Role of exclosure on woody species diversity in comparison to adjacent open grazing land: The case of wenago district, Southern Ethiopia

Mengistu Meresa1*, Menfese Tadesse2 and Negussie Zeray3

Abstract: Ethiopia has suffered from degradation of forests and loss of biodiversity as a result of anthropogenic activities mainly for the purpose of expanding farm lands, construction materials, fuel wood and charcoal production. The objective of the study was to assess the status of exclosure comparing with adjacent open grazing land. In each area exclosure and open grazing land uses, a plot of 20 m x 20 m, 10 m x 10 m and 2 m x 2 m area size for trees, shrubs and herbs, respectively, was drawn using systematic method. A total of 66 plots in 10 hectare area were sampled along the transect line. Diameter at breast height (DBH) was measured using caliper, and tree height was measured using clinometer and Woody species data were analyzed through Shannon–Wiener diversity index ($H'$) and Sorensen similarity coefficient indices (Is) using SPSS version 20, excel software and the linear relationship between diversity mean value and land uses were compared using chi-square. A total of 35 plant species belonging to 25 families were identified and recorded. Shannon’s species diversity index ($H'$) in exclosure and adjacent open grazing was 2.591 and 0.889, respectively. Exclosure had a significantly higher number of woody species diversity compared to adjacent open grazing land. Herbs were not influenced by both compared land uses. In order to keep the present progress and rehabilitation status of woody diversity, sustainable management of area exclosure is very necessary and planners, policy makers and stakeholders need coordination and participatory based plant species conservation strategies.

ABOUT THE AUTHOR

Mengistu Meresa (the corresponding author whose photograph displayed above) is currently a PhD candidate in department of Natural resources management, Dilla University, Ethiopia. He has more than 25 years of teaching experience in different governmental primary & secondary schools, colleges and universities. He also worked as a director of primary schools, supervisor of secondary schools and as educational quality assurance expert in Dilla Town education office. Professionally he has four publications in international peer-reviewed journals. In addition the author has got more than 14 certificates of participation in academic training, proposal development, module preparation and being as a model teacher.

PUBLIC INTEREST STATEMENT

The study is aimed to provide the overall information regarding the role of establishing exclosure area on woody species diversity and other related conservation of biodiversity. The study article has a significant contribution in sustainable land management, rehabilitation of degraded lands, recovery of disappeared plant species, regulation of local climate, protection of wild animals and in enhancing socio-economic development. As conclusion, the author forwarded exclosure measure as one of the best and easy mechanism for rehabilitation of severely degraded lands and regeneration of vegetation by limiting human and animal interference as well as additionally planting native trees through community campaign services.
1. Introduction

Ethiopia is gifted with topography, location, climate, ecology, natural resources and diverse sets of ecosystems. This suitable condition is attributable to the existence of higher biodiversity in the country (Mengistu & Asfaw, 2016). The diversity of fauna and flora of the country ranging from 5,999 and 6,999 species, of this 15% are endemic. According to Gebretsadik (2016), Ethiopia is also rich in large mammals and endemic to it such as Walia Ibex, Simien Fox and Gelada Baboon mainly concentrated in the Southwestern borders of the country. However, the present deforestation rate in the country is estimated to be 90,111–100,111 hectare. The economic loss due to deforestation in the country ranges between 0.4 and 1.5 billion USA per year (Shumi et al., 2021; Sintayehu, 2018; Srinivasan, 2014). In regard to this, Eshetu (2014) and Dawson et al. (2019) estimated a deforestation rate of 1,410 square kilometer per year in Ethiopia with annual deforestation rate of 11%. Loss of plant species diversity poses a clear risk to the wellbeing of subsistence communities (Sintayehu, 2018). As a result deforestation causes a significant challenge particularly in the Ethiopian Highlands Park (WWF, 1999). Gebretsadik (2016) reported that the demand of the fast growing population growth on farm land for cultivation and the consequent environmental degradation leads to loss of forest and biodiversity. Similarly, the report of Eshetu (2014) and Fenetahun et al. (2021) showed that before 100 years, about 59% of Ethiopia’s surface was covered with trees species but now remained not greater than 6%. In this study to assess the impact of land management and conservation practices, enclosure (enclosure) area and adjacent open grazing land uses were tested for their plant species diversity and richness.

