

Effect of Environmental Gradient on Species Composition and Structure of Gemeshat Forest, North Wollo, Ethiopia

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Abstract
A study on Gemeshat remnant forest sites were conducted to determine their woody species diversity and structure to provide information for a sustainable management of the forest. A total of 60 quadrants, measuring 20 × 20 m each, were established along line transects laid across Gemshat forest using stratified random sampling. Sixty species, representing 38 families and 60 genera, were recorded and documented. From all the species identified, 29(48.3%) and 31(51.7%) were trees and shrubs respectively. The major families are Fabaceae and Oleaceae. The highest diversity of woody species was 3.3 recorded in Chekaw forest followed by 3.1 in kelta forest while their corresponding evenness values were 0.81 and 0.86 respectively. The vegetation structure of Gemeshat forest implies that larger diameter classes are lost because of illegal cutting of woody species by local inhabitants for firewood collection and timber production. The highest basal area is recorded by Chekaw forest (6.28 m^2ha^{-1}) followed by kelta forest (4.09m^2ha^{-1}). IVI values of woody species ranges from 0.6 to 63.55. The forest requires urgent conservation measures by minimizing grazing of livestock and selective tree cuttings. Moreover, the remnant forest patches host several woody species, wild animals and bird species. Based on the results, regeneration status of the forest and appropriate conservation measures for sustainable use of the forest resources are suggested.
Keywords: Species diversity, Importance value index (IVI), Population Structure, sustainable use of forest

1. Introduction

Ethiopia is one of the top 25 biodiversity-rich countries in the world as the major center of diversity and endemism for several plant species, due to its great geographical diversity, elevation, vegetation, soil types and also diverse climate (Abiyou *et al.*, 2013, Amogne, 2014). Woody plants constitute about 1000 species out of which 300 are trees (Bekele, 2016). Biodiversity measurement typically focuses on the species level and species diversity is one of the most important indices for sustainable land use practice to reverse the decline of biodiversity by evaluating ecosystems at different scales (Shackelton, 2000, Ardakani, 2004).

According to MEFCC (2016), current Ethiopia's forest cover is 15.5 % which includes enormous areas of forest, dense wood lands,bamboo and plantation forests of the country. Forest is also defined as a land area covering a minimum of 0.05-1 ha that is covered by trees and bamboo at least of height 2m at maturity with tree crown cover of more than 20 %.

The knowledge of the floristic composition of an area is a prerequisite for phytogeographical studies, conservation, protection, management and monitoring forest resource activities, (Jafari and Akhani, 2008).Structural analysis and Species diversity are essential to provide information on species richness, forest management, forest ecology and ecosystem functions (Pappoe *et al.*,2010). Forest composition, community structure and diversity pattern are important ecological attributes significantly associated with principal environmental and anthropogenic variables (Gairola *et al.*,2008).Very few remnant forests remain today due to human activities (Badege ,2001).The flora of North wollo is the least known still now, mainly due to lack of access (Alerts *et al.*, 2006) and the species-elevation relationship is also less studied (Lomolinoes ,2001).

Identifying biodiversity-rich areas along environmental gradients is used as a criterion for biodiversity conservation priority setting (Brashear *et al*., 2005).

Remnant forests are secured from cutting when tropical forests are cleared for agriculture or grazing, act as nuclei of forest regeneration. They have a clear effect on the species diversity, composition, and ecology of the surrounding vegetation (Manette and Robin, 2014).The study areas have been rich in flora, fauna and bird species. However, remnant forest has been pressurized by the surrounding society through in appropriate land use, the increase in settlement expansion nearby dwellers and also an increase in deforestation in associated with landslide. Soil erosion is a serious problem in the study areas (Habru WOA, 2012). Therefore, it is important to prioritize biodiversity conservation sites by taking conservation activities which are basic and useful for the forests as well as the surroundings (Margules *et al.,* 2007).The availability of accurate data on forest resources is an essential requirement for protection, conservation, management and planning for sustainable development (Sandalow, 2000, FAO, 2007). There is a need to generate relevant information in order to ensure the conservation, management and sustainable utilization of remnant forests of north wollo in particular and other forests of Ethiopia in General. Therefore, the objectives of this study were to: (1) assess the species composition the forests; (2) determine the diversity of woody species in and; (3) to study the population structure of woody species.

