Article

Diversity, structure and regeneration status of woody species in *Juniperus* dominated dry Afromontane forest of Beyeda district, northern highlands of Ethiopia

Muhabaw Taju[1], **Asmamaw Alemu**[1], **Endalkachew Teshome**[2]

[1]Department of General Forestry, College of Agriculture and Environmental Sciences, University of Gondar, Ethiopia

[2]Department of Tourism Development, University of Gondar, Ethiopia

E-mail: muhabawtaju10@gmail.com

Received 22 March 2021; Accepted 30 April 2021; Published 1 September 2021

Abstract

Ethiopia is recognized as a major center of biodiversity. The vegetation types are highly diverse, varying from Afro-alpine to Desert vegetation types. However, the country's forest resources are declining alarmingly largely due to anthropogenic factors. The *Juniperu*s dominated Afromontane forest of the northern highlands of Ethiopia is among the most threatened forest which calls for ecological investigations to formulate strategy for protection and sustainable utilization of the forest resources. This study was conducted in the *Juniperus* dominated Afromontane forest of the Northern highlands of Ethiopia to determine woody species diversity, structure and regeneration status along different levels of disturbances and to investigate human induced disturbances on woody species. For vegetation survey the forest was stratified in to three disturbance levels (Less disturbed, moderately disturbed, and highly disturbed forests). The vegetation assessment followed a systematic random sampling and vegetation data were collected from 41 square meters (20 x 20 m^2) sample plots. Species diversity, evenness, similarities, and regeneration statuses along disturbances were computed using Shannon diversity, Evenness indices and Sorenson's similarity index. Further, ANOVA were used to test differences among disturbance levels. A total of 24 woody species belonging to 20 families and 24 genera were identified. Species Richness, Evenness, density and basal area of woody species decreased as intensity of disturbance increased. Woody species density, Richness, and basal areas along disturbance were significantly different as we move from highly disturbed forest to less disturbed forest. Population structure showed trends of inverted 'J' shape pattern in all gradients of disturbance. As intensity of anthropogenic disturbance increases the forest is converted in to low quality shrubby and scrub lands. As a result of the above-mentioned facts human induced disturbance has a negative effect on woody species diversity, structure and regeneration status. But mild disturbance has a positive effect in facilitating regeneration as a result of gap creation. So, attention should be given in formulating forest management plan and strategy to limit the impact of anthropogenic disturbance for the sustainable management of the forest.

Keywords *Juniperus*; Afromontane forest; woody species diversity; disturbance gradient; regeneration status.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The Ethiopian highlands comprise more than 50 % of the land area with Afromontane vegetation, from which the dry evergreen Afromontane forests and grass land complexes forming large coverage in different parts of the country (Berhanu et al., 2017; Ayalew et al., 2020). The Ethiopian highlands were once covered by forests, with co-dominant *Juniperus* and *Olea* species (Bishaw, 2001; Sterck et al., 2010). The current remaining fragmented forests in the Ethiopian highlands are several centuries old, with small and ancient forest patches whichare found around sacered places, highly protected national forest priority areas, and in inaccessible mountains and valleys (Wassie and Teketay, 2006).

Although the country is rich in biodiversity, its biological resources are being destroyed at an alarming rate Friis (1986) and forest resources degradation is intense in the Northern highlands of Ethiopia compared to other parts of the country owing to large human and livestock population and long history of settlement (Amare et al., 2016; Woldearegay et al., 2018; Gemechu and Jiru, 2021). Human-induced disturbances such as conversion of forest land to cultivation fields, livestock over grazing, selective logging and settlement encroachments are generally considered to be among the major causes for forest resource degradation (Mamo et al., 2015; Woldearegay et al., 2018; Gemechu and Jiru, 2021). Due to the above mentioned factors these dry evergreen Afromontane forests are becoming the most threatened forest in Ethiopia (Mucheye and Yemata, 2020). Studies indicated that few remnant high forests are found in southwestern and western parts and as patches in conservation sites, churches and sacred areas in the country (Senbeta, 2006; Alelign et al., 2007; Wassie et al., 2007; Zegeye et al., 2011). Afromontane forests belong to the most fragmented forest ecosystems which should be accorded high conservation priority (Zegeye, 2006).

The *Juniperus* dominated forest which is part of the dry evergreen Afromontane forest of Ethiopia once covered large area for the past 100 years (Pohjonen and Pukkala, 1992). *Juniperus* is a very important woody species to produces timber of high economic value. The wood is used for manufacturing of lead pencil, construction and lining of buildings, and for a variety of outdoor works owing to its fine texture, straight grain, medium hardness, resistance to termite attack and workability (Sterck et al., 2010). Despite these values, the forest is getting deteriorated by several anthropogenic and natural factors that lead the forest to endangered status in some provenance Sertse et al. (2011) as these forests being surrounded by agricultural lands and settlement areas; the size and quality of remnant forest patches have been largely degraded at an alarming rate due to various factors such as encroachment, disturbance and selective logging, leading to the gradual loss of key species like *Juniperus* (Teketay, 2005; Sertse et al., 2011; Wassie et al., 2017).

Anthropogenic disturbance has its own effect on different ecological parameters in a forest. For instance; Species diversity and richness often varies from one forest to another depending on a number of factors. Maximum number of species richness has been obtained in moderately disturbed forest type (Uniyal et al, 2010). On the other hand, other studies have reported of higher species richness in less disturbed stands in relation to other forest types (Addo-Fordjour et al., 2009). Whatever the case, it is clear that species diversity, richness and regeneration capacity is negatively affected by intensive disturbance as observed by Afua (2011). Higher species richness at intermediate disturbance level may occur due to the presence of intermediate resource levels present in which many species make use of it. It was also explained by Uniyal et al. (2010) that mild disturbance provides greater opportunity for species turnover, colonization and persistence of high species richness. The pattern of species diversity and richness along a disturbance gradient may vary from one life form to another whereas tree species richness peaked at undisturbed level, that of shrubs peaked at disturbed forest (Pitchairamu et al., 2008). However, the number of shrub species richness remained higher in the disturbed stand compared to the undisturbed stand (Mamo et al., 2015). Higher species richness of trees in the undisturbed forest was attributed to absence of human disturbance (harvesting of trees) that of shrubs in the disturbed forest has been explained by their ability to resist and adapt any form of disturbance (Hill and Hill, 2001). Whatever the case frequency and magnitude of disturbance are key factors for changes in species diversity, richness and regeneration statuses (Shrestha et al., 2013).

Adequate understanding of woody species diversity, structure and regeneration of a given vegetation formation and the ecological processes such as the response of the constituting species to the different levels of disturbance is essential for designing appropriate management practices. The key research question is thus ‘how does the species composition, diversity, structure and regeneration status vary along the gradients of disturbance? Such scientific investigations can contribute to uncover the ecological processes in such remaining vegetation that were preserved due to inaccessibility. These are important galleries and possible potential germplasm sources for ecological studies, conservation initiatives and plantation development of threatened single species dominated dry Afromontane and sub-Afro alpine species. Moreover, the reminant gallery vegetation of the *Juniperus* dominated Afromontane forest in the northern high lands of Ethiopia have been not yet investigated and even their existence is not recognized by the scientific community. Hence due to lack of sufficient baseline information about the existence and distribution of such type of forest in other areas like ‘Beyeda’ district; most of the researchers concentrated on few National forests’ priority areas. Studying woody species diversity, structure and regeneration status of the *Juniperus* dominated forest which is one of the endangered species is very much helpful in formulating forest management strategies. As the respective forest is not far from two government Universities it’s conservation and preservation may play crucial role for practical teaching practices and scientific researches. This study was therefore, carried out to determine the species diversity, structure and regeneration in the *Juniperus* dominated forest in the northern highlands of Ethiopia in relation to different levels of anthropogenic disturbances.

2 Study area and Methodology

2.1 Study site

The study was carried out in Beyeda District (Fig. 1), Northern highlands of Ethiopia. The merit to select such forest for this research is; having extensive coverage of *Juniperus* dominated forest which is one of the endangered woody species in the country which is uncommon in most highlands of Ethiopia. So, the existence of such forest under different levels of anthropogenic disturbances is the pushing factor to select the forest as a study area.

The study forest was geographically located between 13^{0}4’40’’- 13^{0}6’40’’N latitude and 38^{0}24’00’’- 38^{0}26’40’’Elongitude geographical grids. The topography of the area is characterized by rugged mountains, cliffs, hills, plateaus, valleys and gorges with an altitudinal range of 1232 - 4543 m above sea level. The major soil types are umbric leptosol, eutricleptosol, umbric andosol and eutriccambisol (BoFED, 2016; BDoA, 2017; Adugna, 2017). The rainfall is characterized by a uni-modal distribution which lasts for 3 months stretching from June till August with mean annual rainfall of 1172 mm. Due to the altitudinal differences of the area there are three main vegetation zones, namely Montane forest (1,900 to 3,000 m. a.s.l), Ericaceous belt (Sub-Afro alpine) (2,700 to 3,700 m a.s.l) and finally the Afro alpine zone (3,700 to 4,533 m a.s.l) (Teshome, 2007).

2.2 Data collection

The entire forest area was stratified into three homogeneous strata following disturbance gradients based on practical visual observation and following the methodology used by Afua (2011) and Mamo et al. (2015). The forest types were selected to represent the various degrees of anthropogenic disturbances taking place in the study forest. These were 1) Less disturbed forest hereafter (LDF): situated far from settlement and crop cultivation areas, and with relatively low level of logging and grazing, surrounded by mountain cliffs and rivers and availability of permanent forest guard, 2) Moderately disturbed forest (MDF): situated in areas with no crop cultivation and settlement, but with considerable levels of selective logging and grazing; and 3) Highly disturbed forest (HDF): around settlement and crop cultivation areas and with relatively high intensity of grazing, fuel wood collection, logging, charcoaling and high number of dead stumps (Fig. 2). These forest types were selected in areas with approximately similar topography and altitude so as to eliminate their effects on plant composition and structure.

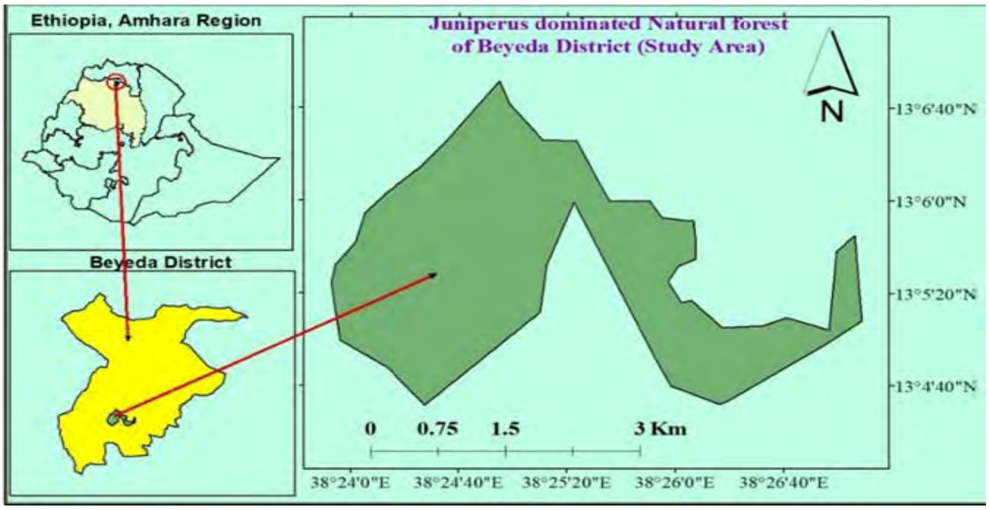

Fig. 1 Map of the Study area.