Area exclosure is a land use which is protected from anthropogenic activities and animal disturbances in order to recover its natural plant species and to reduce additional removal of vegetation and soil erosion of the previously affected lands (Asmare & Gure, 2019; Aerts et al., 2009; Mekuria et al., 2011). According to (Meron, 2010; Mekuria et al., 2011; Yami et al., 2006; Teketay et al., 2018; Fenetahun et al., 2021), rehabilitation of affected areas using exclosures system has been achieved in northern part Ethiopia, which was totally closed from any anthropogenic and animal contact using iron wire fence or recruited guards with the goal of regeneration of natural vegetation. Area exclosures have a significant role in biomass production, enhancement of biodiversity, maintenance of plant species diversity, restoration of native vegetation, rehabilitation of degraded forest wood land, hostage of wild animals, source of animal feed and extraction of medicinal plants for human and animals (Sinoare & Doboch, 2021; Melkamu and Abdella, 2019; Mengistu & Asfaw, 2016; Molla & Kewessa, 2015; Giday et al., 2019). In the study area, there is one successful area exclosure locally named as Kara Saditi park which has 5.4 hectare area size. As reported by Wenago district agriculture and natural resources office (WWANRO) and local kebele office in 2019, the area exclosure was delimited and restricted before 2010 (for nearly 13 years) free from any human and animal intervention so that at present the enclosure has successfully regenerated in terms of plant species diversity restoration and it consisted mainly native (80%) and non-native (20%) plant growth forms. Regenerated exclosures vegetation land uses provide various environmental and economical benefit including as a source of traditional medicine plants to local communities (Mengistu & Asfaw, 2016).

Open grazing land is one type of land uses which is strongly affected by deforestation, soil erosion, over grazing and absence of soil and water conservation practices (Teketay et al., 2018; Hogarth, 2014; Reubens et al., 2011; Melkamu et al. 2019). Open grazing is a disturbed land use type and its vegetation species diversity, richness and structure are extremely influenced by a lot
of environmental factors and human intervention activities (Teketay et al., 2018; Fantahu et al. 2021). However, this does not mean that open grazing lands have not a contribution on formation of plant species (Gebretsadik, 2016; Srinivasan, 2014).

In Ethiopia appropriate land management, afforestation in degraded lands and expansion of exclosure area practices are very crucial to restore formerly degraded grazing areas (Fenetahun et al., 2021; Teshome et al., 2019; Yami et al., 2006). However, there was no research-based information regarding comparison of exclosures with adjacent open grazing lands in terms of woody species diversity conservation in the study area (Mengistu & Asfaw, 2016; Sinore & Doboch, 2021). Besides, previous studies in Wenago district, Southern Ethiopia, were mostly focused on traditional agroforestry systems, woody species potential and forest coverage while the focus to the role of exclosures on woody species diversity was limited, awareness of the local communities and plant species development was not as expected (Burraga et al., 1993; Giday et al., 2019; Mengistu & Asfaw, 2016; Shumi et al., 2021). Therefore, this study was conducted with the aim of investigating the status of woody species diversity in exclosure area in comparison to adjacent open grazing land of wenago district, Southern Ethiopia. The specific objective of this research was (i) to assess the role of exclosure on woody species diversity in comparison to adjacent open grazing land and (ii) to investigate the similarity and difference between exclosure and the adjacent open grazing land in terms of plant species composition, abundance and frequency in Wenago district, Southern Ethiopia.

