast height (DBH) < 2.5 cm and height < 2 m were counted and considered as a seedling (regeneration). The result indicated that a total of 8746 individuals (2916 individuals ha^{-1}) consists of 37 species were found. Number of Individual (density) of wanzaye natural forest (2916 individuals ha^{-1}) was higher compared with Woody density of Biyo-Kelala (1746 and 2215 individuals ha^{-1}) enclosure and open area respectively) [39] and Gedo Dry Evergreen Montane forest (1068 individuals ha^{-1}) [51]. But it was much lower than other dry Afro montane forests reported by [18] (16290 individuals ha^{-1}) at Gera Ades and 32 650 individuals ha^{-1} at Menagesha Forest); [25] (4500 individuals ha^{-1} at Belete natural forest). This is due to different a factor that affects the forest growth such as overgrazing, deforestation and weeding [13,30]. The species richness was higher compared with other dry Afromontane forests reported by [24], (15 woody species) and [44] (33 woody species) whereas, it was less than Gara Ades forest 40 woody species and

Table 5. Abundance and Frequency of seedlings for the most abundant species of Wanzaye Natural Forest, South Gondar, Ethiopia (DBH < 2.5 cm and Height < 2 m)

N0.	Species	Abundance (N. ha^{-1})	Frequency (%)
1	*Dodonaea viscosa*	1184	88
2	*Berberis holstii*	324	61
3	*Flueggea virosa*	300	84
4	*Acokanthera schimperi*	210	29
5	*Carissa spinarum*	194	75
6	*Osyris quadripartite*	90	49
7	*Terminalia brownii*	79	57
8	*senna multiglandulosa*	74	64
9	*Euclea racemosa ssp.schimperi*	67	31
10	*Rhus glutinosa*	49	35
11	*Bersama abyssinica*	42	15
12	*Maytenus arbutifolia*	40	21
13	*Grewia ferruginea*	38	1
	Others 14-37	225	
	Total	**2916**	

Menagesha forest 41 woody species [18]. Species like *Dodonaea viscosa* were the highest number of seedlings 1184 seedling ha^{-1} (41%) followed by *Berberis holstii* 324 seedlings ha^{-1} (11%); *Flueggea virosa* 300 seedlings ha^{-1}(10%) and *Acokanthera schimperi* 210 seedlings ha^{-1} (7%). The rest species shares 31%. Therefore, From Frequency distribution result, it can be concluded that *Dodonaea viscosa* species widely distributed in the study area.

4. CONCLUSION

Sustainable forest management plan is very important for tropical natural forests to maximise the use of forests and make the local people benefited from a forest resource without affecting the environment in a sustainable way. Therefore, to develop more effective approaches for conservation and sustainable utilisation of the forest resources, information on composition, diversity and population structure is a baseline. In the study area, a total 49 woody species and 29 families were identified. (482 individuals ha^{-1}) with DBH ≥ 2.5 cm and Height ≥ 2 m. were encountered where as in the regeneration forest 37 species and 2916 individuals $ha^{-1}$with DBH < 2.5 cm and Height < 2 m was found.

Importance Value Index (IVI) of the study area was calculated and based on the result *Ficus sycomorus* the highest one by occupying (56%) followed by *Dodonaea viscosa* (31%), *then Croton macrostachyus* (19%), *Senna multiglandulosa* (14%), *Caarissa spinarum (*13%) and *Syzygium guineense* (12%) respectively. Based on families, Fabaceae was the dominant family by consists of 9 species (31%), followed by Maraceae 4 (14%), Apocynaceae 3 (10%) and the rest families share 45% from a total family of the study area. Wanzaye Natural Forest tree species were categorised under four frequency classes. The total Woody species basal area was 23.3 m^2 ha^{-1}. More than 74% of the basal area was shared by four species, *Ficus sycomorus* 12.9 m^2 ha^{-1} (55%), *Ficus vasta* 1.72 m^2 ha^{-1} (7%), *Stereospermum kunthianum* 1.35m^2 ha^{-1} (6%) and *Cordia africana* 1.1m^2 ha^{-1} (5%) whereas the rest species share 6.23m^2 ha^{-1} (26%) from a total basal area. Generally, the basal area of the study area was very low with compare to other forests. The diameter distribution of the study area shows that an inverse -J shaped which means that high number of individuals in the lower diameter class and very few numbers of individuals in the high diameter classes. On the other hand, the diameter of the trees increases with decreasing of the number of individuals. According to the result indicated in the diameter frequency distribution graph, 49 % DBH class 2 - 6.9 cm followed by 35 % DBH class 7 - 11.9 cm and the rest shares only 16 % from a total diameter frequency distribution. Based on the result of Importance Value Index (IVI) six species were selected for the analysis of species population structure. Therefore, Wanzaye Natural Forest species population structures were categorised into four population distribution. Inverse J-Shape, Bell- Shape, Broken J- shaped and Irregular shaped. The regeneration statuses of the natural forest were also assessed. Seedling with diameter at breast height (DBH) < 2.5 cm and height < 2 m were counted and considered as a seedling (regeneration). A total of 8746 individuals (2916 individuals ha^{-1}) and 37 species were found. *Dodonaea viscosa* were the highest number of seedlings 1184 seedlings ha^{-1} (41%). Species with low Importance Value Index (IVI) (Appendix 2) such as *Terminalia brownii*, *Pittosporum viridiflorum*, *Stegunotaenia* araiiacea, *Brucea antidysenterica*, *Celtis africana*, *Acokanthera schimperi* and *Dombeya torrida* ssp *Torrida* needs high conservation efforts (Zegeye *et al.,* 2005). Therefore, those rare species should be given big attention and conserve them with the collaboration of the community and government (Dera District Local rural and Agricultural Development Office).