Fig. 2 Picture shows study sites along disturbance level.

Systematic random sampling was employed for the vegetation assessment. Following Teketay (2001) and Fisaha et al. (2013), transect lines were laid in the forest following the disturbance gradient of the site starting from the top of ridge to bottom valley and the sampling plots were situated along disturbance gradients (LDF, MDF, and HDF). As illustrated in Fig. 3, main and sub sample plots were used for data collection on adult trees, seedlings and saplings.

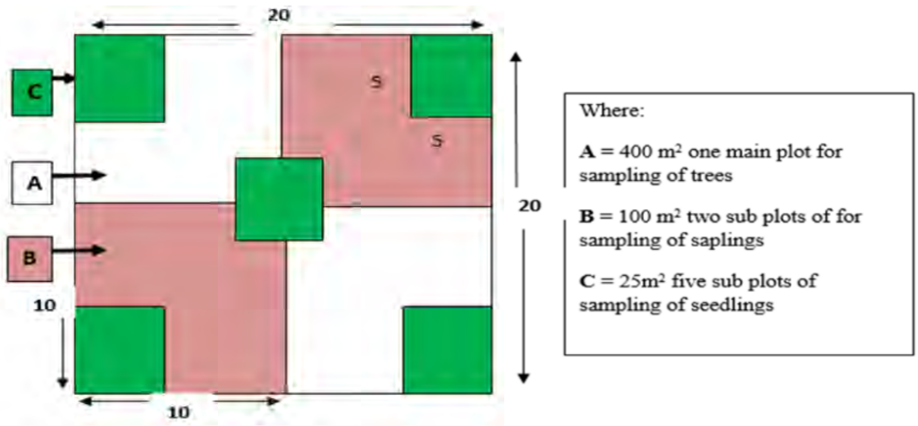

Fig. 3 Simple sketch shows data collection quadrates.

A total of 41 square main sample plots (15 for LDF, 16 for MDF, and 10 for HDF) with a size of 20 m x 20 m for the sampling of adult trees were taken (Fig. 4). Two 10 m x 10 m sub plots in each corners of the main plot (totally 82 sub plots) were laid for the sampling of saplings and five 5 m x 5 m sub plots in four corners and one at the center of the main plot (totally 205 sub plots) for the inventory of seedlings were laid down at a distance between transect lines and sampling plots of 200 m and 100 m respectively using Garmin 60X GPS and Compass.

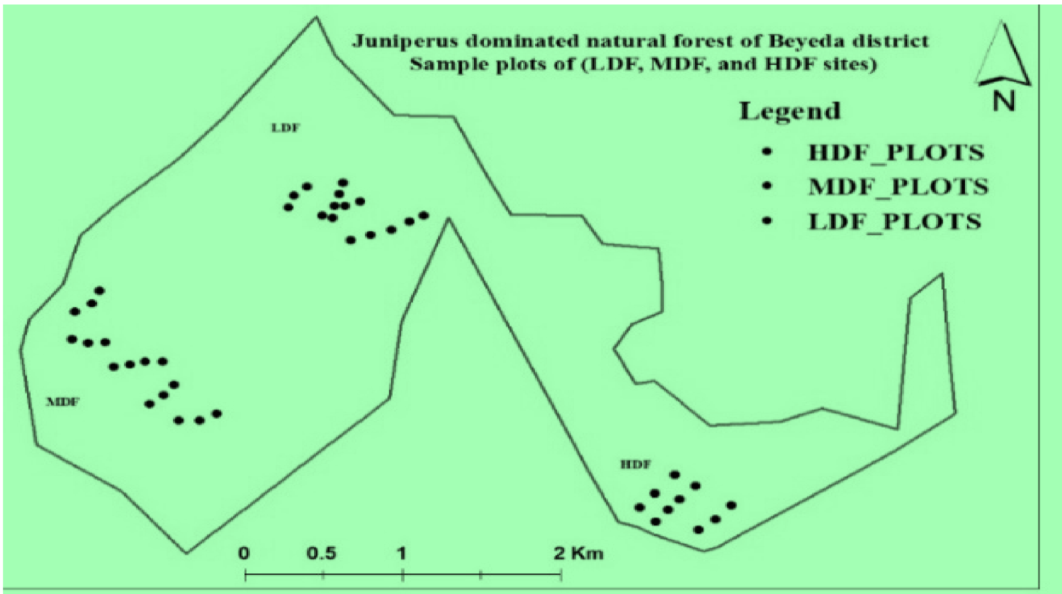

Fig. 4 Map shows sampling plots along the gradients of disturbance.

Species accumulation curve (Fig. 5) was used to determine minimal sample plots as species accumulation curves illustrate the rate at which new species are found (Magurran, 2004). The adequacy of sample size was estimated by stopping sampling at the point at which additional quadrats did not significantly affect the mean of species (Ellenberg, 1974). As a result, the researchers decided to limit the number of sample plots based on the principle of species accumulation curve.

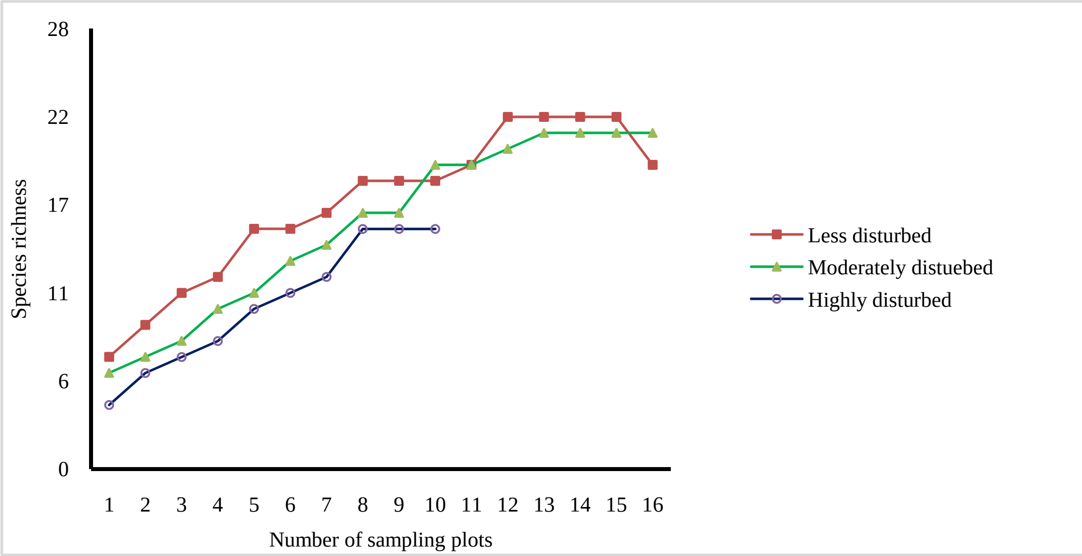

Fig. 5 Species accumulation curve.

All adult tree individuals of the woody species encountered within the main plot and saplings and seedlings of woody species within the subplots were recorded (Fig. 3). In each sampling plot, the diameter at breast height (DBH) (1.3 m above the ground) of each tree was measured using Caliper and height were measured using hypsometer and gratuated stick. For this study, plants were categorized as seedling (height 1 m), sapling (height between 1 m and 2 m) and tree (height 2 m and DBH2 cm) following (Senbeta and Teketay, 2001; Fisaha et al., 2013; Kebede et al., 2013; Melese and Ayele, 2017). In cases where a bole branched tree found measurement at breast height or below, the diameters were measured separately and considered as two trees and in cases where tree boles buttressed, DBH were measured from the point just above the buttresses. Species were identified using published volumes of flora of Ethiopia and Eritrea (Hedberg et al., 1989; Hedberg et al., 1995; Hedberg et al., 2003; Demissew, 2014). To investigated of anthropogenic disturbance on woody species in the forest, all types of disturbances like, the total number of dead standing trees, stumps and logs in the sample plots were counted by involving knowledgeable persons from the local communities as it was key to estimate the level of anthropogenic disturbances.

2.3 Data analysis

Diversity of woody species along disturbances were determined using the Shannon-Wiener Diversity Index (H') and Evenness or Equitability Index (E) (Krebs, 1989; Magurran, 2004)

$$\textbf{Species Diversity }(\mathbf{H'}) = -\sum_{\mathbf{i=1}}^{\mathbf{s}} \mathbf{Pi}\ \mathbf{ln}(\mathbf{Pi})$$

where, H'= Shannon index, S= Species richness, Pi= proportion of S made up of the i^{th} species (relative abundance),

$$Eveness(J) = \frac{\sum_{i=1}^{s} pi\ln(pi)}{\ln(s)}$$

where, J'= Evenness and S= Species richness.

The Shannon-Wiener diversity and evenness index was used as it is the most commonly used diversity index which is done based on information theory and the concept that the diversity or information in a sample or community can be measured in a similar way to the information contained within a message or code. The index makes the assumption that individuals are randomly sampled from an 'infinitely large' population and also assumes that all the species from a community are included in the sample. Values of the index usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5. The Shannon index increases as both the richness and the evenness of the community increase (Kent, 2012).

The similarity in woody species composition between the forests was computed by using Sorensen's similarity index because it relies on presence or absence data and also gives more weight to species that are present in both quadrats and less weight to species that are present in only one quadrat (Kent, 2012)

$$\boldsymbol{Ss} = \frac{\boldsymbol{2a}}{(\boldsymbol{2a} + \boldsymbol{b} + \boldsymbol{c})}$$

where Ss'= Sorensen's similarity coefficient, a= number of species common to the samples, b=number of species in sample 1 only, and c= Number of species in sample 2 only. Often the coefficient is multiplied by 100 to give a percentage similarity index.