2. Materials and methods

2.1. Description of the Study Area

The study area (Figure 1) is located in Habru District, North Wollo Zone,Amahra Region at the distance of 478 km far from Addis Ababa along Dessie to Woldiya road. It is found at 23 km from Habru district at Wurgessa town. The forest is located between UTM 56°40'00"-56°70'00"E longitude and latitude 37N 12°73'.50"to 12°78'.40"N latitude. Gemeshat forest is estimated to cover an area of 527 hectare; of these, 94 hectare accounts an area of kelta forest (2045-2300m a..l), 74 hectare for Gosh Wona forest (and 128 hectare belongs to Chekaw forest(1996-2433m a.s.l). The annual mean temperature of study area is 27˚c with mean annual rain of 923mm. The altitudinal ranges is from 1996 to 2433 meters above sea level (m.a.s.l.) and its rainfall distribution is bimodal with the main rainy season July to September and the small rainy season at end of February to end of April (Shimelse,2007).

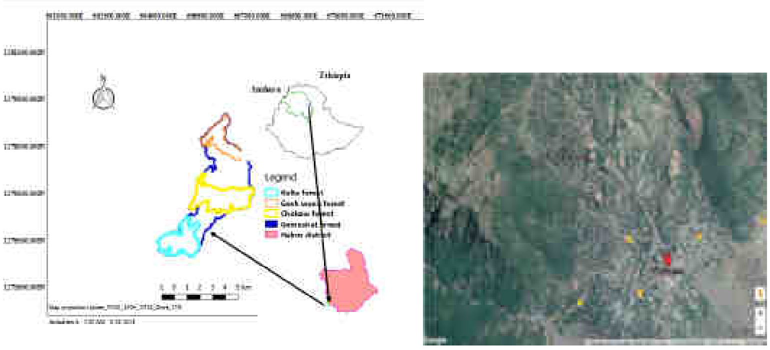

Figure 1.Map of the study area

2.2. Sampling design

A systematic stratified random sampling technique was used to collect vegetation data in the forest. Sample plot of 20 m× 20 m (400 m^2) was for trees of height >2m and DBH>10cm. Five sub plot of 5mx5m (25 m^2) were laid for shrubs with height greater than 0.5-5m.Five smaller plot of 2mx2m (4 m^2) also used for seedling <2m height and DBH<2.5cm and sapling >2m with DBH<10cm at the four corners and one at the center for tree regeneration study (Amare and Bhardwaj, 2016,Feyera,2006,FRA,2015). Sampling sites were arranged along transects which were laid at a distance of 100 m from each other. Along each transect, sample plots of 20 m x 20 m were taken at distance of 100 m from each other. A total of 60 quadrats were laid for vegetation data collection. Five 2 m x 2 m sub plots, one at each corner and one at the centre of the plot were laid to collect seedling ,2m height and DBH <2.5cm and sapling>2m height and DBH <10cm data. In each Gemeshat forest sites, the sample plots were established systematically along ten lines transects at every 100m interval between quadrats and transects. The distance between transects equally for each study sites by entering 20m from the edge of the forest. The sample plots taken for all forests were 19, 15 and 26 for Kelta, Gosh Wona and Chekaw forests respectively. The study areas was classified in to three altitude classes: Lower altitude (1900-2100m a.s.l), middle altitude (2100-2300m a.s.l) and upper altitude class >2300m a.s.l and also slope categorized in to four classes (1=<30%, 2= 30-50%, 3=50-70% and 4= >70%) and E and EW aspects.