2. Materials and methods

2.1. Description of the study area

The research was conducted in Wenago district, Southern Ethiopia, approximately 373 km south of the capital city Addis Ababa. The study area is located between 6° 12’ 30” and 6° 22’ 30” N latitude and 38°15’ 0” and 38°20’ 0” E longitude (Figure 1). The study area is bordered in the west by Abaya (Oromiya region); in the south by Yirga Cheffie District; in the north by Sidama Zone; and in the east by Dilla Zuria Woreda (Figure 1). The study area has a favorable climate condition which is suitable for agroforestry dominated agricultural activities. The rainfall distribution of the study area is bimodal (from August to November and from March to May). The annual rainfall varies from 850 to 1500 mm, whereas mean annual temperature ranges from 12.5°C to 28°C. Nitrosols are dominant soil types covering highest proportion of the study area. The soils are in general derived from volcanic rocks which are important for coffee-growing areas (Hogarth, 2014). The dominant woody trees are Millettia Ferruginea and arabica coffee integrated with cereal crops on a similar farm land which are advantageous for livestock feed and shading for coffee. Based on the 2007 census and recent projection, the total population of the study district is about 152,111 with an area of 248 square kilo meter (km²) and density of 613 persons/km². The majority of the populations of the
study area (90.8%) live in rural areas. The main economic activities of the study communities are agro forestry dominated mixed farming system with livestock keeping (fattening and diary).

“SNNPR” on the map (Figure 1) stands for South Nation Nationalities and People Region which means Southern Ethiopia.

2.2. Site selection techniques
Before starting the actual data survey and data collection, a preliminary field visit and physical observation in order to get the general view of the study area, information regarding presence of area exclosure and identify the sample size was conducted with the help of district office experts, study kebele office administrators and development agents (September, 2020). Accordingly, information from the concerned district office (2020/21) was obtained that area exclosure was found only in one kebele known as Kara Soditi kebele which had been established and in 2010. Therefore, this baseline data to compare and contrast the progress of area exclosure with adjacent open grazing land sites were identified and determined for the study.

“Kebele” refers to the lowest administration units (sub-division of a district) in the administrative structure of Ethiopia

2.3. Sampling design
To collect the required woody species data and to assign the sample plots, a systematic sampling technique was employed. In exclosure (having 5.4 hectare area size) and adjacent open grazing land (having 5 hectare area), four transect lines were laid at a distance of 100 m between each transect line. At this interval, a 20 m x 20 m, 10 m x 10 m and 2 m x 2 m plot sizes were assigned to encompass all trees, shrubs and herbaceous, respectively, as described by Mengistu and Asfaw (2016). The total required plots for the entire research study were determined using the following formula proposed by Teketay et al. (2018), i.e. \( n = \frac{(N \cdot S)^2}{N^2 \cdot E^2 + N \cdot S^2 / t^2} \), where \( n \) is the required plots, \( N \) is the total area transected, \( E \) is allowed error (0.05), \( S \) is standard deviation and \( t \) is t-test. About 33 plots were established in each the exclosure and adjacent open grazing land. Finally, a total of 66 plots were used for the study. Key informants and focus group discussion household head participants were selected using random sampling techniques while office experts were selected using purposive method because they were few in number.

2.4. Woody species inventory
A preliminary field visit and physical observation in order to get the general view of the study area and the presence of area exclosure with adjacent open grazing land sites were identified for the study via the help of district and Kebele office experts from 1 July 2020 to 30 July 2020. The actual plant species survey, inventory, measurement and analysis was carried out from 1 August 2020 to 28 October 2021 when the majority of the plants were at the peak of their growth. Trees were with height > 2 m and DBH > 2.5 cm (at 1.5 m height) while woody species with height < 2 m and DBH < 2.5 cm were shrubs. DBH was measured using caliper while tree height was measured using clinometer and label sticks. For woody species with DBH below 2.5 cm, only stem count was made to know the number of abundance. For tree forked below 1.5 m, individual stem was separately measured, and then the average of DBH was taken. For large stem trees, DBH was also calculated using the formula \( D = C / \pi \) (where \( D = \text{Diameter}, C = \text{circumference}, \pi = 3.14 \)). Herbs with height <1 cm were estimated. For more clarity, local names of woody species were also recorded by the help of knowledgeable local persons and identification of scientific names of all woody species was carried out using woody data field guides. For plant species that was difficult to identify in the field, specimens were collected and taken to the National herbarium at Addis Ababa for identification. To strengthen the main surveyed data, a total of 32 key informants consisted DAs, natural resources management office experts, model farmers, knowledgeable persons, male and female households were interviewed. Group discussion was also made with a total of eight household participants included men, women, rich, poor, elders and office groups.
2.5. Method of data analysis