The density and percentage frequency of woody species were calculated as used by Neelo et al. (2013) and Mueller- Dombois (2016)

$$\text{Total density of species} = \frac{\text{Number of individuals of species A}}{\text{Area sampled}} \times 100$$

The DBH data of trees and shrubs were categorized into six classes, and presented by using histograms. Basal area of trees and shrubs with DBH ≥ 2 cm was calculated. The Importance Value Index (IVI) for each woody species was computed using the following formula

$$\text{Dominance} = \frac{\text{Total basal area}}{\text{Area sampled}}$$

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Total dominance of all species}} \times 100$$

$$\text{Basal area (m)}^2 = \pi \frac{\text{DBH}^2}{4}$$

where

BA = basal area per tree in m^2, π = 3.1416, and DBH = diameter at breast height in cm (1.3 m above the ground).

Importance Value Index (IVI) = Relative density+ Relative frequency+ Relative dominance

$$IVI_i = \left[\frac{B_i}{\sum B_j} \times 100\right] + \left[\frac{n_i}{\sum n_j} \times 100\right] + \left[\frac{f_i}{\sum f_j} \times 100\right]$$

where
IVIi = the Importance Value Index (IVI) of the i^{th} species,
ni = the number of individuals of the i^{th} species,
nj = the sum of individual trees of all species,
Bi = the basal area of the i^{th} species,
Bj = the total basal area (m^2) of all species, and
fi = the absolute frequency of the i^{th} species.

The regeneration status of the major study species along disturbance were summarized based on the total count of seedling and sapling of each species across all quadrants and presented in tables, graphs and frequency histograms following Senbeta and Teketay (2001). Individuals were counted as seedlings with a height of ≤ 1 m and DBH of ≤ 2 cm) and saplings (with a height > 1 m and with a DBH 2 cm) following Peters (1996).

The regeneration status of the forest was assessed using the following categories used by (Vishal, 2011; Fisaha et al., 2013)

1. 'Good', if presence of seedling > sapling > adult trees;
2. 'Fair', if presence of seedling > sapling < adult trees;
3. 'Poor', if a species survives only in the sapling stage, but not as seedlings (even though saplings may be <, >, or = mature trees);
4. 'None', if a species is absent both in sapling and seedling stages, but present as mature; and
5. 'New', if a species has no mature, but only sapling and/ or seedling stages.

Besides the aforementioned ecological analytical procedures both descriptive and inferential statistics were used. For further analysis one-way ANOVA at a significance level of 0.05% was used to test the differences in woody species parameters (species diversity, species richness, species evenness and density) along the gradients of disturbances and Microsoft office Excel were used for data entry and for the analysis of descriptive statistics.

3 Result and Discussion

3.1 Woody species composition, richness, diversity, and similarity along the gradients of disturbance

3.1.1 Composition of woody species

A total of 24 woody species which were belongs to 24 genera and 20 families were identified (Table 1). Among the families, Sapindaceae, Loganiaceae, Rosaceae, and Fabaceae were the most diverse families each represented with 2 species and constituting 40% of the species composition along disturbance gradients; the rest of the 12 families were represented by a single species.

Out of the total species composition, trees share 53%, 42% and 20% in the LDF, MDF and HDF sites, respectively. While the shrubs share 37%, 58% and 80% in the LDF, MDF and HDF sites respectively (Fig. 6). As the result reveals, shrubs constituted the major life form of woody species in the HDF, MDF, and LDF sites as compared to trees. This may be due to the ongoing anthropogenic disturbance like selective logging seriously decreased the number of tree species. Specially, in highly disturbed site shrubs constitute 80% of the whole population, which may be because of the presence of disturbance tolerant and resistant species. If such anthropogenic disturbance continued such valuable canopy forest might be transformed in to lower quality scrub lands. The present findings were confirmed with similar studies (Betemariyam, 2011; Woldearegay et al., 2018).

Table 1 List of woody species identified.

Family name	Species name	Local name	Life form	Disturbance levels		
				LDF	MDF	HDF
Cupressaceae	*Juniperus procera* Hochst. ex Endl.	Tid	Tree	*	*	*
Myrtaceae	*Myrica salicifolia* A. Rich.	Shinet	Tree	*	*	*
Oleaceae	*Olea europaea* subsp. *cuspidata*	Weyira	Tree	*	*	*
Ericaceae	*Erica arborea* L.	Wuchena	Tree	*	*	*
Santalaceae	*Osyris quadripartita* Decn.	Keret	Shrub	*	*	*
Sapindaceae	*Allophylus abyssinicus* (Hochst.)	Embis	Tree	*	*	-
Sapindaceae	*Dodonaea angustifolia* L. f.	Kitkita	Shrub	*	*	*
Myrsinaceae	*Myrsine africana* L.	Kechemo	Shrub	*	*	*
Euphorbiaceae	*Clutia abyssinica* Jaub. & Spach.	Feyelefejj	shrub	*	*	*
Celastraceae	*Maytenus arbutifolia* (A. Rich.) Wilczek	Atatt	Shrub	*	*	*
Rhamnaceae	*Rhamnus staddo* A. Rich.	Teddo	Shrub	-	*	*
Pittosporaceae	*Pittosporum abyssinicum* Del.	Weyl	Tree	*	*	-
Hypericaceae	*Hypericum revolutum* Vahl	Amija	Shrub	*	*	*
Loganiaceae	*Buddleja polystachya* Fresen.	Anfar	Tree	*	*	*
Apocynaceae	*Carissa spinarum* L. (c. edulis)	Agam	Shrub	*	*	*
Rosaceae	*Rosa abyssincia* Lindley.	Kega	Shrub	*	*	*
Polygonaceae	*Rumex nervosus* Vahl	Imbwacho	Shrub	-	*	*
Fabaceae	*Calpurnia aurea* (Ait.) Benth.	Digta	Shrub	*	-	-
Rosaceae	*Hagenia abyssinica* (Bruce) J.F. Gmelin	Kosso	Tree	*	-	-
Araliaceae	*Schefflera abyssinica* (Hochst. ex A. Rich.)	Getem	Tree	*	-	-
Loganiaceae	*Nuxia congeta* R.Br. ex Fresen.	Askwaro	Tree	*	*	-
Sterculiaceae	*Dombeya torrid* (J. F. Gmel.) P. Bamps	Wulkifa	Tree	*	*	-
Salicacea	*Salix subserrata* Willd.	Haya	Tree	*	*	-
Fabaceae	*Acacia abyssinica* Hochst.	B/Girar	Tree	-	*	-

* present; - absent.

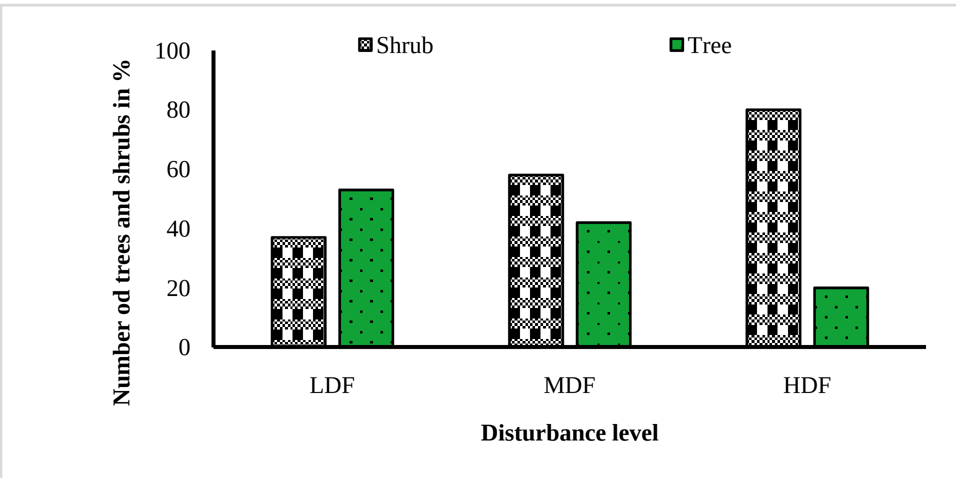

Fig. 6 Composition of woody species along the gradients of disturbance.

Comparing the species composition of the study forests with other similar forests in Ethiopia, the species composition of the study forest resembles more with Denkoro Forest (Ayalew et al., 2006), Ericaceous Forest of Semien Mountains (Teshome, 2007), Menagesha Suba Forest (Benti, 2011), Desa Forest (Betemariyam, 2011), Menagesha Amba Mariam Forest (Tilahun, 2015), Hugumburda Forest (Aynekulu et al., 2016), and Yegof dry Afromontane forest (Woldearegay et al., 2018). All are characterized as *Juniperus* dominated Dry Afromontane forests.

3.1.2 Woody species richness

The overall Species richness of the LDF, MDF, and HDF were 22, 21, and 15 respectively. Hence, Species richness decreases along the gradients of disturbance. The highest woody species richness was recorded in LDF and MDF whereas the woody species richness in HDF was lower. Again, the number of families recoded in the three strata follows similar decreasing trend with the increase in disturbance level. In the LDF, MDF, and HDF the number of families recorded were 20, 19, and 11, respectively. Furthermore, the species richness of life stages along disturbance significantly differ at (p=0.021) showing a general decreasing trend as intensity of disturbance increases (Fig. 7). The decrease in the species richness along the increase in intensity of disturbance gradient may reflect high utilization pressure of the forests. That means, due to the ongoing encroachment some of the woody species might be eliminated either by selective logging or by browsing herbivores animals.

The species richness of this forest was lower than other similar forests like Denkoro Forest (174 species) (Ayalew et al., 2006), Bale Mountain Forest (230 species) (Yineger et al., 2008), Menagesha Suba Forest (112 species) (Benti, 2011), Wof Washa Forest (62 species) (Fisaha et al., 2013), Yegof Forest (76 species) (Woldearegay et al., 2018), and Gelawoldie community forest (59 species) (Mucheye and Yemata, 2020). This might be due to geographical location, habitat differentiation and ongoing anthropogenic impacts (Woldearegay et al., 2018). Moreover, altitude may also be another cause for changes in species richness; as the study forest is situated at an altitudinal range between 3,060 m-3,248 m a.s.l. which is the upper limit of *Juniperus* forest (Sharew, 1994). The decrease in species richness at higher elevations may be due to the decrease in temperature, which may reduce productivity (Betemariyam, 2011). The extents of these effects are dependent on the type and severities of the disturbances (Mamo et al., 2015). As expected, the present study demonstrated that woody species richness varies along disturbance gradients in the studied forest. Overall woody plant species richness of *Juniperus* dominated forest of the study forest were generally decreasing with increasing disturbance (Fig. 7). This pattern of species distribution is supported by other related studies like Addo-Fordjour et al. (2009) in TinteBempo Forest of Ghana; and Afua (2011) in Atiwa range Forest. All these studies have related this trend to the influence of human disturbances.