2.3. Data Collection

2.3.1. Floristic Data Collection

Every plant species encountered in each quadrate was recorded using local name (vernacular names). For those species difficult to identify and give scientific name in the field, plant specimen were collected, pressed and brought to the national herbarium of Ethiopian, Addis Ababa University for taxonomic identification using published volume of the flora of Ethiopia and Eritrea(Hedberge and Edwards, 1989) and NDA (Natural Database for Africa) software. Moreover, for specimens being difficult to identify in the field, voucher samples were collected, pressed, and submitted for proper identification and botanical nomenclature at the National Herbarium, at Addis Ababa University.

For basal area calculation, tree species with DBH >2 cm were selected for comparison of remnant forests.

2.3.2. Structural data collection

The tree density, diameter at breast height (DBH), frequency, basal area and IVI were measured, recorded and used for description of vegetative structure. Trees with height >2 m and diameter at Brest Height (DBH) >2 cm were measured for tree and shrubs and. DBH measurement was taken at about 1.3m from the ground using measuring tape. Seedling and saplings of trees and shrubs were counted to estimate the regeneration status of the forest.

2.3.3 Environmental Data Collection

The altitude of each quadrates was recorded by using global position system (GPS) and geographical coordinates were measured using (Garmin 72 Chanel GPS) and slope degree (using Suunto clinometers), in the middle of the main plots. Engineering compass was used to measure direction and aspect of plots. Altitude, slope, and aspect of each study plots were recorded using GPS and clinometer. Woody species diversity, stand characteristics and regeneration status are the major biotic factors. While Altitude, slope and aspects are the abiotic factors considered for study.

2.4. Data Analysis

2.4.1. Floristic Data analysis

The collected Floristic data were recorded, summarized and analyzed by using Microsoft Excel, SPSS soft ware version 16.

2.4.2. Plant Diversity

Species diversity is determined by Shannon‘s diversity index and it was calculated by using Kent and Coker (1992), which gives more weight to rare species. $H' = -\sum \frac{ni}{N} \times ln \frac{ni}{N}$ — (1)

Species evenness was calculated as the ratio of observed diversity to maximum diversity using the equation (Kent and Coker, 1992): $J = \frac{H'}{Hmax} = \frac{H' = -\sum \frac{ni}{N} \times ln \frac{ni}{N}}{\ln s}$ − − − − − − −(2)

The Sorenson’s coefficient of similarity (SC) was calculated using (Sorensen,1948).

$$SC = \frac{2c}{a+b+2c} \times 100 - - - - - - - - - - - - - - (3)$$

Where C=Number of species common to both forest sites;a and b =the number of species at forest sites a and b (Magurran, 1988).

2.4.3. Plant Population Structure Data Analysis

Relative density, relative frequency, relative basal area, important value index (IVI) and basal area were calculated to determine the vegetation structure and the dominant species of the forest using formulas used by (Mueller-Dombois. and Ellenberg, 1974).

2.4.4. Stand characteristics of remnant forest

Stand characteristics expressed in number of trees/ha, DBH and height class distribution.

The vegetation and environmental factors was analyzed Using SPSS 16 and Microsoft Excel, 2013.Effect of environmental gradient on structure was analyzed using one way ANOVA The result of the analysis was summarized and presented using tables, and bar graphs.

3. Result and discussion

3.1. Species Composition

Sixty species recorded in the quadrats from all Gemehsat forest sites represented 60 genera and 38 families. Totally 31, 38 and 25 families and, 39, 56 and 34 Genera and species were identified in Kelta,Chekaw and Gosh wona forests respectively. Among these 21 families, 25 genera and 25 species are common to Gemeshat forest sites.

