COMPARISON OF WOODY SPECIES DIVERSITY AND POPULATION STRUCTURE ALONG DISTURBANCE GRADIENT IN BABILE ELEPHANT SANCTUARY, ETHIOPIA

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ABSTRACT

The study was conducted at Babile Elephant Sanctuary (BES), to identify and document the list of woody species, and to analyze the diversity, richness, evenness, and population structural status of woody species. The diversity of plant species and population structure of woody species were analyzed from 60 quadrats, each with 20 m x 20 m for trees and 5 m x 5 m for shrubs and climbers, using systematic sampling methods with three levels of disturbances regime, namely, low disturbed (LD), moderately disturbed (MD) and heavily disturbed (HD) sites. Vegetation parameters such as diameter at breast height (DBH), richness, evenness, and density of woody species were recorded. Shannon Weiner Diversity Index was used to analysis vegetation diversity and evenness. A total of 61 woody species were identified in the study area that falls within 29 families and 38 genera of which 50.8 % were shrubs, 39.3 % were trees and the rest 9.83 % were climbers. Fabaceae was represented by the highest number of species (14 species = 22.90). The highest plant species richness was recorded from the low disturbed sites, followed by moderately disturbed and heavily disturbed sites respectively. The population density of vegetation was significantly higher in the MD site, followed by the LD site. The total basal area of LD, MD, and HD were 27.2, 19.8, and 11.2 m^2/ha, respectively. LD site had significantly (P= 0.04) highest Shannon's diversity index value (3.21) than the others two disturbance levels. This result suggests that the consequence of human-induced disturbance on woody species diversity and population structure appeared to be negative depending on the type and intensities of the disturbances.

Keywords: Anthropogenic, babile, disturbance, protected area, species diversity

INTRODUCTION

Biological diversity is the richness and evenness (relative abundance) of species amongst and within living organisms and ecological complexes (Polyakov *et al.*, 2008). Biodiversity is essential for human survival, economic wellbeing, and ecosystem function and stability

(Singh, 2002). Biodiversity, as a part of our daily life, constitutes the resource base upon which our fate of future generations depends. Maintenance and periodic assessment of biological diversity therein and assessment and prevention of the various disturbances affecting it are, therefore, crucial for the long-term survival of humans (Pushpangadan *et al*., 1997; Malik, 2014). Biological diversity is the richness and evenness (relative abundance) of species amongst and within living organisms and ecological complexes (Polyakov *et al*., 2008). The species is one of the major analytical characteristics of the plant community (Haeussler *et al*., 2002). Species richness is a simple and easily interpretable indicator of biological diversity (Peet, 1974). Disturbances play a role in the formation of plant communities and their composition (Malik, 2014).

Disturbances play a role in the formation of plant communities and their composition (Malik, 2014). Any relatively discrete event in time that disrupts a community, or population structure and changes resources, substrate availability, or the physical environment is called disturbance. anthropogenic disturbances like grazing, biomass extraction in the form of fuelwood, fodder and litter collection, construction of roads and dams for hydroelectric projects affect the population stability leading to frequent changes in land and resource use, increased frequency of biotic invasions, reduction in species number, creation of stresses and the potential for changes in the climate system and also retard the successional processes (Kumar & Ram, 2005). Human disturbances, particularly from the overexploitation of biological resources, generally have negative impacts on species diversity on a global scale (Goudie, 2005).

Ethiopia has the fifth largest floral diversity in tropical Africa (Motuma *et al*., 2010), which mainly is as a result of the great variations in altitude, topography, rainfall, and temperature that have provided favorable environmental conditions necessary for the evolution and persistence of a wide variety of floral, as well their associated faunal species (Largen & Yalden, 1992; Bogale et al., 2017; Lemenih & Woldemariam, 2010). Loss of forest cover and biodiversity due to anthropogenic factors is a growing concern in many parts of the world (Feyera *et al*., 2003). To alleviate such losses, due attention has been given to the establishment of natural reserves around the world (Groombridge, 1992). Babile Elephant Sanctuary (BES) is one of the protected areas in the semiarid region of Eastern Ethiopia, which has highly declined in size and quality.

As a result, uncontrolled expansion of agriculture and grazing coupled with illegal harvesting of vegetation and other products have been threatening the function of the protected area system in many parts of the country (Zelealem, 1995). Lack of integration of the livelihood of the local people living around BES and the absence of a law enforcement system are the major constraints to the overall conservation efforts. Understanding the species richness and diversity patterns of tree species in relation to disturbances is a key significance to understand the form and structure of a forest community and for planning and implementation of conservation strategy of the community. Quantification based on woody species is an important aspect when studying disturbance impact on forest structure. This study was initiated to address these concerns and to come up with the natural resource management scheme.

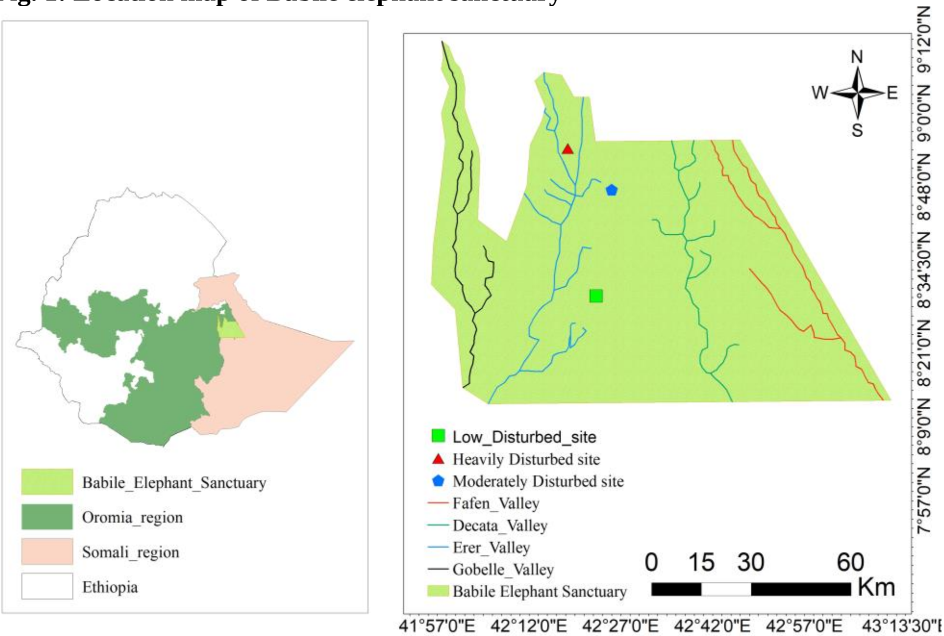
This study aims to determine the effects of anthropogenic disturbances on the status of woody species diversity and structure along anthropogenic disturbance gradient.