3.1.3 Woody species diversity

The overall diversity index (H') of the forest along disturbance gradients (LDF, MDF, and HDF) were 1.95, 1.88, and 2.01, respectively (Table 2). The diversity was quantitatively higher in highly disturbed forest; that could be due to the proportional representation of shrubby and disturbance resistant species like *Dodonaea angustifolia*, *Clutia abyssinica*, *Rumex nervosus*, and *Myrsine africana*. Likewise, Species evenness index (E') along disturbance were 0.64, 0.62, and 0.72 respectively. There was no significant variation in overall woody species diversity along the gradients of disturbance. But, the woody species diversity in between life stages (Seedling, sapling, and trees) quantitatively varied as the intensity of disturbance increases showing a decreasing trend as the intensity of disturbance increases (Table 2).

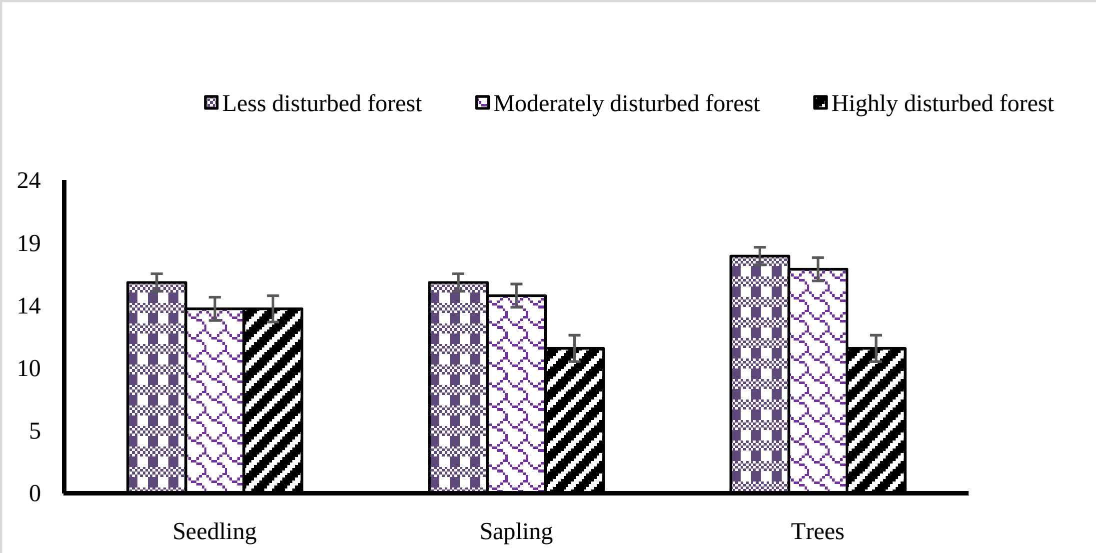

Fig. 7 Woody species richness along disturbance gradients.

Table 2 Species diversity, richness and evenness of the study forest along disturbance levels (LDF, MDF, and HDF).

Forest sites	Life stages	Diversity (H')	Evenness	Woody species density/ha	Species richness
	Seedlings	2.14	0.64	48565	16
	Saplings	2.72	0.83	6666	16
Less disturbed forest	Trees	1.18	0.41	3103	18
	Seedlings	1.67	0.67	37495	14
	Saplings	1.81	0.77	5300	15
Moderately disturbed forest	Trees	1.32	0.47	1878	17
	Seedlings	1.43	0.72	9312	14
	Saplings	1.83	0.76	1885	11
Highly disturbed forest	Trees	0.94	0.52	528	11
Mean		1.67	0.64	12748	14.67
CV		22.88	7	23	18
LSD		0.605	0.04	678.82	2.51
Significance [0.05]		*	**	*	*

The possible reason for the variation of species diversity between life stages along the increased disturbance level may be due to the growth habit of some species and the intensity of grazing and selective logging that eliminates some species along the gradients of disturbance. Based on the species diversity standards used by Melese and Ayele (2017), the overall species diversity of LDF and MDF were low; whereas it was medium in HDF. With respect to life stages; species diversity of the forest at LDF is medium for seedlings and saplings, and low for adult trees. In MDF the species diversity is low for all life stages; and the species diversity in HDF is low for seedlings and saplings; very low for adult trees (Table 2).

Comparing the result to other forests, the species diversity of these study forest along disturbance were lower than Bale Mountain Forest (Yineger et al., 2008), Denkoro Forest (Ayalew et al, 2006), Wof Washa Forest (Fisaha et al., 2013), and Menagesha Amba Mariam Forest (Tilahun, 2015). The possible reason may be due to low altitudinal range between those forest sites (3,060-3,248 m a.s.l) as altitude plays paramount role in plant distribution and richness/diversity (Wassie, 2017).

The low diversity of the study forest indicates that the ecological condition of the study forest is unstable and there is unbalanced species abundance along disturbance gradients. There is a concept that, greater diversity leads to greater productivity in plant communities, greater nutrient retention in ecosystems and greater ecosystem stability (Tilman, 2000), hence, the study forest has a great problem in ecosystem stability as a result of the continuous harvesting of trees for construction wood, fuel wood and timber and clearing of shrubs/trees for other routine purposes by the local community since there are no alternative wood sources like the exotic *Eucalyptus* in the study area; and therefore, there is a great human pressure on the natural forest. The mean evenness index of the study forest is 0.64 showing more or less an even distribution of the different disturbance tolerant species in the forest. The finding of the present result was in agreement with the finding of Betemariyam (2011) and Kebede et al. (2013).

3.1.4 Woody species similarity

The distribution of woody species along disturbance indicates different similarity patterns. The overall similarity coefficient ranges from 73-88% along disturbance. The highest similarity was observed between LDF and MDF (88%) followed by HDF and MDF (80%). whereas the similarity between HDF and LDF was 73% (Table 3). Therefore, there is high species similarity along disturbance gradients. The similarity may be contributed by the similarity of environmental gradients such as elevation ranges and the rainfall and temperature patterns (similar environmental characteristics) of the area. The most dominant canopy species, namely *Juniperus procera*, *Myrica salicifolia*, *Olea europaea*, *Erica arborea*, and *Allophylusabyssinicus* are similarly found in all disturbance levels. Moreover, the sample plots are situated in close proximity. Thus, gene flow is expected along disturbance gradients through seed dispersal agents such as birds and domestic and wild animals (Wassie, 2017).

Table 3 Similarity of woody species between the three sites.

Forest sites	LDF	MDF	HDF
Less disturbed forest	1.00		
Moderately disturbed forest	0.88	1.00	
Highly disturbed forest	0.73	0.80	1.00

3.2 Density, frequency, dominance and importance value index of woody species

3.2.1 Density of species along disturbance gradient

The total density (expressed as the number of stems per hectare) of all woody species in LDF, MDF, and HDF were 58,334/ha, 44,673/ha, and 11,725/ha respectively (Fig. 8 and Table 4). The density along disturbance gradient shows a decreasing trend as the intensity of disturbance increases. The total density of life stages also follows similar trend as shown in. As test result shows, the density of life stages (seedlings, saplings, and adult trees) along the gradients of disturbance differ significantly at (p=0.03).

Few species of seedlings, saplings and adult trees were found to predominate the density of the vegetation of the study forest. For instance, five species: *Myrsine africana*, *Juniperus procera*, *Maytenus arbutifolia*, *Clutia abyssinica,* and *Myrica salicifolia* contributed to 65 % of the total density at LDF (Table 4). Similarly, five species such as *Myrsine africana*, *Juniperus procera*, *Clutia abyssinica*, *Erica arborea*, and *Myrica salicifolia* contributed to 83.5% of the total density ha^{-1} in MDF (Table 4). In HDF *Myrsine africana, Dodonaea angustifolia*, *Clutia abyssinica*, *Maytenus arbutifolia*, and *Rumex nervosus* contributed to 77% of the total density (Table 4). In HDF *Dodonaea angustifolia* species alone contributed about 30% of the total density; which indicates how much the area is affected by human disturbance; since such species is a common species of disturbed sites (Hedberg et al., 1989).

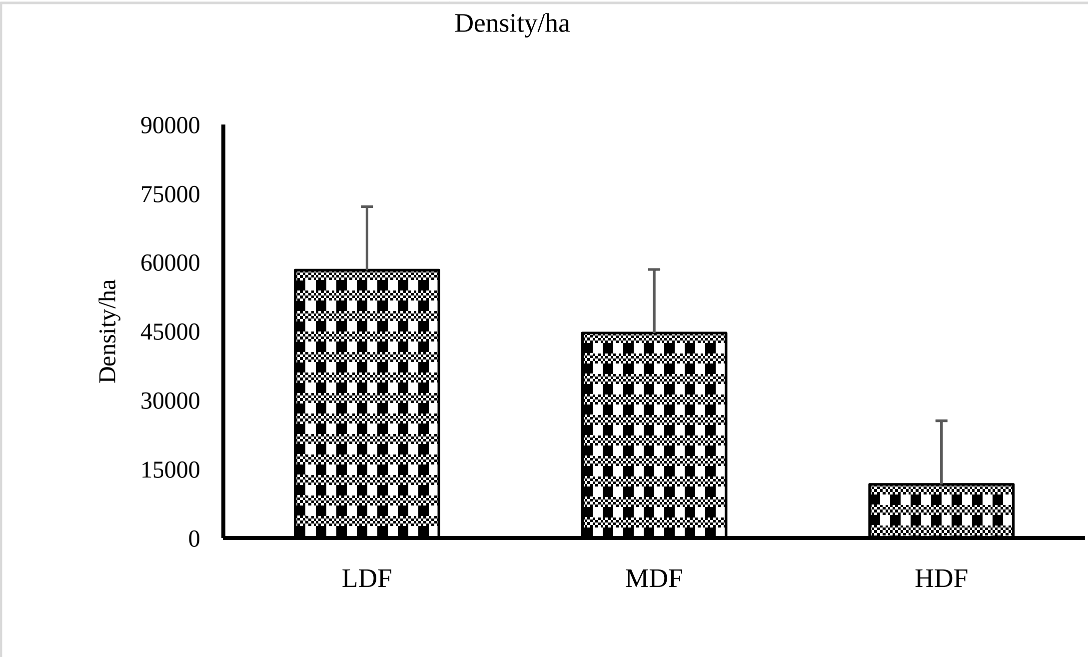

Fig. 8 Density of the forest along the gradients of disturbance.

The density of seedlings, saplings and trees decreased when the intensity of disturbance increased (Table 4). This decline may be due to a gradual and consistent increase in the extraction of fuel wood and construction wood for local consumption. This result was supported by the findings of Addo-Fordjour et al. (2009) and Kumar et al. (2016). The density seedlings and saplings of the forest is higher than similar forests in Ethiopia. But, the density of adult trees along disturbance is lower than similar forests like Yegof Forest (5,574 stems/ha) (Mohammed and Abraha, 2013), and Menagesha Amba Mariam Forest (4,362 stems/ha) (Tilahun, 2015). But it is higher than the density of Shello Giorgis Forest (659 stems/ha) (Ayalew et al., 2020). The high density of seedlings and saplings may be attributed by the opening of regeneration gaps as a result of the ongoing selective logging of bigger mature trees and the high demand of mature trees for their local consumption, as species like, *Juniperus procera*, *Olea europaea. Schefflera abyssinica*, and *Hagenia abyssinica* are some the preferred timber species (Gemechu and Jiru, 2021).