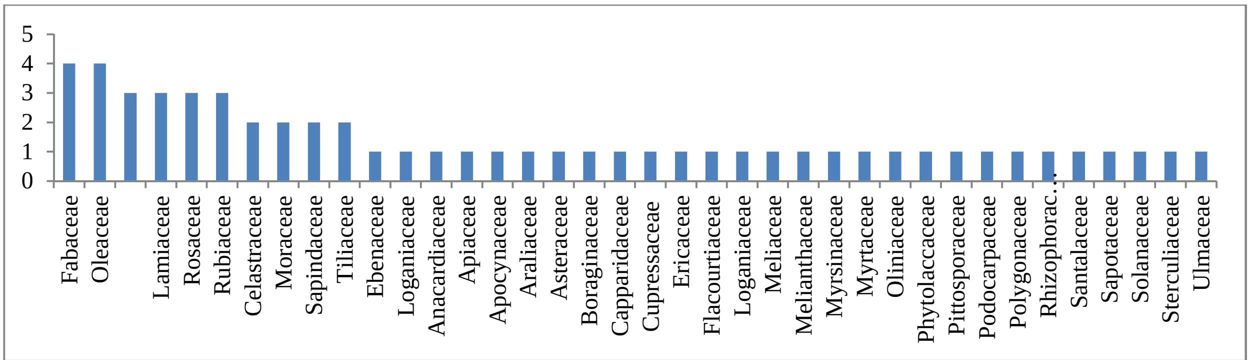

Figure 2.All woody species per families across Gemeshat forest sites

The most frequent families are Fabaceae and Oleaceae (4 species), and Euphorbiaceae, Lamiaceae, Rosaceae, and Rubiaceae (3 species each),Celastraceae, Moraceae, Sapindaceae, and Tiliaceae (2 species each) 28 families(represented by 1 species accounts 5.26%, 10.53%, and 10.53% share in the study areas respectively. Twenty eight families were represented by only one species (73.68%).

The number of families recorded is greater than the works of (Kitessa and Bishaw .2008).This might be due to the more percentage of trees than shrub species. Woody species belongs to shrub and trees account 48.3% and 51.7 % respectively. The total number of tree species recorded from the study area also comparable with Wof-Washa reported by (Gebremicael et *al*., 2013).

3.2. Species diversity indexes and similarity of Gemeshat Forest sites

Sixty woody species were recorded from Gemeshat forests. The total number of woody species recorded (i.e., species richness) were 34 and 60 for Gatira Georgis and Gemeshat forest respectively. The Shannon wiener index and Species richness is higher in Chekaw forest followed by Keleta forest (Table 1).

Table 1.Diversity indices across remnant forest sites in North Wollo, Ethiopia

Diversity indices	Keleta forest	Chekaw forest	Gosh wona forest
Shannon-weiner index	3.1	3.3	2.78
species richness	39	56	34
Species evenness	0.86	0.81	0.8

The species diversity values are highest in Chekaw forest followed by Keleta forest. Moreover, the study areas in species diversity are also higher than yilat natural forests (H'=2.94 and lower E=0.84 reported by (Sisay, 2016).

Higher species diversity is generally thought to indicate a more complex and healthier community due to a variety of species allowed for more species interaction, hence greater system of stability. The difference in species diversity and evenness between remnant forests is due to type of tree, number of regenerated species, soil nutrient status and geographical location (Robert and John, 2014, Manette *et al.*, 2014, Koushik *et al.*, 2015, Ermias, 2011).In general, compared to most of the studies conducted in the country higher species richness and diversity index were recorded for Gemeshat forest sites.

Woody species retained on Gemeshat forest are remnants of the natural vegetation found in the same agro ecology with slight altitudinal difference in north Wollo, Ethiopia. Hence, similarities in woody species composition are expected between the forests. Accordingly, 80 % of the species in the Kelta forest were also observed chekaw forests followed by 78.3% of species found in Kelta and Gosh wona (Table 2). This difference is due to nature of species, altitude and soil status of the forest.