In the case of woody species inventory, all data analyses were performed using Shannon diversity index $H' = -\sum_{i=1}^{S} p_i \ln p_i$ where $H'$ stands for Shannon diversity index, $S$ represents the total of species in the quadrates, $p_i$ represents individuals found in the $i^{th}$ species, $I_n$ represents the natural log. Distribution of woody diversity was evaluated by the formula of evenness index $(E) = H'/\ln S$, where $H'$ is Shannon's diversity, $\ln$ is the natural logarithm of the whole species while $S$ stands for number of species (Melkamu and Abdella, 2019). Sorensen's similarity coefficient index $(IS)$ was employed to determine the composition similarity between exclosure and open grazing land by using the formula $Is = 2a/(2a+b+c)$ and $Id = 100\% - Is$, where $Is$ stands for Sorensen similarity coefficient index, $a$ refers to species common to both exclosure and open grazing land, $b$ represents species present only in exclosure but absent inside open grazing, $c$ indicates the number of species present only in open grazing land but absent inside exclosure and $Id$ is Sorensen difference coefficient index. Data of woody species collected through inventory and measurement were analyzed using SPSS version 20 and Excel software. To compare woody species diversity between exclosure and open grazing land, Native and exotic, chi-square were used at $p \leq 0.05$ level of significance. Information obtained from interviewed key informants, focus group discussion and field observation were descriptively interpreted.

3. Results and discussion

3.1. Composition, abundance, structure and frequency of woody species

A total of 35 woody species belonging to 25 families were identified in wenago district which laid in 10 hectare area. Besides, from 35 identified woody species 267 number of individual species were counted and recorded (Table 1). The composition of species counted inside exclosure were 20, 10 and 4 for trees, shrubs and herbs, respectively. Inside the open grazing land use, 11, 5 and 3 were counted for trees, shrubs and herbs, respectively (Tables 1 and 2). As opportunity, there were no climbers either inside the exclosure area or adjacent open grazing land. Among the total 34 woody species counted in exclosure area, the dominant trees were Juniperus procera hochst ex endl. 67 (29%), Millettia ferruginea (Hochst.) baker. 15(6.4%), Cynodon dactylon (L.) pers. 12(5.1%), Acacia saligna (Labill.) syn.A. mballisima. 11(4.7%) While in the adjacent open Grazing land Cynodon dactylon (L.) pers. 7(21.9%) and Vernonia amygdalina Del. 3(9.4%) were the most dominant woody species. The woody species with highest individual frequency observed at exclosure area and open grazing land were Juniperus procera hochst ex endl 67(29%) and Cynodon dactylon (L.) pers. 7(21%), respectively. In exclosure area, trees, shrub and herbs shared (70.91%), (19.2%) and (9.82%), respectively. Similarly, open grazing land was covered by 43.75%, 25% and 31.25% for trees, shrubs and herbs, respectively (Tables 1 and 2). This implies that the composition of woody species in both exclosure and open grazing land was covered by trees than shrubs and herbs (Table 2). This result was contradicted with the finding of (Melkamu and Abdella, 2019) who reported that the composition in area exclosure was largely covered by shrubs than trees and herbs.

The dominance of woody species in free grazing area was 3 times smaller than in exclosure area (Table 1, 2). This might be due to lack of any restriction and regulations on the use of free grazing land resource and even the continuity of the remaining very few species is under question. This result was contradicted with the findings of (Mengistu & Asfaw, 2016) who reported that shrubs were dominant in open grazing land than trees. Concerning origin of plant species, of the total 35 identified woody species in the study area, 28 (80%) were native while 7(20%) were exotic (non-native; Table 1). The over all analysis result showed that there was statistically significant difference of species diversity between exclosure area and adjacent open grazing land at $p \leq 0.05$ level of significance, but there was no statistically significant difference of species evenness (species distribution) between exclosure and open grazing land uses at $p \leq 0.05$ level of significance.