Table 4 Density of life stages of all species along the gradients of disturbance.

No	Species name	Density of seedling/ha			Density of sapling/ha			Density of tree/ha		
		LDF	MDF	HDF	LDF	MDF	HDF	LDF	MDF	HDF
1	*Juniperus procera*	3317	7025	368	1303	1219	265	1943	1083	305
2	*Myrica salicifolia*	1253	1170	312	670	691	210	655	298	143
3	*Olea europaea*	1675	975	496	333	291	0	13	9	8
4	*Erica arborea*	2069	1800	72	857	1197	25	285	316	10
5	*Osyris quadripartita*	1584	1005	184	460	394	20	77	78	5
6	*Allophylus abyssinicus*	832	85	80	153	19	0	33	9	8
7	*Dodonaea angustifolia*	1915	1060	2792	590	213	760	32	25	30
8	*Myrsine africana*	20699	18520	968	897	566	85	5	0	3
9	*Clutia abyssinica*	3173	3115	2096	467	481	255	0	0	0
10	*Maytenus arbutifolia*	7557	1770	96	723	122	130	3	8	0
11	*Rhamnus staddo*	1813	740	608	80	25	0	0	0	0
12	*Pittosporum abyssinicum*	704	40	0	40	0	0	2	5	0
13	*Hypericum revolutum*	0	0	40	10	38	20	15	27	3
14	*Buddleja polystachya*	336	0	0	10	16	20	8	6	8
15	*Carissa spinarum*	496	0	112	0	0	0	0	3	0
16	*Rosa abyssincia*	683	30	0	70	16	0	0	3	8
17	*Rumex nervosus*	0	160	1088	0	16	95	0	0	0
18	*Calpurnia aurea*	459	0	0	0	0	0	2	0	0
19	*Hagenia abyssinica*	0	0	0	3	0	0	7	0	0
20	*Schefflera abyssinica*	0	0	0	0	0	0	5	0	0
21	*Nuxia congeta*	0	0	0	0	0	0	10	2	0
22	*Dombeya torrida*	0	0	0	0	0	0	3	2	0
23	*Salix subserrata*	0	0	0	0	0	0	5	3	0
24	*Acacia abyssinica*	0	0	0	0	0	0	0	2	0
	Total	48565	37495	9312	6666	5300	1885	3103	1878	528

Table 5 Density of life stages (seedlings, saplings, and mature trees) along disturbance.

Life stages	Disturbance levels		
	Less Disturbed Forest	Moderately Disturbed Forest	Highly Disturbed Forest
Seedlings	48565	37495	9312
Saplings	6666	5300	1885
Adult trees	3103	1878	528

3.2.2 Frequency of woody species along disturbance

In all the three disturbance levels *Juniperus procera* was the most recurring species. The frequency of occurrence of woody species along disturbance (LDF, MDF, and HDF) was varied when the level of disturbance increases; for instance, in LDF the most frequent species were *Juniperus procera*, *Myrica salicifolia*, *Erica arborea*, *Osyris quadripartita*, and *Allophylus abyssinica*. In MDF *Juniperus procera*, *Myrica salicifolia*, *Erica arborea*, *Osyris quadripartita*, and *Hypericum revolutum* were the most frequently encountered species. Coming to HDF *Juniperus procera*, *Dodonaea angustifolia*, *Myrica salicifolia*, *Olea europaea*, and *Erica arborea* were the most frequent species which indicates that the area is seriously disturbed by many factors being such species are a common species of disturbed environments (Wassie, 2017) (Table 6).

Comparing these species with other forests, it was highly similar with Menagesha Amba Mariam Forest (Tilahun, 2015), Hugumburda Forest (Betemariam, 2011), Yegof Forest (Mohammed and Abraha, 2013), and Wof Washa Forest (Fisaha et al., 2013). This similarity may be attributed to the climatic condition of the study area and the study forest is resembled to the single dominant dry Afro montane forest (Friis, 1986). Except few variations, many of the most frequent species in the study forest along disturbance were similar one another.

3.2.3 Dominance of woody species along disturbance gradients

Dominance which is a function of basal area provides a better measure of the relative importance of the species than simple stem count (Tilahun, 2015). Thus, species with the largest contribution to basal area can be considered as the most ecologically important species in the forest. The basal area of the forest along disturbance (LDF, MDF, and HDF) were 8.96 m^2/ha, 3.90 m^2/ha, and 1.09 m^2/ha respectively (Fig. 9). In each of the three disturbance gradients *Juniperus procera* contributes the highest basal area and *Dombeya torrida*, and *Hypericum revolutum* were contributed to the lowest basal area/ha (Table 6).

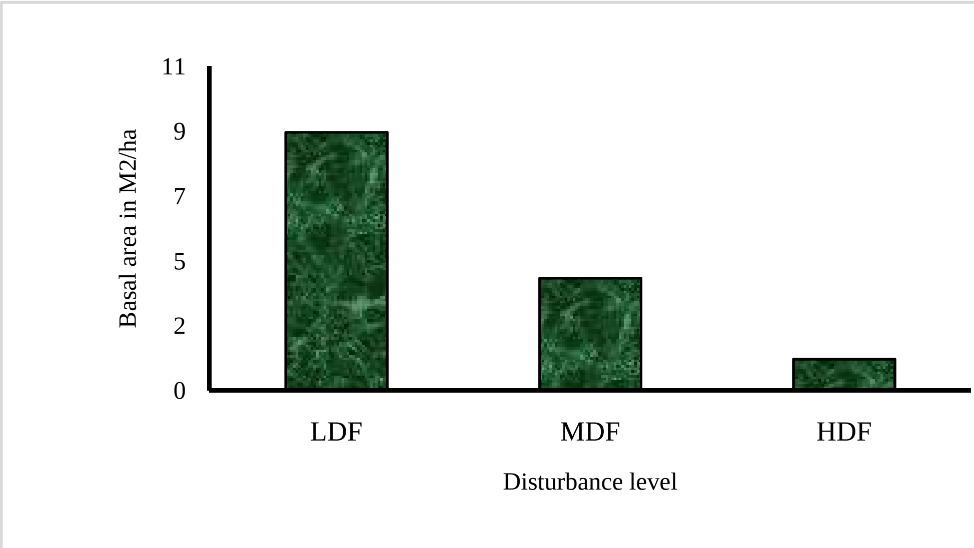

Fig. 9 Basal area along disturbance levels.

The cutting down of large trees in the MDF and HDF may contributed to the relatively lower basal area of woody species along disturbance. Total Basal area of the forest was very small and it is not comparable with typical dry Afro montane forests in Ethiopia like: Ericaceous Forest of Semen Mountains (18.3 m^2//ha) (Teshome, 2007), Wof Washa Forest having 64.3 m^2/ha (Fisaha et al., 2013),Yegof Forest having 25.4 m^2/ha (Mohammed and Abraha, 2013), Menagesha Amba Mariam Forest having 84.17 m^2/ha (Tilahun, 2015), and ShelloGiorgis forest was having 132 m^2/ha (Ayalew et al, 2020). The only forest which resembled with the study forests were Hugumburda Forest having a Basal area of nearly 9 m^2/ha (Betemariyam, 2011). Moreover, the total basal area of woody species (ha^{-1}) was generally in the lower range provided for tropical and subtropical dry and wet forests of the world (Murphy and Lugo, 1986). Hence the study forest is under heavy pressure of human disturbance and this finding is in agreement with the findings of (Mucheye and Yemata, 2020).

The basal area of the study forest decreased with increasing disturbance and which were in agreement with the findings of Addo-Fordjour et al. (2009) and Betemariyam (2011). The possible reason for having smaller Basal area may be due to selective removal of bigger woody species for fuel wood, construction wood and other local usages. Moreover, based on the existing situation of the forest shows that there was a major disturbance in the past times and this may be attributed to the indiscriminate destruction of woody species in the area (Mucheye and Yemata, 2020).

Table 6 Relative Density, frequency, dominance and importance value of woody species across the three sites.

Species	LDF				MDF				HDF			
	RD	RF	RBA	IVI	RD	RF	RBA	IVI	RD	RF	RBA	IVI
Juniperus procera	62.6	15.8	71.1	149.5	57.7	16.3	62.9	136.8	57.8	25.7	65.7	149.2
Myrica salicifolia A. R	21.1	14.7	15.5	51.4	15.9	16.3	14.2	46.4	27.0	20.0	17.5	64.5
Olea europaea	0.4	4.2	2.7	7.4	0.5	5.1	3.2	8.8	1.4	8.6	8.4	18.4
Erica arborea L.	9.2	15.8	5.2	30.2	16.8	15.3	12.5	44.6	1.9	5.7	2.8	10.4
Osyris quadripartita	2.5	12.6	0.7	15.8	4.2	11.2	2.7	18.1	1.0	2.9	0.5	4.3
Allophylus abyssinicus	1.1	8.4	0.2	9.7	0.5	3.1	0.4	3.9	1.4	5.7	1.8	8.9
Dodonaea angustifolia	1.0	3.2	0.2	4.3	1.3	7.1	0.4	8.9	5.7	14.3	1.8	21.8
Myrsine africana L.	-	-	-	-	-	-	-	-	0.5	2.9	0.0	3.4
Maytenus arbutifolia	0.3	3.2	0.1	3.5	0.4	3.1	0.2	3.6				
Pittosporum abyssinin	0.1	1.1	0.0	1.1	0.3	3.1	0.1	3.4				
Hypericum revolutum	0.5	3.2	0.1	3.8	1.4	8.2	0.9	10.4	0.5	2.9	0.1	3.5
Buddleja polystachya F	0.3	3.2	0.1	3.6	0.3	2.0	0.2	2.6	1.4	5.7	0.7	7.9
Carissa spinarum L.					0.2	2.0	0.1	2.3				
Rosa abyssincia Lin.					0.2	2.0	0.1	2.3	1.4	5.7	0.7	7.9
Calpurnia aurea (Ait.)	0.1	1.1	0.0	1.1								
Hagenia abyssinica	0.2	2.1	0.4	2.7								
Schefflera abyssinica	0.2	2.1	0.9	3.2								
Nuxia congeta R.Br. ex	0.3	4.2	2.0	6.6	0.1	1.0	0.5	1.6				
Dombeya torrida J. F.	0.1	2.1	0.0	2.2	0.1	1.0	0.0	1.1				
Salix subserrata Willd.	0.2	3.2	0.8	4.1	0.2	2.0	1.2	3.4				
Acacia abyssinica					0.1	1.0	0.6	1.7				
	100.0	100.0	100.0	300.0	100.0	100.0	100.0	300	100.0	100.0	100.0	300.0

RD=relative density; RF=relative frequency; RBA=relative basal area; IVI=importance value index.