Table 2.Sorensen similarity coefficient in Gemeshat forests of North Wollo, Ethiopia

Forest sites	Keleta forest	Chekaw forest	Gosh wona forest
	Similarity		
Keleta forest	1	80	78.3
Chekaw forest		1	66.7
Gosh wona forest			1

3.3. Vegetation structure

3.3.1. Density and diameter at breast height

Woody species with a diameter at breast height (DBH) greater than 2.5cm were measured to analyze the DBH and height class distribution in the forests. The DBH size classes were defined as to nine class intervals(<2.5 cm, 2.5-5 cm, 5.1-10 cm,10.1-15 cm,15.1-20 cm, 20.01-25 cm, 25.01-30 cm, 30.1-35cm and >35cm. Individuals with DBH less than 2.5 cm and height less than 2m were counted.

The number of tree species in DBH class less than 2.5cm.were represented by 526 stems ha^{-1}(42.1%) ,470 stem /ha(26.2%), and 328 stems/ha(26.2%) at Kelta forest,chekaw and Gosh , while,453(31.86%) stems/ha at Gemeshat forest While the DBH class >10cm were also highest in chekaw forest followed by Keleta and Gosh wona forests(Figure 3).

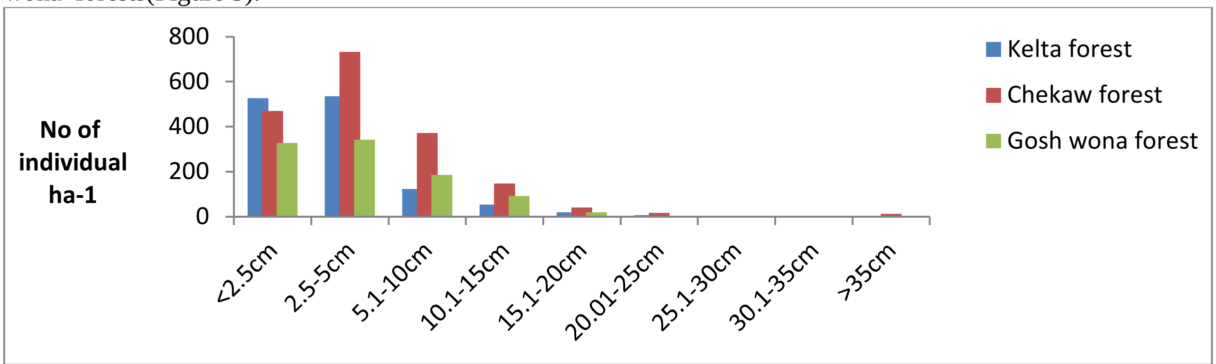

Figure 3.The DBH class of Gemeshat forest sites

The density of woody species also decrease as the DBH class increases, implies the number of individuals ha-1 is highest in the lower DBH class. A similar result was reported by (John *et al.,* 2015, Ahmed et al., 2017,Tesfaye *et al.,* 2017,).The density of plant species with DBH class as their contribution of the numbers of species were given in Table 3.The density of woody plant species increases with increasing number of species. So the general pattern of DBH class size distribution forms an irregular inverted J-shape (Figure 3) for the most selected dominant trees species. This might be associated with selective cutting of trees by people for construction and other house use.

Table 3.DBH class and the density of plant species in Kelta,chekaw and Gosh wona forest

DBH Class	No. Species			Density ha^{-1}			BA($m^2 ha^{-1}$)		
	Kelta	Chekaw	Goshona	Kelta	Chekaw	Goshona	Kelta	Chekaw	Goshona
<2.5cm	15	26	14	526	470	328	0.19	0.17	0.11
2.5-5cm	10	25	11	536	732	342	0.58	0.83	0.37
5.1-10cm	12	13	7	122	371	185	0.69	1.57	0.84
10.1-15cm	6	8	6	54	147	92	0.83	1.82	1.17
15.1-20cm	5,	7	3	20	41	20	0.63	0.92	0.45
20.1.-25cm	2	3	1	7	16	2	0.26	0.68	0.82
25.1-30cm	2	1	1	4	4	2	0.28	0.28	0.13
30.1-35cm	0	1	1	0	1	2	0	0.08	0.23
>35cm	1	5	1	4	12	2	0.63	2.05	0.29

The density of all woody species in Gemeshat forest sites based on DBH (Diameter at Breast Height) greater than 10 cm (a) was found to be 74,188 and 112 individuals per hectare in kelta, Chekaw and Gosh wona forest respectively. While it was 15, 20 and 28 individuals per hectare on DBH greater than 20 cm (b) in Kelta, Chekaw and Gosh Wona forest respectively. Similar result on Bale mountain national park also reported (Haile *et al.*,2008).