In the study area, woody species of the area exclosure have J shaped which shows there was good recovery of plant species diversity (Figures 2 and 3). This could be as the result of good land
Table 1. List of trees, shrubs and herb recorded in exclosure and adjacent open grazing land of Wenago district

| No | Scientific name | Family | Origin | Vernacular name | Local name | Habit | Total no of individual species distinctive to area exclosure unit | Frequency | Total no of individual species distinctive to open grazing unit | Total no of individual species common to both exclosure and open grazing land units | Their main local uses |
|----|-----------------|--------|--------|-----------------|------------|-------|---------------------------------------------------------------|-----------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------|
| 1  | Acacia abyssinica | Mimosaceae | I | Grar | Ebicha | T | 5 | 1 | 1 | T, Fe, Fl, Sh |
| 2  | Acacia saligna | Mimosaceae | E | Akacha | Comexso | Sh | 11 | 0 | 0 | Fl, Sh, Fln |
| 3  | Annona rhynophylla | Annonaceae | I | Gohta | Gohta | Sh | 3 | 0 | 0 | - | F, Ci |
| 4  | Brucea antidysenterica | Simaroubaceae | I | Grm qebit | Kpparro | Sh | 1 | 0 | 0 | - | F, Ci |
| 5  | Casuarina cunninghamiana | Casuarinaceae | E | Shewshewe | Shewshewae | T | 9 | 1 | 1 | Fe |
| 6  | Coffee Arabica L. | Rubiaceae | I | Buna | Bunno | Sh | 0 | 1 | 1 | - | Cl, Sh, St |
| 7  | Cordia africana | Boraginaceae | I | Wanza | Waddissa | T | 1 | 1 | 1 | Fl, Ci, Sh |
| 8  | Croton macrostachyus | Euphorbiaceae | I | Bivana | Melanosa | T | 7 | 2 | 2 | Fl, Fe, Sh |
| 9  | Cupressus lusitanica | Cupressaceae | E | Yefer/Tid | Yefernsa | T | 9 | 0 | 0 | - | T, Fe, Ci |
| 10 | Cynodon dactylon | Poaceae | I | Serdo | Serdoo | H | 12 | 7 | 7 | Fe |
| 11 | Eleonobia capensis | Meliaceae | I | Sessa | Sessa | T | 6 | 1 | 1 | T, Fl |
| 12 | Euclea abyssinica | Mimosaceae | I | Kontir | Goara | Sh | 3 | 1 | 1 | Fe |
| 13 | Euclea abyssinica | Mimosaceae | I | Kontir | Goara | Sh | 3 | 1 | 1 | Fe |
| 14 | Ficus sur | Moraceae | I | Sholal | Sholae | T | 1 | 1 | 1 | T, Fl |
| 15 | Ficus vallata | Moraceae | I | Warka | Warae | T | 1 | 1 | 1 | T, Fl |

(Continued)
| No. | Species Name | Family | Habbit Type | Common Name | Local Uses | Sources |
|-----|--------------|--------|-------------|-------------|------------|---------|
| 19  | *Hagenia abyssinica* (Brune.) J.F.Gmel | Rosaceae | 1 | Kossa zaf | Heito | T | 4 | 0 | ° | Sh, Fl, FeM |
| 20  | *Jacaranda mimosifolia* D.Don | Bignoniaceae | E | Jacaranda | Jacaranda | T | 2 | 0 | ° | T, Ci, Fl, Sh |
| 21  | *Juniperus procera* hochst. ex endl. | Cupressaceae | J | Yehabef Tcil | Xcila | T | 67 | 2 | 2 | T, Ci, Fl, Sh |
| 22  | *Mangifera indica* L | Anacardiaceae | I | Mango | Mango | T | 7 | 0 | ° | T, Ci, Fl, Sh |
| 23  | *Milletia ferruginea* (Hochst.) Baker | Papilionoideae | J | Birara | Taltato | T | 15 | 0 | ° | Sh, Sf, Fl |
| 24  | *Moringa stenopetala* (Bak.) cuf. | Moringaceae | E | Shiferaw | Yubarrae | Sh | 2 | 0 | ° | Sh, Fl, M |
| 25  | *Ochrea longifolium Hochst. Ex Benth | Lamioaceae | J | Damakose | Damakose | H | 6 | 1 | 1 | N |
| 26  | *Persea Americana* Mill | Lauraceae | I | Abokato | Abokato | T | 5 | 0 | ° | T, Ci |
| 27  | *Phytolacca dodecandra* L’Herit | Phytolacaceae | J | Indoda | Indoodae | Sh | 3 | 2 | 2 | M |
| 28  | *Podocarpus falcatus* (Thunb) Mirb | Podocarpaceae | J | Zigba | Birbria | T | 7 | 1 | 1 | T, Sh, Fl, Fe |
| 29  | *Prunus Africana* (Hook.f.Kalim.) | Rosaceae | I | Tik’Einhet | Garbe | T | 6 | 1 | 1 | T, Sh, Fl, |
| 30  | *Prunus persica* (L.) Boiss | Rosaceae | J | Kok | Koke | Sh | 6 | 0 | ° | Fl, Fi |
| 31  | *Rhamnus prinoides* L’Herit | Rhamnaceae | J | Geine | Geine | Sh | 5 | 0 | ° | Fl |
| 32  | *Ruta chalepensis* L | Rutaaceae | J | Tenudum | Tenudomed | H | 2 | 0 | ° | M |
| 33  | *Syzygium guineense* (Willd). DC | Myrtaceae | J | Badessa | Badessa | T | 2 | 0 | ° | T, Fl, Sh |
| 34  | *Senna occidentalis* L. Link | Fabaceae | J | Assenmeka | Assenmeka | H | 3 | 2 | 2 | M |
| 35  | *Vernonia amygdalina* Del. | Asteraceae | J | Groko | Reje | Sh | 4 | 3 | 3 | M |
|     | Total 35     |             | 25          |              | 235 232 31 |        |     |     |     |     |