3.2.4 Importance Value Index (IVI) of woody species in each study sites

Based on the IVI value as shown in (Table 6 and Fig. 10), the most dominant species in LDF and MDF in decreasing order were *Juniperus procera*, *Myrica salicifolia*, *Erica arborea*, *Osyris quadripartita*, and *Allophylus abyssinica*. Whereas the most dominant species in HDF in order of descending were *Juniperus procera*, *Myrica salicifolia*, *Dodonaea angustifolia*, *Olea europaea*, and *Erica arborea*. These show that much of IVI was attributed by a few woody species. These tree individuals were tolerant species that resist high pressure of disturbance, natural and environmental factors, and the effect of local communities Benti (2011).

As most research findings suggested that species having the highest IVI value are ecologically dominant and less demanded by the local communities and due to this less priority should be given for conservation. Whereas those rare species having lesser IVI values are needed urgent conservation priority as they are on the verge to be endangered (Gurmessa et al., 2012). But, on the case of the study forest those woody species having the higher IVI value are the most valuable and preferable woody species which are adoptable to the existing situation of the area. So, priority for conservation of these dominant species should be given (the first priority for species with the highest IVI value and the last priority of conservation for species with least IVI values) to these species (Benti, 2011; Zegeye et al., 2011; Aynekulu et al., 2016) (Table 6). Almost 50% of the IVI value was contributed by *Juniperus procera* which is one of the highly valuable woody species. Hence, this species is the most ecologically important species of the study area (Fig. 10).

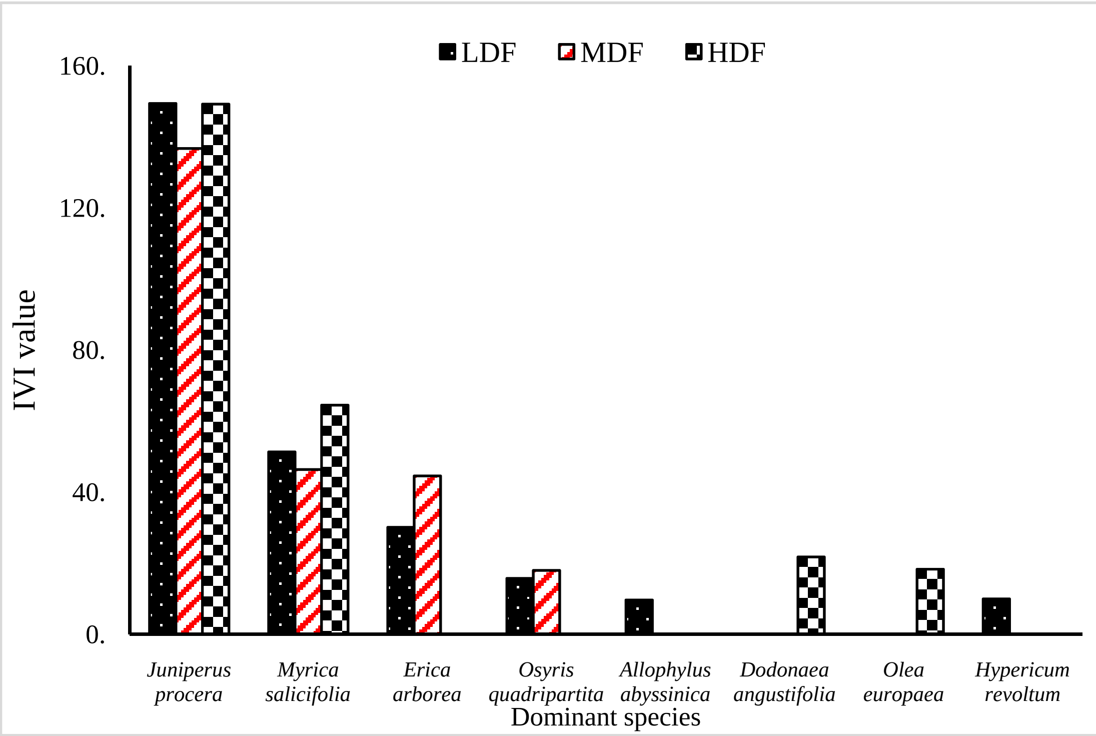

Fig. 10 The proportion of the dominant woody species along disturbance gradient.

The overall population structure of the three disturbance levels indicates the dominance of small-sized trees and shrubs because of selective logging of bigger trees. This result agrees with the findings of Mekuria (2007) in Douga Tembein Forest and Betemariyam (2011) in Desa Forest. By observing the inverted ‘J’ shape pattern, it can be said that the forests are in a good recruitment capacity. But, it is difficult to generalize based on the shape of the population pattern of the whole forest alone as indicator of forest health; because a highly skewed inverted ‘J’ shaped population pattern may to some extent indicate abnormal distribution of population densities in the forests undergoing secondary development after forest clearance or disturbance such as selective logging of individuals having higher DBH and height classes (Friss, 1986 cited in Wassie, 2017). The situation on the studied forest reflects this argument. Therefore, if such condition is continued the fate of the forest will be in danger.

3.3 Regeneration status of woody species along gradients of disturbance

The total density of seedling and saplings along variability of disturbance were 48,565 ha^{-1} and 6,666 ha^{-1} in LDF, 37,495 ha^{-1} and 5,300 ha^{-1} in MDF, and 9,312 ha^{-1} and 1,885 ha^{-1} in HDF respectively (Fig. 11). So, this result indicates that the distribution of seedling population is greater than that of sapling and sapling population is greater than mature individuals. Hence according to the standard used by Fisaha et al. (2013) the regeneration status of the forests became in a good condition. The distribution of seedlings, saplings and mature trees shows an inverted ‘J’ shaped distribution patterns; and hence the forest is healthy in those study sites with variable degree of disturbance intensities.

The density and composition of seedlings and saplings indicate the status of regeneration of the common species along the gradients of disturbance. From the total identified 24 woody species about 14 in LDF, and 14 in both MDF and HDF had seedlings of variable densities. On the other hand, nearly 10 woody species did not have seedlings; some of the woody species that lack seedlings include *Hypericum revolutum*, *Hagenia abyssinica*, *Schefflera abyssinica*, *Nuxia congeta*, *Dombeya torrida*, and *Salix subserrata.* Moreover, about 16 species in LDF, 15 in MDF, and 13 in HDF did not have saplings; some of those saplings lacking woody species are *Carissa spinarum*, *Calpurnia aurea*, *Schefflera abyssinica*, *Nuxia congeta*, *Dombeya torrida*, and*Salixsubserrata*. About 18 species in LDF, 17 in MDF, and 11 in HDF didn’t have adult trees at all. Among the species that lacks tree/shrub stage are *Rumex nervosus*, *Rhamnus staddo,* and *Clutia abyssinica* (Table 4). The seedling density for each species ranged between 2 and 20,699 individuals’ ha^{-1}. The highest seedling density was exhibited by *Myrsine africana*, *Maytenus arbutifolia*, followed by *Clutia abyssinica, Juniperus procera*, *Rhamnus staddo* and *Erica arborea.*

The possible reason for the absence of seedling and sapling for the aforementioned species might be due to habitat preference and microsite conditions; moreover, the ever-increasing human induced disturbance also has an impact on the seedling mortality rate of such species. In addition, species that lacks seedling and sapling like *Hypericum revolutum*, *Dombeya torrida*, *Salix subserrata* and *Carissa edulis* may be due to the grazing pressure of the area as these species are palatable by herbivores and lowers production capacity of viable seeds.

The good regeneration status may be attributed to opening of canopy due to disturbance and availability of seeds. The high density of seedling and sapling in LDF and MDF forest may be due to the low disturbance intensities. This result was in agreement with Lalfakawma et al. (2009) observed in semi evergreen forest of India and Wassie et al. (2009) in church forests of South Gondar. As it was closely observed species like *Juniperus procera* and *Erica arborea* regenerated well in areas having mosses and ferns and abundant sun light. This may be due to the moisture holding and soil improvement capacity of mosses (Teshome, 2007).

In less disturbed forest, the density of matured trees exceeds the density of seedlings and saplings. Which may be due to the closeness of the canopy that hampers regeneration whereas in MDF and HDF the density of seedlings and saplings decreased with increasing intensity of disturbance. This may be due to several reasons; the first is the high restriction effort of grazing in LDF and MDF by the District Office of Agriculture that favors survival of seedling and saplings. The second reason is the opening of regeneration gap by the ongoing selective logging of big trees creates conducive environment for the emergence of seedlings (Wassie et al., 2009). The third reason may be the less demand of seedling and sapling by local communities for their local usages. And another reason may be availability of viable seed in the soil seedbank and presence of seed dispersal agents like herbivores animals. This argument was supported by the findings Senbeta and Teketay (2001) (Gemechu and Jiru, 2021).

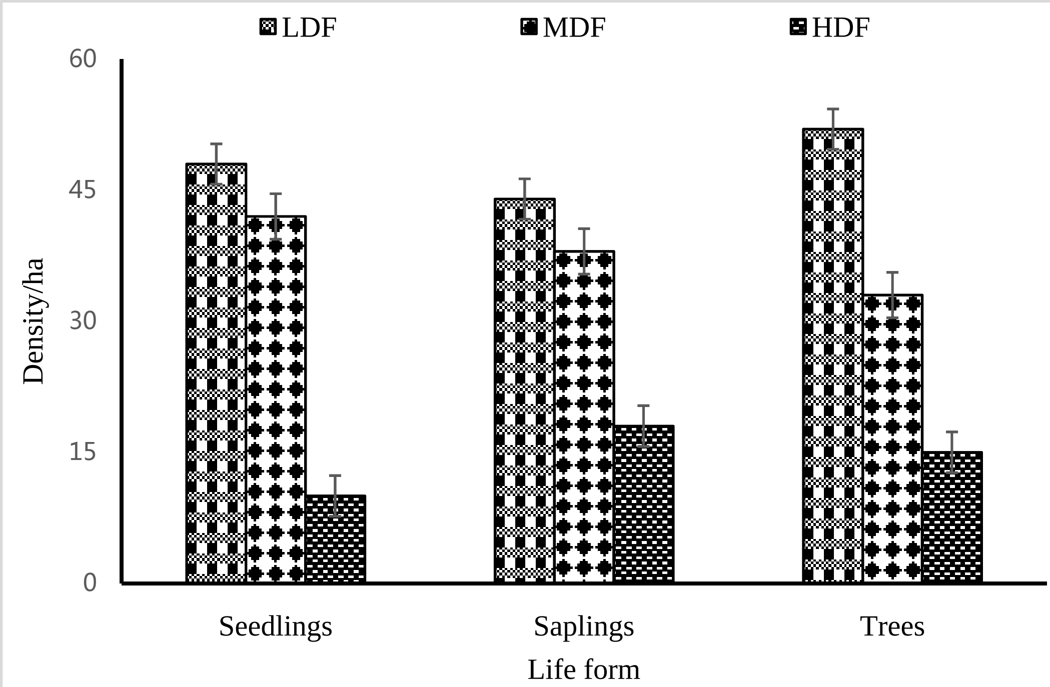

Fig. 11 The proportion of seedlings, saplings, and adult trees along the gradient of disturbance.