The highest basal area is recorded in DBH class 10.1-15 cm and the highest basal area attained by chekaw forest followed by Gosh Wona forest.In Gemeshat forest sites, the number of individuals per hectare for both DBH classes (DBH>10 and DBH > 20) was also high. This indicates the forest is under serious degradation due to human activities such as illegal cutting of woody species; grazing and browsing of by livestock. The ratio of DBH greater than 10 cm (a) to DBH greater than 20 cm (b) for Kelta, Chekaw and Gosh wona forest was found to be 4.9,9.4 and 4 respectively,. So, this ratio is used as a good indicator as to the status of a particular forest. In this regard, compared many forests, the Gemeshat forest sites showed a higher ratio implies the predominance of small size trees and shrubs. Hence, it could be considered as a regenerating forest.

The total number of species found in the lower DBH class is highest in Chekaw forest followed by Keleta and Gosh wona forest. This trend also decrease as the DBH class increases in all Gemeshat forest sites. The result is higher than Wotagisho forest south west Ethiopia reported by (Dikaso and Tesema, 2016).

Table 4.The three most abundant species in each Gemeshat forest sites according to decreasing order of the importance value index (IVI)

Forest type	Species	Relative frequency (%)	Relative density (%)	Relative basal area (%)	IVI (%)
Keleta forest	*Juniperus procera*	8.8	6.4	22.0	37.1
	Olea europaea	8.1	6.4	14.3	28.8
	Olinia rochetiana	11.2	6.4	8.5	26.1
Chekaw forest	*Podocarpus falcatus*	8.67	3.35	14.34	26.36
	Olinia rochetiana	6.15	5.49	12.25	23.89
	Psdyrax shemperi	7.01	4.57	11.22	22.80
Gosh-wona forest	*Juniperus procera*	15.29	8.33	39.93	63.55
	Acacia abyssinica	14.79	8.33	34.14	57.26
	Maytenus arbitifolia	13.78	9.03	2.74	25.55

Juniperus procera and *Olinia rochetiana* are the most important species in Keleta and Gosh wona forests. *Podocarpus falcatus* is the most important species in Chekaw forest. Species less than 10 ranks in the IVI values deserve appropriate conservation measures (Simon and Girma, 2004).

Basal area

The normal value of basal area in Africa is expected to be between 23-37m^2/ha reported by (lamperchet, 1989).In this regards, the total basal area of Gemeshat forest sites was recorded in the order of Chekaw forest (6.28 $m^2 ha^{-1}$) followed by kelta forest (4.09$m^2 ha^{-1}$), and Gosh wona forests (2.43 m^2 ha^{-1}) (Table 5).However, the total basal area recorded in the study areas are less than Gurra Farda Forest(90.6 m^2 ha^{-1})(Kitessa and Bishaw,2008),and lammo natural forest(13.35 m^2 ha^{-1})(Melese and Wendawek,2016),Wof-Washa,Wontagisho forest(46.32$m^2 ha^{-1}$) (Gebermicael et al.2013) and Denkoro forest(45 m^2 ha^{-1})(Ayalew et al.,2006) of Ethiopia.

While, the total basal area of Gemeshat forest are greater than Yilat(1 m^2 ha^{-1} (Sissay(2016).