Woody species basal area was relatively low with compared to other drymontane forest as the result of the low woody species density and illegal cutting of big trees for different purposes. So, some Gaps were created in the forest area. Therefore, it needs forest rehabilitation program through different mechanisms such as enrichment planting because tree planting enhances forest succession through nursing effect [57]. In addition to this, discussion with the local community should be made on issues such as how to avoid illegal cutting of trees and how to manage the forest resources in the sustainable way. Beside the study of forest composition, diversity and vegetation structure of the forest, there should be also detailed study on the ethno botanical Knowledge of wanzaye natural forest because it will help for the conservation of plant species. Further studies should be carried out on soil properties of the study area.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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APPENDICES

Appendix 1. Diameter Classes Distribution for trees with DBH ≥ 2.5 cm per hectare of Wanzaye Natural Forest, Dera District South Gondar, Ethiopia

No	Species	Diameter Distribution of Wanzaye Natural Forest														
		Diameter Classes in (cm)														
		0 - 4.9	5- 9.9	10 -14.9	15 -19.9	20 -24.9	25 -29.9	30 -34.9	35 - 39.9	40 - 44.9	45 - 49.9	50-54.9	55 - 59.9	60 - 64.9	65 -69.9	>70
1	*Acacia abyssinica subsp.abyssinica*		11	6	2	2										
2	*Acacia seyal*	4	6	2												
3	*Acacia tortilis*	1	9		1											
4	*Acokanthera schimperi*	10	26	2		2										
5	*Acokanthera schimperi*					1										
6	*Albizia gummifera*	1	3	5	1	2	1									
7	*Allophylus abyssinicus*	2	16	9	4	2										
8	*Berberis holstii*	25	20	2												
9	*Bersama abyssinica*	4	19	2												
10	*Brucea antidysenterica*				1											
11	*Buddleia polystachya*		3													
12	*Carissa spinarum*	40	45	3												
13	*Celtis africana*		5													
14	*Clausena anisata*	1	2													
15	*Cordia africana*		3	2	1	1						1				1
16	*Croton macrostachyus*	13	82	28			1			1						
17	*Dichrostachys cinerea*	5	7													
18	*Dodonaea viscosa*	144	129	2												
19	*Dombeya torrida subsp. Torrida*		2													
20	*Entada abyssinica*	1	13	3	3	1										
21	*Erythrina abyssinica*							1								
22	*Euclea racemosa subsp.schimperi*	10	19													
23	*Ficus ingens*			1							1	1				1
24	*ficus sycomorus*		1	2		1	1		1			4	1	1	2	10
25	*Ficus thonnangi*		2													1
26	*Ficus vasta*															1
27	*Flueggea virosa*	44	35													
28	*Gardenia volkensii*	2	15		1											
29	*Grewia ferruginea*	14	26	5	1											
30	*Lannea sp.*		1	3	3											

No	Species	Diameter Distribution of Wanzaye Natural Forest														
		Diameter Classes in (cm)														
		0 - 4.9	**5- 9.9**	**10 -14.9**	**15 -19.9**	**20 -24.9**	**25 -29.9**	**30 -34.9**	**35 - 39.9**	**40 - 44.9**	**45 - 49.9**	**50-54.9**	**55 - 59.9**	**60 - 64.9**	**65 -69.9**	**>70**
31	*Maytenus arbutifolia*	10	2													
32	*Milletia ferruginea*	2	2													
33	*Mimusops kummel*		8													
34	*Myrica salicifolia*	8	29	2												
35	*Osyris quadripartite*	11	16													
36	*Pavetta abyssinica*	1	5													
37	*Phyllanthus ovalifolius*	1	7													
38	*Pittosporum viridiflorum*		1													
39	*Premna schimpri*	10	18													
40	*Rhus glutinosa*	10	43	9												
41	*Rosa abyssinica*	2	1													
42	*Schrebera alata*		7													
43	*Senna multiglandulosa*	32	51	1												
44	*Stegunotaenia araiiacea*			1												
45	*Stereospermum kunthianum*		2		1		1		1			1				1
46	*Syzygium guineense*	9	51	14	2		3		2		1					1
47	*Terminalia brownii*	1														
48	*Terminalia schimperiana*	5	60	7	2											
49	*Ximenia americana*	5	17	2												
		428	**820**	**113**	**23**	**12**	**7**	**1**	**4**	**1**	**2**	**7**	**1**	**1**	**2**	**16**