3.4 Investigation of the effect of anthropogenic disturbance

During the study, the number of dead and coppiced stumps were recorded so as to see the human pressure on the forest species. Based on the counted data the overall density of dead stumps/ha were 32 in LDF, 310 in MDF and 468 in HDF. The density of Coppiced stumps/ha in those sites were 147 in LDF, 305 in MDF, and 81 in HDF sites. As shown in the result, the highest removal of woody species was exhibited in highly disturbed forest site as a result of high intensity of disturbance. The intensity of selective removal varies from species to species. Among those species the most cut out species in the three disturbance levels were *Juniperus procera*, *Myrica salicifolia*, *Olea europaea*, and *Erica arbore.* From these *Juniperus procera* were the most logged out species than the other woody species (Fig. 12 and 13) as *Juniperus procera* is a preferred timber species. This result was supported by similar findings of Wassien et al. (2007), in church forests reveal that the most exploited tree species in the higher altitudes were the most dominant species (*Juniperus* and *Olea*), which are known for their valuable woods harvested for church building construction and maintenance.

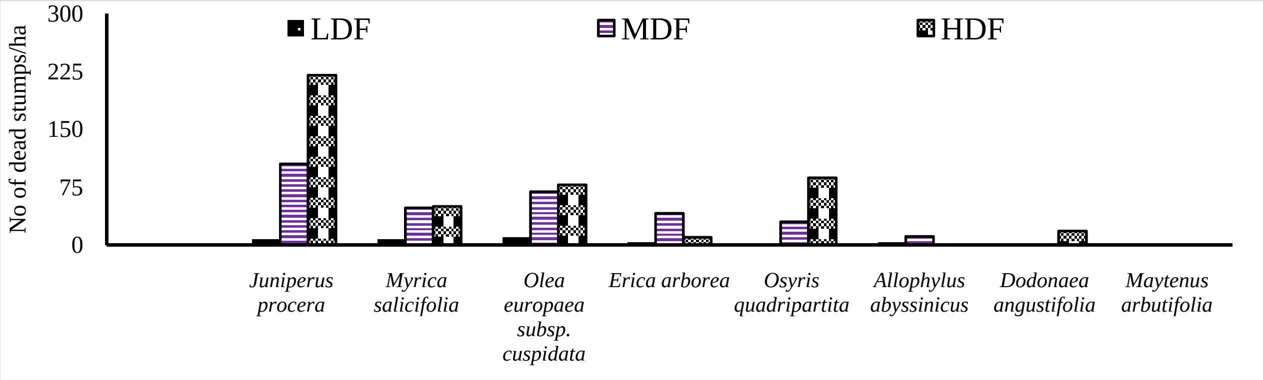

Fig. 12 Density of dead stumps/ha in along disturbance.

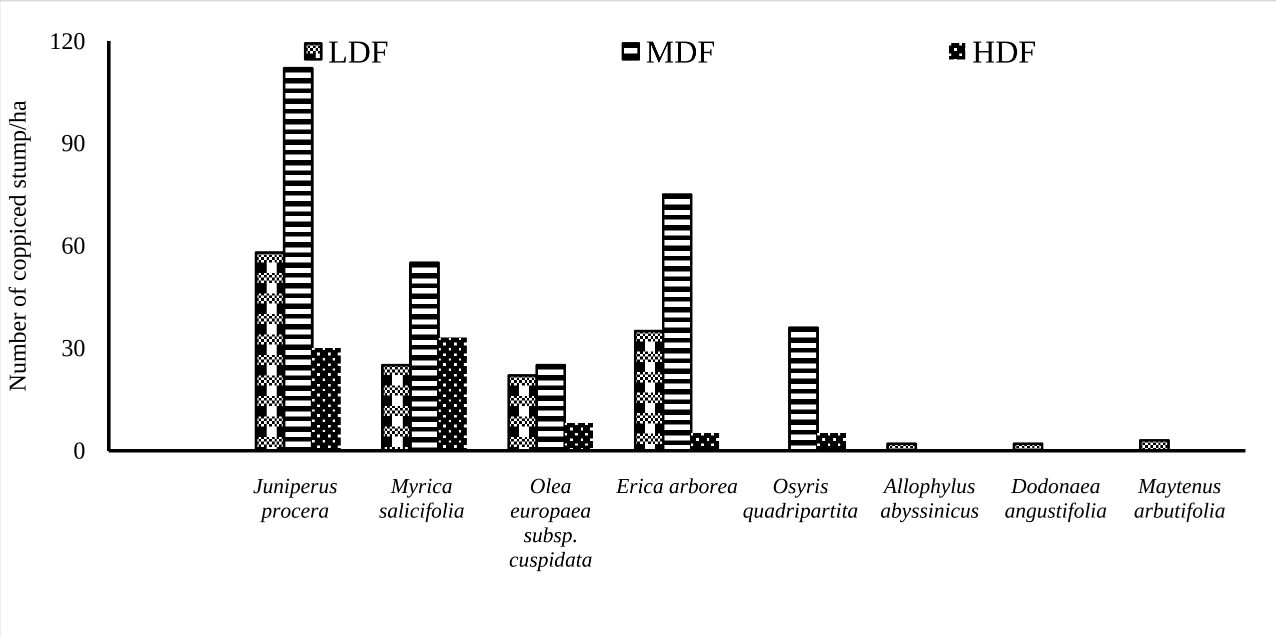

Fig. 13 Density of coppiced stumps/ha along disturbance.

Even if *Juniperus procera* is the most hunted species, it resisted the human pressure by acquiring an ability of stem and root sprouting. So, an important finding of the study is that, unlike other conifer species *Juniperus procera* has high coppicing capacity. The possible reason for high number of dead and coppiced stump on these forests might be due to the suitability and economic importance of such species for construction and other local uses. As clearly depicted on (Fig. 13), high density of coppice was exhibited in moderately disturbed forest; which could be resulted from availability of gap which facilities coppicing ability of those woody species. In fact, there is higher gap in HDF than MDF but, in HDF there is higher grazing and encroachment pressure that affects coppicing.

4 Conclusions

The result of the present study revealed that anthropogenic disturbance has created negative consequences on species composition, diversity, species richness, density, basal area, and regeneration status of the study forest. As the intensity of anthropogenic disturbance increases as a result of selective logging in highly disturbed and moderately disturbed forest the forest was transformed from tree dominated to shrub dominated low quality forests. Concerning species diversity, slightly higher species diversity was found on highly disturbed forests as a result of proportionate abundance of disturbance resilient shrubby species and these findings supported intermediate disturbance hypothesis. Based on the result species richness, density of individuals, and basal area of the whole forest significantly varied and follows a decreasing trend as the intensity of disturbance increases. Although there were irregularities in between representative woody species; the forest structure across disturbance followed the normal inverted ‘J’ shape curve; having higher number of seedlings and saplings in a less disturbed forest and these is an indication of healthiness of the forest. Considering the regeneration status of the forest the density of seedling and sapling exceeds the density of trees in the three disturbances levels and hence the forest has high regenerating capacity due to the opening of gaps as a result of disturbances. Therefore, one can conclude that to have a good regeneration in a certain forest mild disturbance is important and we can say that mild disturbance has a positive effect on regeneration.

Human induced disturbance like selective logging has a negative impact on growth and productivity of the forest. Observing the actual human pressure by counting dead and coppiced stumps species like *Juniperus procera*, *Myrica salicifolia*, *Olea europaea*, *Erica arborea*, and *Allophylus abyssinicus* are the most hunted species where the local community most preferred. Therefore, the ongoing anthropogenic disturbance is seriously affecting the most valuable Afromontane woody species. Compared to other logged out woody species *Juniperus procera* were highly affected by selective logging. But the species resist such impact by having coppicing ability unlike other coniferous species. the study revealed that the study forest is under sever anthropogenic disturbances and the forest is being transformed to shrubby and scrub land from high canopy Afromontane forest. So, sustainable forest conservation, management, and utilization strategy should be formulated to save such highly important forest.

Acknowledgement

The authors are gratefully acknowledging the University of Gondar and Central Gondar Zone Office of Agriculture for supporting this research grant, and many thanks goes to the Department of General Forestry of the University of Gondar in supervising this research.

References

Addo-Fordjour P, Obeng S, Anning AK, Addo MG. 2009. Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. International Journal of Biodiversity and Conservation, 1(2): 21-37

Afua EK. 2011. Patterns of Woody Plant Species Richness, Diversity and Structure Along a Disturbance Gradient in the Atiwa Range Forest Reserve, Eastern Region. Thesis. Ghana

Alelign A, Teketay D, Yemshaw Y, Edwards S. 2007. Diversity and status of regeneration of woody plants on the peninsula of Zegie, northwestern Ethiopia. Tropical Ecology, 48(1): 37-49

Amare D, Mekuria W, Twold, T, Belay B, Teshome A, Yitaferu B, et al. 2016. Perception of local community and the willingness to pay to restore church forests: the case of Dera district, northwestern Ethiopia. Forests Trees and Livelihoods, 25(3): 173-186. https://doi.org/10.1080/14728028.2015.1133330

Anne EM. 2004. Measuring Biological Diversity. Blackwell Publishing, USA

Ayalew A, Bekele T, Demissew S. 2006. The undifferentiated Afromontane forest of Denkoro in the central highland of Ethiopia: a floristic and structural analysis. SINET: Ethiopian Journal of Science, 29(1): 45-56. https://doi.org/10.4314/sinet.v29i1.18258

Ayalew T, Merawi E, Alemu S. 2020. Woody plant species diversity of Shello Giorgis dry Afromontane forest, Farita district, West Amhara. Biodiversity International, 4(1): 59-65. https://doi.org/10.15406/bij.2020.04.00165

Aynekulu E, Aerts R, Denich M, Negussie A, Friis I, Demissew S, Boehmer HJ. 2016. Plant diversity and regeneration in a disturbed isolated dry Afromontane forest in northern Ethiopia. Folia Geobotanica, 51(2): 115-127. https://doi.org/10.1007/s12224-016-9247-y

Benti DB. 2011. Floristic Composition, Diversity and Structure Of Woody Plant Species In Menageshasuba State Forest, Central Ethiopia. Addis Ababa University School of Graduate Studies Plant Biology and Biodiveristy Management Program Unit, Ethiopia

Berhanu A, Demissew S, Woldu Z, Didita M. 2017. Woody species composition and structure of Kuandisha Afromontane forest fragment in northwestern Ethiopia. Journal of Forestry Research, 28(2): 343-355. https://doi.org/10.1007/s11676-016-0329-8