MATERIALS AND METHODS

Description of study site

The study was carried out in Babile Elephant Sanctuary (BES), geographically, the Sanctuary lies between Oromia Regional State and Somali Regional State of Ethiopia. It is located, at about 560 km from Addis Ababa to the east. It is delimited with coordinates of latitudes 08°22'30" – 09°00'30" N and longitudes 42°01'10" – 43°05'50" E and its elevations ranges between 850 and 1,785 m a.s.l. (Stephenson, 1976; Yirmed, 2008). The Sanctuary covered an area of about 6,984 km^2 (Stephenson, 1976; IUCN, 1990).

Fig. 1: Location map of Babile elephant sanctuary



The geological structure of the study area in particular and the adjacent areas in general consist of Precambrian complexes, Mesozoic-Tertiary sediments and upper Tertiary Quaternary complexes (Mohr, 1964). The area has tropical rainy climate and tropical arid climate agro-climatic zones. Mean annual temperature and precipitation of this area are 21.9 °C and 1093.8 mm, respectively. In general, the Sanctuary is represented by Acacia-commiphora woodland, desert and semi desert scrubland and evergreen scrub ecosystem (White, 1983; Anteneh, 2006).

RESEARCH METHODS

Stratification of the Study Area

Plant species diversity and vegetation structure of the study area with a different disturbance status was studied by using stratified sampling following the method of Krebs (1999). Forest patches were classified in to three categories of disturbance level (based on the forms and severities of these disturbances recorded at each of them) as: low disturbed site, moderately disturbed site (MD) and heavily disturbed site following the method of Newton

(2007). LD sites are those vegetation patches where there were no settlement and crop cultivation, and with relatively low level of logging and grazing. The low-disturbed site has not undergone any major form of human disturbance. This is partly due to low accessibility to it by the local community as it is far from the village. MD sites are those where there were low (< 5 % cover ha^{-1}) crop cultivation and settlement (<3 houses ha^{-1}), but relatively with high levels of logging and grazing, and HD sites are those where crop cultivation and settlement are common (> 65 % coverage), and logging and grazing are relatively high level (Mitiku, 2013; Sintayehu & Merkebu, 2019). These sites (HD, MD and LD) were selected in areas with approximately equal topography so as to eliminate their effects on vegetation status.

Vegetation sampling

In each disturbance sites, a total of two transect lines of 1000m were established systematically, so a main quadrat of 20 m x 20 m (400 m^2 equivalent to 0.04 ha) was systematically set along the transect line within each sites using 100 m distance between quadrats and 200 m between transect lines for vegetation inventory. Within the main quadrats five sub-plots of (5 m x 5 m) were set up, four at each corner and one at the center, to collect data on shrubs and climbers and the mean value of these five subplots were used in the analysis (Anteneh *et al*., 2011). Tree/shrub is defined as woody plants with DBH/DSH ≥ 2.5 cm and height ≥1.5 m (Gemedo, 2006; Negash *et al*., 2013). To study the woody species composition and diversity data on species identity, density, and frequency, diameter at breast height, diameter at stump height and Height of individual species were recorded for tree, shrub and climber species in all quadrats. The species diameter (DBH) was measured using caliper and height was measured using hypsometer. Trees that were branched at the stamp height, diameter was measured separately above the swelling and average measurement was recorded. For tree species forked below 1.3 m, individual stems were separately measured and treated as single tree (Abed & Stephens, 2003). Trees and shrubs on the border of the quadrat were included if more than 50 % of their basal area falls within the quadrat and excluded if more than 50 % of their basal area falls outside the quadrat (Bhishma *et al*. 2011).

In the case of multi-stemmed shrub each stem was measured and diameter equivalent of the plant calculated as the square root of the sum of diameter of all stems per plant (Snowdon *et al*., 2002),

$$d = \sum_{i}^{n} \sqrt{\mathrm{di}^2}$$

where: d = diameter equivalent height, di = diameter of the ith stem at the measurement height.

Scientific nomenclature was carried out using published volumes "Flora of Ethiopia and Eritrea" (Sebsebe, 1997), Useful Trees and Shrubs of Ethiopia (Azene, 2007) and Natural Database for Africa (NDA) Version 2 (Ermias & Emeritu, 2011). For some species that were unable to identify directly in the field, plant specimens were collected, pressed, dried and brought to Herbarium of Haramaya University, Department of Natural Resource Management and Environmental Science for further identification.

Woody Species richness, diversity and similarity analysis

Diversity has emerged as the most widely used criterion to assess the conservation potential and ecological value of a site (Magurran, 1988). Shannon diversity index is the best and widely used diversity index. It accounts for both the richness and evenness of the species present in a community. This index takes in to consideration of species composition and evenness within the given land or community. The Shannon diversity indices of diversity and evenness was used to look at the level of species diversity and evenness of species distribution (Kent & Coker, 1992). Shannon diversity index calculated by:

$$H' = -\sum_{i=1}^{S} (\text{Pi} \ln \text{Pi})$$

Where; H' = Shannon species diversity Index, S = number of species, Pi = n/N is the proportion of individuals found in the ith species (ranges 0 to 1), n = number of individuals of a given species, N = total number of individuals found and Pi = proportion of S made up of the ith species (Shannon and Wiener, 1949)

Evenness or equitability, a measure of similarity of the abundances of the different species in a given site (Krebs, 1999; Magurran, 2004). Species evenness (measure of species balance) is a measure of the relative abundance of the different species making up the richness of an area. Evenness calculated as follows:

Shannon evenness

$$(E) = \frac{H'}{H' \max}$$

Where; E= Evenness, H' = Shannon-Wiener diversity index and H’ max = lnS where S is the number of species.

Jaccard’s similarity index was used to determine the pattern of species turnover among the different community types. It was calculated as follows (Chidumayo, 1997).

$$J = \frac{a}{a + b + c}$$

Where: J = Jaccard’s similarity coefficient, a= Number of species common to both samples, b= number of species present in the first site only and, c= number of species present in the second site only. Often, the coefficient is multiplied by 100 to give a percentage similarity index.

Principal component Analysis (PCA), an ordination analysis, was performed to demonstrate compositional similarities/differences among sites that can be categorized into discrete groups. PCA, an indirect gradient analysis, is suitable for displaying floristic gradients and composition (Kindt & Coe, n.d.). Unconstrained ordinations were used to test the differences in the species composition among vegetation sites of different site as in PCA.