Abiyot, 2013; Tadesse, 2002; Bogale, et al. 2007; Tesfaye, 2005; Fesseha, et al. 2007.

*Habbits:* T-tree, Sh-shrub, H-herb (*Origin:* I-Indigenous, E-Exotic).

*Local uses:* F-food, T-timber, Fi-firewood, Fd-fodder, Fe-fence, Ci-cash income, Sh-shade, M-medicine, Sp-spices, St-stimulant, Sf-soil fertility. sources: field plant species inventory and measurement result (November, 2021).
management system, effective conservation measures of area exclosure by building complete restriction of human and domestic animals interference. In contradicting, the pattern of plants inside the adjacent free grazing land made inverted L and bell shape revealed that absence of woody plant species (Figure 3). This might be because of human-induced disturbance, unwise use of resources, tree cutting or unlimited grazing in open grazing land use.

During the focus discussion and key informant interview, the respondents replied that there is introduced exotic tree species used for cash earning and timber production (e.g., Cupressus lusitanica Mill. and Eucalyptus saligna smith, shade (e.g., Jacaranda mimosifolia D.Don), Protection Fence (e.g., Casurina cunninghamiana Miq) and medicinal value (e.g., Moringa stenopetala (Bak. cuf.) in the understudy system. The information gathered from the interviewed key informants was in agreement with (Asmare and Gure, 2019; Fenetahun et al., 2021) who reported the dominance of exotic trees such as Eucalyptus trees are useful for pole and fuelwood purposes in different parts of Ethiopia. The interviewed key informants were also noticed that anthropogenic factors such as over exploitation of natural resources, clearing trees for expansion of agricultural land and charcoal production are the currently ranked causes of woody species diversity extinction in the study area. The response of the interviewers was in line with result of the study that they mentioned some of the major causes of deforestation in the study area are expansion of agricultural land and unwise use of vegetation resources.

As indicated in Figure 2, the names of woody species identified in exclosure were recorded

As indicated in Figure 3, the names of woody species identified in adjacent open grazing land were recorded.

As shown in Figure 4, the study area is occupied by trees than shrubs and herbs (left) and covered more by native woody species four times greater than exotic ones (right).

### 3.2. Woody species diversity and evenness

Depending upon Shannon-Wiener diversity index, the calculated value of woody species diversity in exclosure and adjacent open grazing land of Wenago district was $[H^e = 2.591]$ and $[H^o = 0.889]$ respectively which shows that woody species diversity is higher in exclosure $[H^e = 2.591]$ than its adjacent open grazing land $[H^o = 0.889]$ (Tables 3 and 4). This result also indicated that the woody species diversity in the study area ranges from 0.889 to 2.591. According to Shannon’s-Wiener ranking method, the study area has moderate woody species diversity. The present result was contradictory with the finding of Sinore and Doboch (2021) who reported that woody species diversity had found high (not moderate) in area exclosure in Amlake sub-watershed, Southern Ethiopia.