Table 5.Basal area distribution across Gemeshat forests of North Wollo, Ethiopia

Forest sites	Gosh wona forest	Kelta forest	Cheakw forest
Basal area(m^2/ha)	2.43	4.09	6.28

3.4. Population structure and diversity environment gradient relationship of Gemeshat forest sites

Altitude had showed a decreasing trend for Shannon weiner index, species evenness and species richness in the remnant forests.The highest and lowest species diversity is attained in the lower and upper altitude classes respectively (Table 5).The maximum species diversity values recorded in 1900-2100m a.s.l.While the minimum values of species diversity is attained by >2300m a.s.l.This imlies shannon weiner index , species evenness and species richness values decrease as altitude increases. The result is comparable with other studies (Alemayehu et al., 2010).

Table4.Altitudinal effect on species diversity of remnant forests of north Wollo

Altitude	Shannon-weiner index	Species evenness	Species richness
1900-2100	3.32	0.84	52
2100-2300	3.19	0.81	49
>2300	3.05	0.79	49

Altitude had showed significant effect on height and basal area at $p<0.05$.While altitude had no significant effect on DBH (Table 6). Many studies comparing tropical forests along an altitudinal gradient demonstrate that not only species diversity but also forest structure decrease with increasing altitude (Lacoul and Freedman,2006).Altitude and slope affect population structure (Rohollah and Hamid 2015).Slope aspect has effect on structure of the forest. Comparable results also reported by (Farzam and Mehrzad, 2014).

Table 6.Enviroment gradient effect (Mean + std) on Population structure of Gemeshat forest sites

Abiotic factors	DBH	Ht	BA
Altitude 1900-2100	6.7 ± 9.6^{Ns}	5.7 ± 4.2^{a}	0.1 ± 0.2^{a}
2100-2300ma.s.l	7.2 ± 6.9^{Ns}	5.6 ± 4.1^{ab}	0.04 ± 0.1^{b}
>2300 m a.s.l	6.5 ± 0.8^{Ns}	5.2 ± 3.4^{b}	0.05 ± 0.1^{b}
Slope <30%	5.9 ± 9^{Ns}	4.4 ± 3.4^{b}	0.07 ± 0.1^{Ns}
30-50%	$6\pm4,8^{Ns}$	6 ± 4^{a}	0.04 ± 0.1^{Ns}
50-70%	7 ± 5.8^{Ns}	5.6 ± 4^{ab}	0.06 ± 0.5^{Ns}
>70%	6.8 ± 7^{Ns}	5.5 ± 3.9^{ab}	0.13 ± 0.1^{Ns}
Aspect E	6.7 ± 0.1^{Ns}	5.8 ± 4.1^{a}	0.06 ± 0.1^{Ns}
EW	6.9 ± 9^{Ns}	4.7 ± 3.1^{b}	0.05 ± 0.1^{Ns}

Mean within the same column followed by the same letter are not significantly different at ($p = 0.05$).Ns=non significant

4. Conclusion and recommendation

The major families identified in Gemehsat forest include Fabaceae and Oleaceae (four species each).

The highest species diversity is attained in Chekaw forest and the lowest species diversity is recoded in Gosh Wona forest. The less diverse forest site implies degraded forest than the two forest sites.

The highest basal area is recorded by Chekaw forest (6.28 m^2ha^{-1}) followed by kelta forest (4.09m^2ha^{-1}).

The highest IVI value was contributed by *Juniperus procera* in Gosh wona and Keleta forest.

The density of woody species decreases with increasing DBH implies the larger trees in Gemeshat forest were under huge pressure due to illegal cutting of woody species and cattle grazing in the forest.

it can be concluded that remnant forests in the study area possess high species diversity, diverse floristic composition, & healthy structural population with good regeneration status.

However, the major natural & anthropogenic activates observed include landslide, erosion, overgrazing, inappropriate land use, illegal cutting of tree for timber and fuel wood collection.

Therefore, it needs effective management intervention to sustain goods &services from forests.

Based on the findings the following recommendation was forwarded:

Raising awareness on the values of the forest and its ecological consequences of deforestation..

Species with low IVI needs to be prioritized for conservation.

Sustainable protection and management of the forests needed through the collaborative effort of the government, NGO and the local community for reduction of woody species cutting.

Regeneration and soil status of the forest should be further investigated from remnant forest on suitable basis

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