Appendix 2. List of species and their IVI of Wanzaye Natural Forest, Dera District, South Gondar, Ethiopia

No.	Local name	Latin name	Abundance (N ha^{-1})	Dominance ($m^{2.}$. ha^{-1})	Frequency (%)	IVI (%)
1	Kiteketa	*Dodonaea viscosa*	90	0.54	62	30.8
2	Bisana	*Croton macrostachyus*	41	0.81	46	19.3
3	Agam	*Carissa spinarum*	30	0.21	38	13.1
4	Dokima	*Syzygium guineense*	28	0.47	25	11.7
5	Bebisha	*senna multiglandulosa*	28	0.21	46	13.9
6	Ambeleta	*Terminalia schimperiana*	27	0.34	29	11.5
7	Wonaye	*Flueggea virosa*	26	0.15	34	11.5
8	Dedeho	*Euclea racemosa subsp.schimperi*	22	0.07	16	7.4
9	Lenquata	*Grewia ferruginea*	15	0.15	25	7.8
10	Qamo	*Rhus glutinosa*	15	0.27	37	10.4
11	zigeta	*Berberis holstii*	14	0.11	20	6.8
12	kalaba	*Myrica salicifolia*	13	0.13	12	5.0
13	Merenz	*Acokanthera schimperi*	13	0.19	16	6.0
14	keret	*Osyris quadripartite*	9	0.06	25	6.1
15	Embus	*Allophylus abyssinicus*	9	0.33	20	6.4
16	Checho	*Premna schimpri*	9	0.06	20	5.3
17	Azamir	*Bersama abyssinica*	8	0.09	9	3.6
18	Inkoy	*Ximenia americana*	8	0.07	20	5.1
19	Bamba	*ficus sycomorus*	8	12.28	13	56.3
20	Gambello	*Gardenia volkensii*	7	0.09	14	4.1
21	Girar	*Acacia abyssinica subsp.abyssinica*	7	0.23	8	3.7
22	Kontir	*Entada abyssinica*	7	0.18	12	4.1
23	Atat	*Maytenus arbutifolia*	4	0.02	6	2.0
24	Nech Girar	*Acacia tortilis*	4	0.05	3	1.4
25	Key Girar	*Acacia seyal*	4	0.05	1	1.3
26	Jirura	*Phyllanthus ovalifolius*	3	0.03	5	1.5
27	Wanza	*Cordia africana*	3	1.0	8	6.1
28	Sesa	*Albizia gummifera*	3	0.15	4	1.9
29	Ishe	*Mimusops kummel*	2	0.02	3	1.1
30	Dengay seber	*Pavetta abyssinica*	2	0.02	5	1.4
31	Worchebo	*Lannea sp.*	2	0.1	5	1.7
32	Zana	*Stereospermum kunthianum*	2	1.35	7	7.3
33	Kezikize	*Schrebera alata*	2	0.02	4	1.2

No.	Local name	Latin name	Abundance (N ha^{-1})	Dominance (m$^{2.}$. ha^{-1})	Frequency (%)	IVI (%)
34	Gendero	*Dichrostachys cinerea*	2	0.01	6	1.5
35	Avalo	*Terminalia brownii*	1	0.01	2	0.4
36	Anfar	*Buddleia polystachya*	1	0.01	3	0.6
37	Birbira	*Milletia ferruginea*	1	0.01	3	0.7
38	kega	*Rosa abyssinica*	1	0.01	4	0.8
39	Kuara	*Erythrina abyssinica*	1	0.07	1	0.6
40	Linbech	*Clausena anisata*	1	0.01	4	0.8
41	kewut	*Celtis africana*	1	0.01	1	0.2
42	Tota miraq	*Acokanthera schimperi*	1	0.03	1	0.4
43	Wagesho	*Brucea antidysenterica.*	1	0.02	1	0.3
44	Yebel genbo	*Stegunotaenia araiiacea*	1	0.01	1	0.3
45	Anqualit	*Pittosporum viridiflorum*	1	0.01	1	0.2
46	Chibha	*Ficus thonnangi*	1	0.72	3	3.7
47	Qulsa	*Ficus ingens*	1	0.83	1	4.0
48	Wulkeffa	*Dombeya torrida subsp. Torrida*	1	0.01	3	0.6
49	Warka	*Ficus vasta*	1	1.72	1	7.6
	Total		**482**	**23.3**		**300.0**

Peer-review history:
The peer review history for this paper can be accessed here:
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