#### Table 2. Identified growth forms in exclosure and adjacent open grazing lands and an area they covered

| Area            | Life forms | Total species | Number of individual species | Area covered (%) | Life forms | Total species | Number of individual species | Area covered (%) |
|-----------------|------------|---------------|------------------------------|------------------|------------|---------------|------------------------------|------------------|
| exclosure       | Trees      | 20            | 166                          | 70.64            | Trees      | 11            | 14                          | 43.75            |
|                 | Shrubs     | 10            | 45                           | 19.57            | Shrubs     | 5             | 8                           | 25               |
|                 | Herbs      | 4             | 23                           | 9.79             | Herbs      | 3             | 10                          | 31.25            |
| Total           | 34         | 235           |                              |                  | 19         | 32            |                              |                  |

Source: Own vegetation data survey computation results (2021).
### Table 3. Frequency and diversity ($H'$) of woody species in exclosure of the study area (Wenago district)

| Scientific name                                      | p   | $p_i$  | $\ln(p_i)$ | $p_i\ln(p_i)$ | $-\sum p_i\ln(p_i)$ |
|-------------------------------------------------------|-----|--------|------------|---------------|----------------------|
| Acacia abyssinica Hochst. ex Benth.                   | 5   | 0.023  | -3.772     | -0.086        |                      |
| Acacia saligna (Labill.) syn. A. mollisima            | 11  | 0.051  | -0.975     | -0.049        |                      |
| Annona chrysophylla Baj.                              | 3   | 0.014  | -4.268     | -0.059        |                      |
| Bruea antidysenterica J.F. Mill.                      | 1   | 0.004  | -5.521     | -0.022        |                      |
| Casuarina cunninghamiana Miq                          | 9   | 0.042  | -3.17      | -0.133        |                      |
| Cordia africana Lam.                                  | 1   | 0.004  | -5.521     | -0.022        |                      |
| Croton macrostachyus Del.                             | 7   | 0.033  | -3.411     | -0.112        |                      |
| Cupressus lusitanica Mill.                            | 9   | 0.042  | -3.17      | -0.133        |                      |
| Ekebergia capensis Sparrm.                            | 6   | 0.028  | -3.575     | -0.059        |                      |
| Entada abyssinica Steud. Ex A. Rich                   | 3   | 0.014  | -4.268     | -0.059        |                      |
| Erythrina brucei Schweinf.                            | 4   | 0.018  | -4.017     | -0.072        |                      |
| Eucalyptus globulus Labill.                            | 3   | 0.014  | -4.268     | -0.059        |                      |
| Eucalyptus saligna smith                              | 5   | 0.023  | -3.772     | -0.086        |                      |
| Euphorbia tirucalli L.                                | 8   | 0.037  | -3.296     | -0.121        |                      |
| Ficus sur Forssk.                                     | 1   | 0.004  | -5.521     | -0.022        |                      |
| Ficus varsa Forssk.                                   | 1   | 0.004  | -5.521     | -0.022        |                      |
| Hagenia abyssinica (Bruce.) J. F.Gmel                 | 4   | 0.018  | -4.017     | -0.072        |                      |
| Jacaranda mimosifolia D.Don                           | 2   | 0.009  | -4.71      | -0.042        |                      |
| Juniperus procera hochst ex endl.                     | 67  | 0.316  | -1.152     | -0.364        |                      |
| Mangifera indica L.                                   | 7   | 0.033  | -3.17      | -0.112        |                      |