Structural data analysis

The structure of the vegetation was described based on the analysis of species density, DBH, height, basal area, frequency and important value Index (IVI). Density (D) of woody plant species was calculated by using the following formula;

$$D = \frac{\text{Number of indiviguals woody species}}{\text{Sum of all plot areas}}$$

$$\text{Relative density (\%)} = \frac{\text{Total number of individuals of species A}}{\text{Total number of individuals of all species}} \times 100$$

Frequency (F) of plant species was calculated by using the following formula;

$$\text{F} = \frac{\text{Number of quadrats in which a species occur}}{\text{Total number of quadrats sampled in the study site}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of species A}}{\text{Frequency of all species}} \times 100$$

Basal area (BA): It is the area outline of a plant near ground surface for trees. The analysis of tree basal area was made using basal area measurements.

$$\text{BA} = \frac{\pi d^2}{4}$$

Where; BA = Basal Area in m^2 per hectare, d = diameter at breast height in meter and π= 3.14

$$\text{Relative dominance (\%)} = \frac{\text{Basal area of species A}}{\text{Total basal area of all species}} \times 100$$

IVI of woody species was calculated from the sum RDO, RD and RF (Kent & Coker, 1992). Mathematically it can be expressed as IVI = RBA + RD + RF

One-way ANOVA comparisons of means was used to test the differences in woody species diversity and species structure between the three sites. In addition to this, descriptive statistics were also used to show proportion of stand parameters. Statistical analyses were carried out using Vegan package in R software (R Development Core Team, 2015) and at 5 % significance level for both vegetation ad ESs data analysis. Tables and Figures were used to present the result of descriptive and inferential statistics of the study.

RESULT

Woody Species Composition

A total of 61 woody species representing 29 families and 38 genera were recorded in Babile Elephant sanctuary. Of these, 31 (50.8 %), 22 (36.06 %), 6 (9.86 %) and 2 (3.27) were shrub, tree, climbers and T/Sh, respectively. Among these, 44 species of plant were collected under LD site, of which 19 (43.18 %) were shrub species. Tree accounted (38.63 %) whereas climber and T/Sh take a minimal amount 13.63 % and 4.54 % respectively. In MD site the proportion of shrub took the paramount proportion with 51.21 %, followed by tree 29.26 % and climber and T/Sh share 14.63 % and 4.87 % respectively among 41 species found within the site. Similarly, in HD site the proportion of shrub possessing 55.17 %, followed by tree 31.03 %, and T/Sh and climber share the lowest value (6.89 % each) among 29 species found in the site (Table 1).

The number of families (n=23) recorded in LD site of the study area was found to be highest, followed by Moderately (n=22) and heavily (n=19) disturbed site respectively. Fabaceae was found as the most species-rich family in the area consisting of 14 (22.9 %)

species, of which 14, 11 and 8 species were found in low, moderately and heavily disturbed site respectively. It was followed by Tiliaceae (11.4 %), Capparidacea, Anacardiaceae, Olacaceae and Euphorbiaceae accounting (4.9 %) of species for each. Eighteen families were represented by only 1 species each (29.8 %) and the least abundant families in the study area (Table 2).

Table 1: Summary of woody species composition in Babile Elephant sanctuary

	Tree species		Shrub species		T/Sh		Climber species		Total	
Strata	Number	%	Number	%	No	%	Number	%	Number	%
HD	9	31.03	16	55.17	2	6.89	2	6.89	29	100
MD	12	29.26	21	51.21	2	4.87	6	14.63	41	100
LD	17	38.63	19	43.18	2	4.54	6	13.63	44	100
Over all	22	36.06	31	50.8	2	3.27	6	9.83	61	100

HD=heavily disturbed, MD=moderately disturbed and LD=low disturbed

Table 2: List of percentage of richest family's species in BES

Family	Species number	%	Site found
Anacardiaceae	3	4.91	All
Capparidaceae	3	4.91	All
Euphorbiaceae	3	4.91	All
Fabaceae	14	22.92	All
Olacaceae	3	4.91	All

Density, Frequency, Dominance and IVI of Woody Species of BES

Density

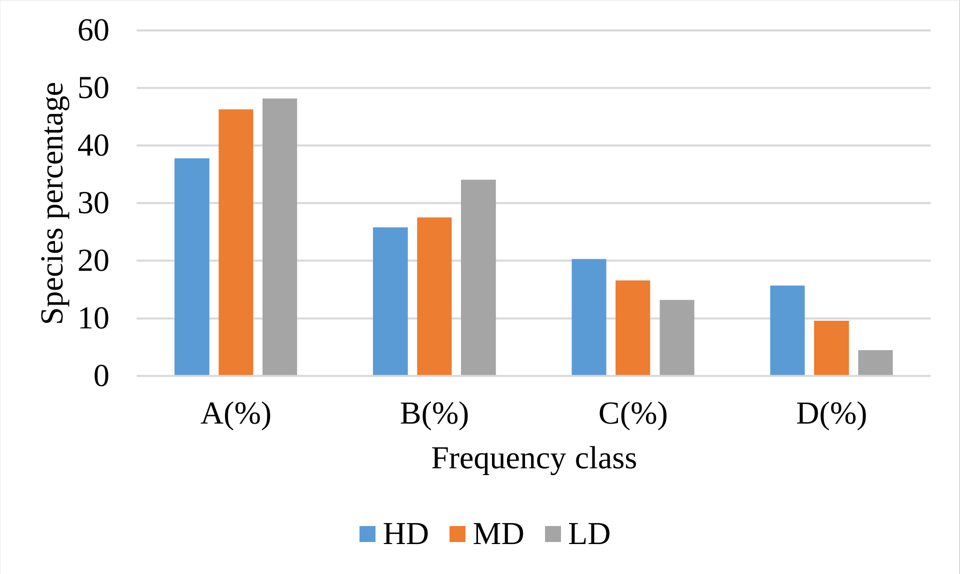
Density is expressed as the number of plants per unit area and it is a crucial parameter for sustainable forest management. The average overall density of BES vegetation was estimated around 784.3 individuals per hectare. The highest density of species was recorded for Acalypha fruticosa for all MD, HD and LD sites with 2440, 2180 and 1700 individuals/ha, respectively. The second highest density was contributed by A. mellifera (1320 individuals per hectare) and A. brevispica (2380 and 2260 individuals per hectare) for both MD and HD, respectively. However, the lowest density value was recorded in LD for Acacia etabaica with 11.25 individuals per hectare. Similarly, Schleichera oleosa had the lowest density value for MD with 7.5 individuals per hectare. While Salvadora persica had just 6.25 individuals per hectare for the MD as the lowest density.

Statically analysis of density indicates that there is a significant difference among the three vegetation strata (P=0.046). MD had significantly highest mean density (525.6 individuals/ha) than HD and LD. On the other hand, HD had significantly lowest mean density of woody species (388.2 individuals/ha) than MD and LD, while LD possess the intermediate density figure with 429.39 individuals/ha.