Betemariam EA. 2011. Forest diversity in fragmented landscapes of northern Ethiopia and implications for conservation. Most, 1-32

Bishaw B. 2001. Deforestation and land degradation in the Ethiopian Highlands: A strategy for physical recovery. Northeast African Studies, 8(1): 7-25. https://doi.org/10.1353/nas.2005.0014

Demissew S. 2014. Overview of the flora of Ethiopia and Eritrea: the long road to a completion. The Biological Society of Ethiopia, 13: 1-27

Ellenberg H, Mueller-Dombois D. 1974. Aims and Methods of Vegetational Ecology. Wiley and Sons, NY, USA

Etefa L. 2011. Floristic Composition and Diversity of Herbaceous Flowering Plants in Menagesha Suba State Forest, Oromia Region, Ethiopia. Etefa, Lema, Addis Ababa, Ethiopia

Fisaha G, Hundera K, Dalle G. 2013. Woody plants’ diversity, structural analysis and regeneration status of Wof Washa natural forest, north-east Ethiopia. African Journal of Ecology, 51(4): 599-608. https://doi.org/10.1111/aje.12071

Friss I. 1986. The Forest Vegetation of Ethiopia. Symbolae Botanicae Uppsaliensis, 26: 31-47

Gemechu HW, Jiru DB. 2021. Review on factors affecting regeneration of indigenous tree species in Ethiopia. European Journal of Biophysics, 9(1): 24-29. https://doi.org/10.11648/j.ejb.20210901.14

Hill JL, Hill RA. 2001. Why are tropical rain forests so species rich? Classifying, reviewing and evaluating theories. Progress in Physical Geography 25(3): 326-354. https://doi.org/10.1177/030913330102500302

IB Friis. 1986. The forest vegetation of Ethiopia. Symbolae Botanicae Upsalienses, 26(2): 31-47

Inga Hedberg SE. 1989. Flora of Ethiopia, Pittosporaceae to Araliaceae (Vol. 3). Addis Ababa and Asmara, Ethiopia Uppsala, Sweden: The National Herbarium, Biology Department, Science Faculty, Addis Ababa University, Ethiopia, and The Department of Systematic Botany, Uppsala University, Sweden

Inga Hedberg SE. 2003. Flora of Ethiopia and Eritrea, Apiaceae to Dipsacacea (Vol. 4 Part 1). Addis Ababa,Ethiopia; Uppsala, Sweden: The National Herbarium, Biology Department, Science Faculty, Addis Ababa University, Ethiopia and The Department of Systematic Botany Uppsala University, Sweden

Kebede M, Yirdaw E, Luukkanen O, Lemenih M. 2013. Plant community analysis and effect of environmental factors on the diversity of woody species in the moist Afromontane forest of Wondo Genet, South Central Ethiopia. SCIENDO, 12: 63-80. https://doi.org/10.2478/biorc-2013-0003

Kent M. 2012. Vegetation Description and Data Analysis. The Atrium, Southern Gate, Chichester, West Sussex, John Wiley & Sons, UK

Krebs CJ. 1989. Ecological Methodology. The Benjamin/Cummings Series in the Life Sciences, USA. https://doi.org/10.1007/s007690000247

Kumar M, Kumar R, Kumar A. 2016. Patterns of diversity and regeneration in unmanaged moist deciduous forests in response to disturbance in Shiwalik Himalayas, India. Journal of Asia-Pacific Biodiversity, 9(2): 144-151. https://doi.org/10.1016/j.japb.2016.01.004

Lalfakawma, Sahoo UK, Roy S, Vanlalhriatpuia K, Vanalalhluna PC. 2009. Community composition and tree population semi-evergreen forest stands of north-east India. Applied Ecology and Environmental Research, 7(4): 303-318

Magurran AE. 2004. Measuring Biological Biodversity. Blackwell Publishing, USA

Mamo Y, Mengesha G, Shimelis A, Authority WC, et . 2015. Woody plant diversity along disturbance gradients in the northern Afromontane forests of the Bale Mountains, Ethiopia. International Journal of Development Research, 5(3): 3745-3754

Mekuria W. 2007. Vegetation restoration in area closures: The case of Douga Tembein, Central Tigray, Ethiopia. Energy, ii: 50-53

Melese SM, Ayele B. 2017. Woody plant diversity, structure and regeneration in the Ambo State Forest, South Gondar Zone, Northwest Ethiopia. Journal of Forestry Research, 28(1): 133-144. https://doi.org/10.1007/s11676-016-0280-8

Mesfin Woldearegay ZW. 2018. Species diversity, population structure and regeneration status of woody plants in Yegof dry Afromontane forest, north eastern Ethiopia. European Journal of Advanced Research in Biological and Life Sciences, 6(4): 20-34

Mohammed S, Abraha B. 2013. Floristic composition and structure of Yegof Mountain Forest, South Wollo. Ethiopian Journal of Science and Technology, 6(1): 33-45

Mucheye G, Yemata G. 2020. Species composition , structure and regenera - tion status of woody plant species in a dry Afromontane forest , Northwestern Ethiopia. Cogent Food and Agriculture, 6(1): https://doi.org/10.1080/23311932.2020.1823607

Mueller-Dombois D, Ellenberg H. 2016. Aims and Methods of Vegetation Ecology. The Blackburn Press, USA

Murphy PG, Lugo AE. 1986. Ecology of tropical dry forest. Annual Review of Ecology and Systematics, 17(1): 67-88. https://doi.org/10.1146/annurev.es.17.110186.000435

Neelo J, Teketay D, Masamba W, Kashe K. 2013. Diversity, population structure and regeneration status of woody species in dry woodlands adjacent to Molapo Farms in Northern Botswana. Open Journal of Forestry, 3(4): 138-151

Peters CM. 1996. The Ecology and Management of Wetlands (May No. 322) (Vol. 1). Washington DC, USA

Pitchairamu M. 2008. Floristic inventory and quantitative vegetation analysis of tropical dry deciduous forest in Piranmalai Forest, Eastern Ghats, Tamil Nadu, India Pitchairamu. Ethnobotanical Leaflets, 2(12): 204-216

Senbeta F. 2006. Biodiversity and ecology of Afromontane rainforests with wild *Coffea arabica* L. populations in Ethiopia. Ecology and Development, 49(38): 1-9

Senbeta F, Teketay D. 2001. Regeneration of indigenous woody species under the canopies of tree plantations in Central Ethiopia. Tropical Ecology, 42(2): 175-185

Sertse D, Gailing O, Eliades NG, Finkeldey R. 2011. Anthropogenic and natural causes influencing population genetic structure of *Juniperus procera* Hochst. ex Endl. in the Ethiopian highlands. Genetic Resources and Crop Evolution, 58(6): 849-859. https://doi.org/10.1007/s10722-010-9623-z

Sharew H. 1994. Regeneration of *Juniperus procera* and *Afrocarpus gracilior* in the Afromontane forests of Ethiopia. Geography, Corpus ID: 130604569

Shrestha KB, Måren IE, Arneberg E, Sah JP, Ole R. 2013. Effect of anthropogenic disturbance on plant species diversity in oak forests in Nepal, Central Himalaya. International Journal of Biodiversity Science, Ecosystem Services and Management, 9(1): 21-29. https://doi.org/10.1080/21513732.2012.749303

Sterck F, Couralet C, Nangendo G, Wassie A, Sahle Y, Sass-Klaassen U, et al. 2010. *Juniperus procera* (Cupressaceae) in Afromontane forests in Ethiopia: From tree growth and population dynamics to sustainable forest use. Degraded Forests in Eastern Africa: Management and Restoration, 291-303. https://doi.org/10.4324/9781849776400

Teshome E, Glatzel G. 2007. Regeneration Ecology of *Erica arborea* L. in Simen Mountains National Park and Surroundings, North Western Ethiopia. LAP LAMBERT Academic Publishing, Germany

Tilahun A. 2015. Structure and Regeneration Status of Menagesha Amba Mariam Forest in Central Highlands of Shewa, Ethiopia. Agriculture, Forestry and Fisheries, 4(4): 184. https://doi.org/10.11648/j.aff.20150404.16

Tilman D. 2000. Causes, consequences and ethics of biodiversity. Nature, 405

Uniyal P, Pokhriyal P, Dasgupta S, Bhatt D, Todaria NP. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. Current Science, 98(7): 938-943

Vishal PG. 2011. A Study on The Effect Of Protection on Regeneration Status, Species Diversity, Structure and Biomass Pattern of Three Sites of Tropical Deciduous Forest. College of agriculture Indira Gandhi , India

Wassie AB. 2017. Vegetation Ecology and Conservation Status of Evergreen Afromontane Forest Patches in Awi Zone of Amhara Region, Northwestern Ethiopia. Addis Ababa University, Ethiopia

Wassie A, Sterck FJ, Bongers F. 2010. Species and structural diversity of church forests in a fragmented Ethiopian Highland landscape. Journal of Vegetation Science, 21(5): 938-948. https://doi.org/10.1111/j.1654-1103.2010.01202.x

Wassie A, Sterck FJ, Teketay D, Bongers F. 2009. Effects of livestock exclusion on tree regeneration in church forests of Ethiopia. Forest Ecology and Management, 257(3): 765-772. https://doi.org/10.1016/j.foreco.2008.07.032

Wassie A, Teketay D. 2006. Soil seed banks in church forests of northern Ethiopia: Implications for the conservation of woody plants. Flora: Morphology, Distribution, Functional Ecology of Plants, 201(1): 32-43. https://doi.org/10.1016/j.flora.2005.04.002

Wassie et al. 2007. Ethiopian Church Forests Opportunities and Challenges for Restauration. PhD Thesis. Wageningen University, Wageningen, Netherlands. https://doi.org/10.1017/S0014479702003046

Woldu Z, Mohammed Saleem MA. 1999. Grazing induced biodiversity in the highland ecozone of East Africa. Agriculture, Ecosystems and Environment, 79(1): 43-52. https://doi.org/10.1016/S0167-8809(99)00141-3

Yineger H, Kelbessa E, Bekele T, Lulekal E. 2008. Floristic composition and structure of the dry Afromontane Forest at Bale Mountains National Park, Ethiopia. Ethiopian Journal of Science, 31: 103-120. https://doi.org/10.4314/sinet.v31i2.66551

Zegeye H, Teketay D, Kelbessa E. 2006. Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. Flora: Morphology, Distribution, Functional Ecology of Plants, 201(6): 483-498. https://doi.org/10.1016/j.flora.2005.10.006

Zegeye H, Teketay D, Kelbessa E. 2011. Diversity and regeneration status of woody species in Tara Gedam and Abebaye forests, northwestern Ethiopia. Journal of Forestry Research, 22(3): 315-328. https://doi.org/10.1007/s11676-011-0176-6