Frequency

For frequency analysis species were grouped into four major classes: A ≤25; B = 26– 50; C = 51 –75; D ≥75. The result showed in all the three disturbance regime there was high value in lower frequency classes and low values in higher frequency. This indicates that generally the study sites had heterogeneous species composition.). HD and MD had more species percent with higher frequency class (class D) which are 15.7 % and 9.6 % respectively as compare to LD that had only 4.5 % of species. While in lower frequency class (A) LD had species percent (48.2) than MD (46.3) and HD (37.8) (Fig 3). The highest frequency percentage (100 %) was obtained in all strata which were recorded in 20 plots. A. fruticosa and A. brevispica were frequently occurring species in moderately disturbed site wih 100 % of species. A. fruticose, having a frequency value of 100 % in both HD. However, in LD site only A. robusta was 100 % frequency value. The species with the least Frequency include Cissus rotundifolia, Commicarpus sinuatuss and Commiphora schimperi in the HD, MD and LD site respectively, each were recorded only in 1 plot.

Fig. 2: Frequency class distribution of woody species at all three disturbance sites



Basal Area

The average covered basal area of natural vegetation in BES was estimated around 19.4 m^2/ha. The total basal area for HD, MD and LD were 11.2 m^2/ha, 19.8 m^2/ha and 27.2 m^2/ha, respectively. However, there is significantly difference in basal area among the three disturbance sites (p= 0.03). So, LD had significantly higher basal area coverage than the other two sites followed by MD. But HD had significantly lower basal area coverage. This directly relational trend indicated that disturbance influence basal area and dominance of an area, the value of basal area was higher as disturbance level decrease. This might be due to the presence of relatively higher proportion of larger and aged trees in LD site because of little intervention by human activities like tree cutting, farming, and grazing.

The highest proportion of basal area was recorded for *Acacia robusta* (2.8 m^2/ha), *Ficus vallis-choudae* (3.1 m^2/ha) and *Schleichera oleosa* (3.6 m^2/ha) in HD, LD and MD site respectively. Only four species covered about 63 % of basal area in HD. *A. robusta*, *Balanites aegyptiaca*, *Acacia nilotica* and *A. mellifera* were the top four species in HD. Even though they are used in relatively larger quantities by human, these plant species are still considered relatively available.

Important Value Index

The results of important value index in HD site showed that *A. fructicose*, (30.5) *Acacia brevispica* (26.5) and *A. bussei* (23.7) were the three species with higher important value index. While (Table 3). So, these species are the most ecologically important species in HD site. They are species that are well adapted to the environmental factors of the area and need to be monitored to maintain healthier interaction between components of that ecosystem. Oppositely in HD *Cissus rotundifolia*, *Ximenia caffra* and *Oncoba spinose* had the lowest value of IVI with 3.02, 3.2 and 3.7 values, respectively. This indicates that these species are the least ecologically significant species in the site.

Table 3: Relative density, frequency, dominance, BA and IVI of woody species HD site

Scientific Name	RD (%)	RF (%)	RDO (%)	IVI
Acacia brevispica Harms	18.86	5.97	1.66	26.50
Acacia bussei Harms ex. Sjostedt	0.66	3.80	19.29	23.77
Acacia mellifera (Vahl) Benth.	3.84	5.43	2.88	12.16
Acacia nilotica (L.) Wild. ex Del	0.66	1.08	3.96	5.72
Acacia robusta Burch	0.85	2.71	8.92	12.49
Acacia senegal (L.) Wild	1.50	3.80	6.94	12.25
Acacia. tortilis (Forsake.) Hayne	0.15	2.17	6.05	8.38
Acalypha fruticosa Forssk.	18.19	10.86	1.51	30.58
Acokanthera schimperi (A.DC.)	0.83	1.63	3.73	6.20
Aloe pirottae Berger.	1.00	2.17	4.20	7.37
Boscia minimifolia Chiov.	0.09	4.34	4.95	9.39
Celtis africana Burm.	1.83	4.34	2.31	8.50
Cissus rotundifolia (Forssk.)	0.33	0.54	2.14	3.021
Dodonoea angustifolia L.f.	2.17	3.26	1.37	6.80
Euclea racemosa Murr.Ssp.	5.84	9.23	2.88	17.96
Gardenia lutea Lobin. W.	0.08	3.26	4.44	7.79
Grewia erythraea Schweinf	6.51	3.80	1.97	12.29
Grewia ferruginea Hochst. Ex A.	2.17	4.89	1.66	8.72
Grewia schweinfurthii Burret	1.50	2.17	2.14	5.82
Grewia tenax (Forssk.) Fiori	8.34	4.89	1.23	14.47
Grewia villosa Will.	2.00	5.43	1.81	9.25
Hibiscus micranthus L. f.	1.50	2.17	1.37	5.04
Lantana camara L.	6.51	2.71	1.97	11.20
Oncoba spinose Forssk.	0.08	2.17	1.51	3.77
Opuntia ficus-indica (L.) Miller	11.18	1.63	2.68	15.50
*Rhus natalensis (*Sw.) DC.	2.00	1.08	1.11	4.20
Salvadora persica L.	0.05	2.17	2.68	4.91
Ximenia caffra Sond.	0.50	1.08	1.66	3.24
Ziziphus spina-christi (L.) Desf.	0.66	1.08	2.50	4.25
Total	100	100	100	300

Key: RF=Relative Frequency; RD-Relative Density; BA=Basal Area; RDO=Relative Dominance and IVI= Important Value Index

Like HD, in MD species with highest IVI figures are *Schleichera oleosa* (21.5), *A. fruticosa* (18.2), and *Acacia brevispica* (17.1) accordingly. This also indicates that these species are the most ecologically significant in MD. In this site species with the lowest IVI value were *Jasminum eminii*, *Commicarpus sinuat*, and *Capparis sepiaria* with 0.5, 0.6, and 1.2 values, respectively (Table 4).

Table 4: Relative density, frequency, dominance, BA, and IVI of woody species MD site

Scientific Name	RD (%)	RF (%)	RDO (%)	IVI
Acacia albida Del.	0.10	1.72	12.65	14.48
Acacia brevispica Harms	11.04	5.76	0.30	17.11
Acacia bussei Harms ex. Sjostedt	0.44	3.74	8.17	12.35
Acacia mellifera (Vahl) Benth.	0.32	4.03	2.07	6.43
Acacia nilotica (L.) Wild. ex Del	0.04	1.72	1.25	3.03
Acacia oerfota (Forssk.) chweinf	5.19	1.15	0.54	6.89
Acacia robusta Burch	0.41	4.89	3.63	8.94
Acacia Senegal (L.) Wild	4.54	4.32	1.50	10.37
*Acacia tortilis (*Forsake.) Hayne	4.75	5.47	3.87	14.10
Acalypha fruticosa Forssk	11.32	5.76	1.12	18.20
Acokanthera schimperi (A.DC.)	2.69	2.01	0.82	5.53
Agave sisalana Perro ex Eng.	1.67	1.44	0.40	3.51
Aloe pirottae Berger.	4.08	0.57	0.64	5.30
Balanites aegyptiaca (L.) Del.	0.07	4.32	8.29	12.69
Berchemia discolor (Klotzsch) Hemsl.	0.16	1.72	1.83	3.72
Boscia angustifolia A.Rich	2.04	0.86	0.79	3.69
Boscia minimifolia Chiov.	0.20	3.17	1.56	4.93
Capparis sepiaria L.	0.27	0.57	0.51	1.37
Cissus rotundifolia (Forssk.)	0.18	0.86	0.35	1.40
Commicarpus sinuatuss Meikle	0.09	0.28	0.28	0.66
Cordia africana Lam.	0.02	1.15	16.52	17.01
Dichrostachys cinerea (L.) Wight & Arn.	2.50	1.44	0.45	4.40
Dicoma tomentosa Cass.	0.74	0.57	0.17	1.49
Dodonoea angustifolia L. f.	0.55	1.15	2.94	4.65
Euclea racemose Murr.Ssp.	8.16	5.18	0.68	14.03
Euphorbia burger M. Gilbert	0.37	0.86	1.50	2.74
Grewia erythraea Schweinf	5.47	5.47	0.43	11.38
Grewia ferruginea Hochst. Ex A.	3.80	4.03	0.37	8.21
Grewia tenax (Forssk.) Fiori	7.51	3.74	0.58	11.84
Hibiscus micranthus L. f.	1.02	1.44	0.23	2.69
Jasminum eminii Vatke	0.09	0.28	0.19	0.57
Jasminum floribundum (R.Br. ex Fresen.)	0.64	1.15	0.35	2.15
Lantana camara L.	9.09	2.59	0.30	11.99
Oncoba spinose Forssk.	0.05	2.88	0.25	3.19
Opuntia ficus-indica (L.) Miller	8.16	4.89	0.48	13.55
Ozoroa insignis Del.	0.26	4.61	1.50	6.38
Pentarrhinum somaliense Liede	0.37	0.86	0.28	1.51
Rhus natalensis *(*Sw.) DC.	0.46	0.57	0.40	1.44
Schleichera oleosa (Lour.)	0.03	0.57	20.91	21.53
Ximenia caffra Sond.	0.37	0.86	0.37	1.61
Ziziphus spina-christi (L.) Desf.	0.55	1.15	0.32	2.03
Total	100	100	100	300

In the LD site, *Ficus vallis-choudae* (17.15), *Acalypha fruticosa* (15.3), and *Acacia brevispica* (13.9) are the top three ecologically important species with having highest IVI values. *Acalypha fruticosa* and *Acacia brevispica* species are similar to that of HD and MD, but *Ficus vallis-choudae* species are different from the top three species identified in HD and MD. This shows that there is a little bit of similarity of the sites in most of the factors as they are adjacent to each other. The least ecologically significant species based on their IVI value in this site were *Dicoma tomentosa, Bridelia micrantha,* and *Commicarpus sinuatuss* with 1.6, 1.7, and 1.8 IVI values respectively (Table 5). These species are perfectly different from the least significant species found in both the HD and MD sites. This also indicates that there is high variation of status of disturbance among the three disturbance regimes.

Table 5: Relative density, frequency, dominance, and IVI of woody species in LD site

Scientific Name	RD (%)	RF (%)	RDO (%)	IVI
Acacia albida Del.	0.35	2.24	6.80	9.40
Acacia brevispica Harms	10.62	3.08	0.28	13.99
Acacia bussei Harms ex. Sjostedt	0.74	5.05	1.37	7.17
Acacia etbaica Schweinf.	0.07	1.96	7.00	9.04
Acacia mellifera (Vahl) Benth.	9.10	3.08	1.20	13.39
Acacia negrii Pic.-Serm.	4.27	4.21	0.66	9.15
Acacia oerfota (Forssk.) chweinf	2.48	1.68	0.60	4.77
Acacia robusta Bruch.	0.81	5.61	2.46	8.89
Acacia Senegal (L.) Wild	9.52	4.21	1.00	14.73
Acacia seyal Del.	0.25	2.52	9.14	11.92
*Acacia tortilis (*Forsake.) Hayne	0.60	3.93	1.41	5.95
Acalypha fruticosa Forssk	11.72	2.52	1.08	15.33
Agave sisalana Perro ex Eng.	1.51	2.80	0.57	4.89
Balanites aegyptiaca (L.) Del.	1.12	5.01	1.50	7.64
Berchemia discolor (Klotzsch) Hemsl.	0.34	1.40	1.24	1.99
Boscia angustifolia A.Rich	9.10	1.12	v	2.45
Boscia minimifolia Chiov.	0.43	3.93	1.22	9.88
Boswellia neglecta S. Moore	0.42	1.68	4.66	7.00
Bridelia micrantha (Hochst.) Baill.	0.68	0.84	0.43	1.71
Capparis sepiaria L.	0.82	1.40	0.55	2.48
Cissus rotundifolia (Forssk.)	1.55	1.96	0.25	1.83
Commicarpus sinuatuss Meikle	0.55	1.12	0.36	3.30
Commiphora schimperi (Berg) Engl.	0.56	0.56	2.36	12.09
Cordia africana Lam	0.06	1.40	13.13	3.29
Dichrostachys cinerea Wight & Arn	1.24	1.96	0.52	2.55
Dicoma tomentosa Cass.	1.20	0.84	0.14	1.63
Dodonoea angustifolia L. f.	1.37	1.68	2.41	4.84
Euclea schimperi Murr.	9.38	3.65	0.28	10.32
Euphorbia burger M. Gilbert	1.79	2.52	0.83	4.52
Ficus vallis-choudae Del.	0.09	0.84	11.93	32.08
Grewia erythraea Schweinf	2.34	1.96	0.57	4.23
Grewia flavescens Juss.	4.27	1.40	0.23	4.88
Grewia bicolor Juss.	0.55	4.21	0.71	4.74
Hibiscus micranthus L. f.	1.65	2.24	0.13	3.47
Jasminum eminii Vatke	1.10	2.24	0.32	3.28
Justicia schimperiana T. Anders.	1.65	2.80	0.55	4.43
Opuntia ficus-indica (L.) Miller	3.03	3.08	0.74	5.84
Ozoroa insignis Del.	0.38	3.37	0.68	6.63
Pentarrhinum somaliense Liede	1.24	1.12	0.20	2.15
Premna schimperi Engl.	0.08	2.8	5.35	8.87
Rhus natalensis (Sw.) DC.	1.10	1.40	0.47	2.60
Salvadora persica L.	0.40	0.84	2.00	3.42
Tamarindus indica L.	0.31	1.12	2.69	4.27
Terminalia brownie Fresen.	0.06	1.40	3.22	5.25
Total	100	100	100	300

RF=Relative Frequency; RD=Relative Density; RDO=Relative Dominancy and IVI= Important Value Index¨

Woody Species Diversity, Richness and Evenness

The average overall woody species diversity and evenness were 2.9 and 0.80 respectively in BES. Shannon diversity index is considered as high when the calculated value is 3.0, medium when it is between 2.0 and 3.0, low when between 1.0 and 2.0, and very low when it is 1.0 (Cavalcanti & Larrazabal, 2004). In this respect, BES had a medium Shannon diversity index. However, the three disturbance sites had a significantly different values of species diversity and values of evenness. HD site had a significantly lower Shannon diversity index value (2.14) than the other two sites. However, the MD and LD sites had not significantly different from each other, even though MD was slightly lower (2.89) than LD (3.21) (Table 6).

Table 6: Summary of Shannon Weiner diversity index (H'), evenness (J), and richness (S)

Frost sites	Shannon diversity index (H')	Evenness (H′/Hmax)	Species richness
HD	$2.14^{a}\pm0.58$	$0.79^{a}\pm0.023$	$9.66^{a}\pm7.50$
MD	$2.89^{b}\pm0.70$	$0.83^{b}\pm0.03$	$13.66^{a}\pm7.63$
LD	$3.21^{b}\pm0.85$	$0.89^{b}\pm0.06$	$14.64^{a}\pm7.83$
P-value	0.047*	0.037 *	0.705

In all vegetation types, average evenness decreased significantly (p=0.03) from the low disturbed site through the moderately disturbed site to the heavily disturbed site. However, the mean of the richness of woody species decreased not significantly from the low disturbed forest to the moderately and heavily disturbed sites respectively (Table 8)

Jaccard Coefficient of Species Similarity

Jaccard's coefficient of similarity was computed to compare the similarity in family, genera, and species composition of different sites (HD, MD, and LD) of vegetation. The Jaccard's similarities of woody species for MD and LD were 63 % of species. Similarly, 48%, similarity values were obtained from MD and HD sites. However, the similarities between HD and LD were found to be 41 % of species (Table 7). The highest similarity value was obtained for the species level between MD and LD followed by HD and MD sites, while the lowest was recorded in between HD and LD.

Table 7: Similarity of woody species between three sites

Forest type	HD	MD	LD
HD	0		
MD	0.48	0	
LD	0.41	0.63	0

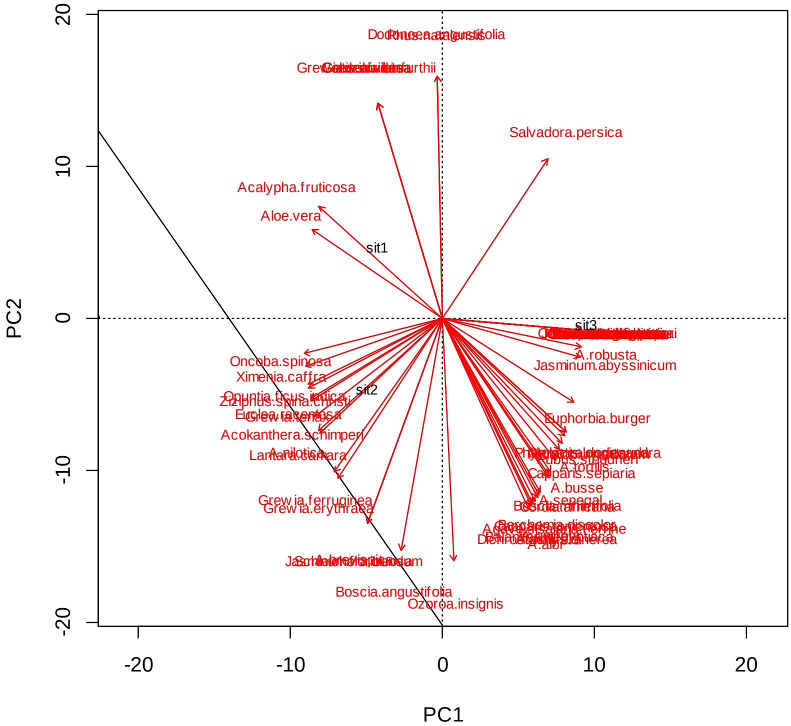
HD=heavily disturbed, MD=moderately disturbed and LD=low disturbed sites

Principal components analysis

The results of ordination are typically viewed as 2-dimensional graphs. In these graphs, each site is presented. Sites that are close together in the graph are interpreted as being similar in species composition, whereas sites that are far apart in the graph are interpreted as containing different species. In this respect, MD and LD sites are placed closest together, this reflects the smaller distance between these two sites in terms of species composition. The species scores show the direction from the origin (the point with coordinates (0,0) shown in the middle of the below Fig 4) where sites occur that have a larger than average value for the particular species. In this study, the HD site is expected to have larger average values for *Acalypha fruticose* since this species and the HD sites occur in the same direction (upper-left) from the center (Fig 4). LD Site is projected on the opposite side of the particular species vector. So, the expected abundances of this species were lower in the LD site which lead to low similarity between HD and LD sites.

Moderately disturbed site is projected farthest from the origin in the direction of *Acokanthera schimperi* and *Lantana camara* species vector, these implies these sites have larger abundances for the particular species than other sites. However, the PCA graph shows that the LD site has the largest abundance for *A. albida* and *A. bussei* whereas HD does not have the largest position on the *A. albida* and *A. bussei* species vector (Fig 4). Generally, MD and LD sites share the average value of most species in the study site and have a high ecological similarity.

Fig. 3: PCA ordination graph for the species and site score



Site 1=heavily disturbed, site 2=moderately disturbed and site 3=Low disturbed

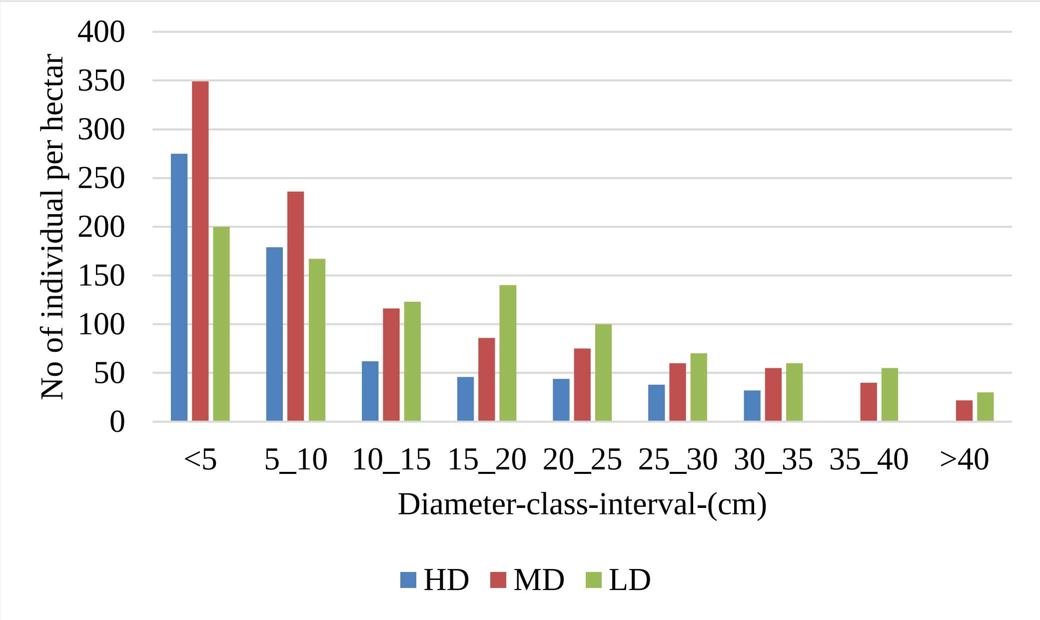
Population Structure of Woody Plant Species

Density against DBH class

The diameter class of species in MD and LD sites were classified into nine classes. However, in HD site continues only up to seven diameter classes. The overall pattern of diameter class in all three sites exhibited a reversed J-shaped distribution (Figure 5). In this study, 76.3 %, 68.4 %, and 51.8 % of total DBH frequency lie between the first three diameter classes in HD, MD, and LD, respectively. There was a gradual increment in a number of species with higher diameter class as the disturbance decreased.

Tree species which had included under higher diameter class i.e. ≥ 40 cm mainly included species of *A. robusta*, *A. Seyal*, and *B. aegyptiaca* which were the tallest tree species that were dominantly found within the low disturbed site. Contrarily, the proportion of species in the last three diameter classes for each of the three sites looks at 6.8 %, 10.9 %, and 15.3 % in HD, MD, and LD respectively. This also exhibits that there is gradual increment in large trees as the disturbance decrease.

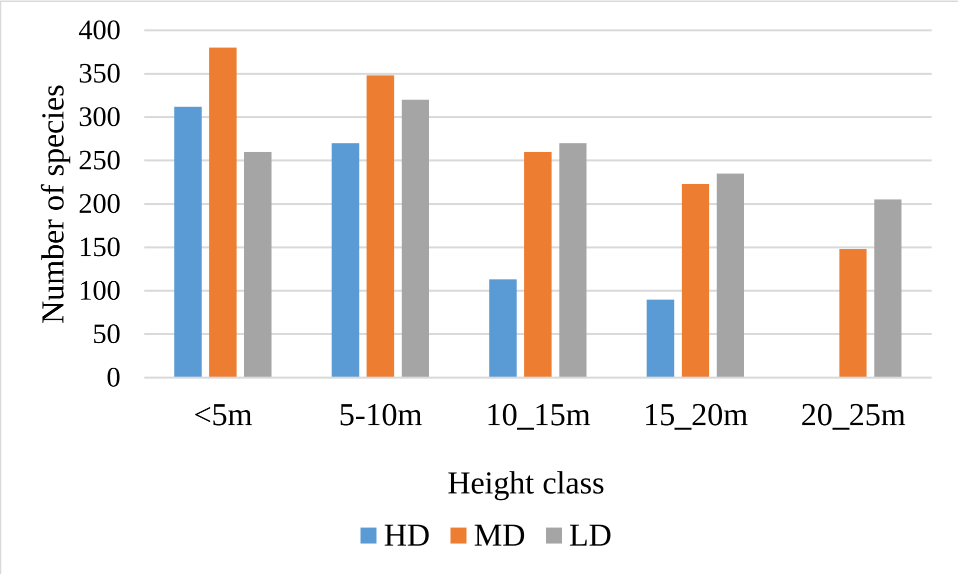
Fig. 4: Diameter distribution of species in three sites (HD, MD and LD=heavily, moderately and low disturbed site respectively)



Height Distribution

Height class were classified in to five class in MD and LD sites. However, in HD site height class were classified in to four class. Height class distribution also similar reversed J-shape pattern obtained like that of dimeter class in HD and MD sites with gradual decrement towards the largest highest class. However, most species were attained the medium canopy layer class (5-10 and 10-15m) in LD, which shows that the number of individuals were high in the middle classes and decreased towards the lower and higher height classes. The number of species which can reach the height of less than 5m across the three vegetation types were 39.7 %, 28.1 % and 19.3 % in HD, MD and LD respectively. In this height class most common shrub species were included such as *Aloe Pirottae*, *Euclea racemose*, *Grewia erythraea*, *Grewia ferruginea* species. These species were basically abundant in the heavily disturbed site. The species of medium canopy class (5-10m) contribute 33.6 %, 24.5 % and 24.3 % of totally selected individuals of woody species in HD, MD and LD sites (Fig 6).

Fig. 5: Height class distribution of woody species at the three sites (HD=heavily disturbed, MD=moderately disturbed and LD=low disturbed)



Discussion

Human-induced disturbances are the major causes for changes in forest structure and composition (Kumar & Ram, 2005), and the extent of these effects are dependent on the type and severities of the disturbances (Chown, 2011). The most probable reason for the domination of shrub species may be specialization of the different species to different dispersal agents. Wind can carry light seeds with thin cotyledons, e. g. Acacia mellifera for a considerable distance. Some of the plant species may have a wide range of dispersal mechanisms and/or rapid reproduction strategies. Cowling & Kerley (2002) also suggested that since most of the shrubs produce bird dispersed fruits, they are able to recolonize areas successfully. The highest presence of shrubs is due to the domination of small sized shrubs in the floristic composition in all study sites. The presence of some of the species in the HD site was due to their resistance to grazing and trampling of human and cattle (Eshaghi Rad *et al*. 2009). The family Fabaceae ranks first comprising due to them are known for their drought tolerance, deciduous and well developed spiny species as defense mechanism for the environmental and human induced hazards (Anteneh *et al*., 2011).

The least density of the most important woody species such as *Balanites aegyptiaca*, *Pentarrhinum somalensis*, *A. etbaica*, *A. albida* and *Tamarindus indica* might be due to selective overexploitation for construction, firewood, charcoal and other multipurpose uses by local peoples. Similarly, the highest densities of some species like *L. camara*, could be due to their unpalatable nature for both wild and domestic animals and wide range of dispersal mechanisms and rapid reproduction strategies (Feyera, 2006; Anteneh *et al*., 2011). In fact, the significant differences that existed among the sites in terms of mean density of species clearly demonstrates the effects of human disturbance on this structural attribute of the vegetation (Addo-Fordjour *et al*., 2009).

Frequency indicates an approximate homogeneity and heterogeneity of species. The high value in higher frequency and low value in lower frequency classes indicate constant or similar species composition where as high value in lower frequency classes and low values in higher frequency indicate high degree of floristic heterogeneity (Lamprecht, 1989). The result indicates that generally the study sites had heterogeneous species composition. The reason for lack of perfectly frequent for some species in HD site might be due to relatively higher human intervention and animal grazing in the site relatively as it is closer to residency area with minimal protection from the authorities. Species of such least frequency need to be given priority in conservation to enhance their frequency distribution. Species like *A. fruticosa* and *Lantana camara* with highest frequency value in the study sites are a sign of degradation in the area as it is highly intervening by human and animals (Raghubanshi & Tripathi, 2009).

LD had significantly higher basal area coverage than the other two sites followed by MD. But HD had significantly lower basal area coverage. This directly relational trend indicated that disturbance influence basal area and dominance of an area, the value of basal area was higher as disturbance level decrease. This might be due to the presence of relatively higher proportion of larger and aged trees in LD site because of little intervention by human activities like tree cutting, farming, and grazing. Similar results also obtained the same trend, Atsbha *et al.* (2019) concluded that the greater difference in basal area between the sites could be due to the high number of multi-stemmed trees in undisturbed site leading to bigger diameters.

IVI is an important parameter that indicates the ecological significance of species in a given ecosystem. The species with high IVI value in all (HD, MD and LD) sites will be regarded as more important than those with low IVI values (Zegeye *et al.*, 2011). Low IVI value might also be a sign of over utilized or non-properly managed species in the three study sites. So if their stand stays this way after some period of time the vegetation community may loss these species. Hence proper management and conservation require for these species.

Anthropogenic disturbances, such as logging or cutting trees, charcoal production and farming practices usually, result in an immediate decline or complete destruction in species diversity (Noble & Dirzo, 1997). As expected, the study demonstrated that vegetation diversity varies along disturbance regime in the studied sites. Lowest Shannon diversity index and evenness registered in HD was due to its excessive anthropogenic disturbances that inhibit plant growth and excessive exploitation of woody species, and attracts only some adaptive plant species. The high evenness value in LD forest strata from the result may be due to similar adaptation potential of woody species in that particular ecosystem and low human intervention. In congruent with the finding; Atsbha *et al*. (2019) concluded that repeated habitat disturbances due to frequent and intensive interference of both humans and livestock for grazing and other communal uses significantly influence species diversity. Similarly, Desalegn & Zerihun (2005) stated that low species diversity and evenness could be attributed to the presence of forest disturbance and absence of adequate nutrient and moisture.

Increased fragmentation of natural habitats by human disturbances leads to reduced species richness, and that many variables cause species loss along the disturbance (McKinney, 2002). This finding is also in line with Anteneh (2006) who stated that, the highest agricultural expansion, tree cutting and over browsing along the Erer river leads for the reduction in the species richness in community. Similarly, other studies showed that the expansion of agricultural is a major threat to natural vegetation in BES (sintayehu and Merkebu, 2019).

Overall, it is possible to conclude that difference in woody species richness, diversity and evenness between forest types is basically showed that how natural communities are influenced by anthropogenic disturbances, it agrees with findings of Bhuyan *et al*. (2003) in a tropical wet evergreen forest in Arunachal Pradesh, northeast India and Mishra *et al*. (2004) in northeast India and Esther *et al.* (2014) in Kakamega forest, western Kenya. Similarly, Feyera (2006) stated that the low species richness and evenness in the Maji forest was due to anthropogenic disturbances, such as burning, grazing, and wood collection. There is a significant negative correlation between disturbance and plant species richness (Feyera, 2006)

Even though the three sites were found adjacent to each other, they have different similarity coefficients. The reasons for such results were higher variation between the sites in extent of anthropogenic disturbance, excessive exploitation of same species. But the adjacent position of MD for both other sites makes it to possess the highest similarity value with LD and the second highest value with that of HD. The low level of destruction of vegetation by human activity in the low, disturbed site as compare to the heavily disturbed one, also contribute to the inflated value of low similarity between the sites. Similar to this, study by Bitew & Tesfaye (2017) found a similar result in their research findings. *A. bussei* and *A. robusta* was found to be one of the most abundant and characteristic of the LD, contributing high percentage value to the low similarities between the LD site and HD site. The existence of low similarities between these sites which in turn implies the importance in terms of floristic diversity and evenness needs attention from a conservation point of view. As reported by Dereje (2007) anthropogenic forest disturbance and other environmental factors such as, soil physical and chemical properties and have sound effects on patterns of natural forest composition.

Principal components analysis (PCA) is one of the ordination techniques. It provides graphs that show the Euclidean distance between sites (Legendre & Gallagher, 2001). Ordination methods geometrically arrange sites so that the distances between them in the graph represent their ecological distances.

Description of diameter distribution class indicates reversed J-shaped, where species frequently had the highest frequency in low diameter classes and a gradual decrease towards the higher class. There was gradual increment in number of species with higher dimeter class as the disturbance decreases. This was due to easiness of the HD site species for selective cutting and transportation as there is relatively favourable closeness to the homestead than the other. In congruent with the finding; Getaneh (2007) concluded that woody species with higher DBH (>30 cm) harvested by the local people for construction and charcoal preparation. This is also in line with the finding of Nord & Cao (2006) stated that, deforestation and over utilization causes the decrease in the density of species in a natural forest. Similarly, Atsbha *et al.* (2019) reported that there was selective removal of middle and high diameter class trees for various purposes by local people like for, fencing, farm implementing, house construction, and fuel wood when allowed by the community leaders

Highest canopy covers in low disturbed site while light intensity height class was high in the heavily disturbed site. The works of Rao *et al*. (1990) and Sang (2009) followed the same trend. This distribution was might be due to selective cutting by the local people for construction and firewood, occurrence of a poor reproduction status and over harvesting of seed bearing individual (Feyera, 2006). This pattern is supported by the work of Pereira *et al*. (2001) that states the direct removal of trees by logging and farming activities were directly responsible for the decrease in height in disturbed forests.

Generally, this study has shown that the consequence of human disturbance on woody plant diversity was negative depending on the type and intensities of the disturbances.

Disturbance had resulted in decreased species richness and population density of overall woody species in the HD sites where intensities crop cultivation and settlement encroachments are practiced compared to the MD sites and LD site. Alternatively, designating the forests as community-based conservation areas might be useful to ensure a regulated and sustainable natural resource use in the areas. Finally, future studies focusing on the impacts of disturbances on the diversity and population structure of woody species in the present area would be of paramount to increase our understanding of the subject matter.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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