(Continued)
| Scientific name                        | P | pi   | ln(pi) | pi*ln(pi) | -∑pi*ln(pi) |
|---------------------------------------|---|------|--------|----------|-------------|
| Millettia ferruginea (Hochst.) Baker | 15| 0.07 | -2.659 | -0.186   | -2.591      |
| Moringa oleifera (Boer.)             | 2 | 0.009| -4.71  | -0.042   |             |
| Persea americana Mill                 | 5 | 0.023| -3.772 | -0.086   |             |
| Phytolacca dodecandra L. Heit.       | 7 | 0.034| -4.268 | -0.059   |             |
| Podocarpus falcatus (Thunb.)         | 3 | 0.033| -3.17  | -0.059   |             |
| Prunus africana (Hook.f.)            | 6 | 0.028| -3.757 | -0.086   |             |
| Prunus persica (L.) Batsch           | 7 | 0.023| -3.772 | -0.086   |             |
| Syzygium guineense (Willd.) DC.      | 4 | 0.018| -4.017 | -0.072   |             |

Source: Own vegetation data survey computation result (2021).

Table 3. (Continued)
Relatively, the presence of higher woody species diversity in exclosure than open grazing land could be as a result of effective land management, restriction from any human disturbance which allowed plant species to regenerate themselves. This study result was in line with the finding of (Sinore and Doboch, 2021) who reported that area exclosure was showed active and fast regeneration trend than adjacent open grazing. Similarly, the study result revealed that woody species evenness of exclosure and adjacent open grazing area was \[ E = 0.867 \] and \[ E = 0.715 \], respectively (Table 4). Since the evenness result of the two compared land uses produced nearly similar value, then this implies that plant species were more or less evenly distributed in exclosure and adjacent open grazing areas of the study area. The woody species richness was higher at exclosure land use (34) than adjacent open grazing land (19; Table 4). The reason for higher woody species richness for exclosure might be due to the fact that woody species were not disturbed by anthropogenic activities, as a result they had an opportunity to regenerate themselves. The result of this study is in line with argument of (Shumi et al., 2021; Giday et al., 2019) who reported that woody species richness increases as soil and water conservation practices increase. For the overall study, there had statistically significant difference between exclosure and adjacent open grazing land in terms of species diversity at \( p \leq 0.05 \) significance level (Table 4).

As shown in Figure 5, the picture indicates the overview physical image of the exclosure and adjacent open grazing land

### 3.3. The linear relationship between exclosure, adjacent open grazing and woody species diversity

In this study, treatment was made to see the effect of exclosure on woody species diversity. In terms of correlation strength, both exclosure \( R^2 = 0.0014 \) (Figure 6A) and adjacent open grazing land \( R^2 = 0.1706 \) (Figure 6B) have weak relationship with their respective woody species diversity. In terms of relationship, the result of the simple regression model revealed that woody species diversity have no any correlation with the exclosure area (Figure 6A) compared to its adjacent
The reason could be due to competition of sunlight and succession of only few dominant trees. However, the simple linear regression model pattern showed that woody species diversity is positively associated with adjacent open grazing land (Figure 6B). The possible reason for increasing woody species diversity in open grazing land as compared to exclosure area might be due to the existence of free space to receive sunlight and having an opportunity of freely dispersing seeds by the help of agents such as wind, animals and vector insects.

The result of this study was in agreement with the finding of Fantahun (2021) who found that the pattern of woody species diversity was positively associated with open grazing land in the case of Borana rangeland, Southern Ethiopia. The present result was also in line with the finding of and Gebretsadik (2016) who reported that woody species have a positive association in grazing lands in Tigray region. However, the current result was contradictory with the finding of Mekuria et al., (2011) who found that the pattern of woody species diversity was positively related with exclosure in Tigray region. Similarly, the current study result was contradictory with the finding of Melkamu.
and Abdella (2019) who found that woody species diversity has a negative association with its open grazing land case of jabiTehnan district north western Ethiopia.

3.4. **Species similarity and difference between exclosure and adjacent open grazing land**

The overall Sorensen’s similarity coefficient (%) of the study area varied from 32% to 68% which means that there was 68% plant species similarity and 32% difference coefficient between exclosure and adjacent free grazing area, respectively (Table 5). The higher species similarity indices (68%) could be due to environmental, ecological, whether condition homogeneity and uniformity which results in favourable plant species growth. On the other hand, the moderate species difference coefficient (32%) might be due to well management and protection of exclosure area and human induced disturbance in open grazing land. This study result was in agreement with the finding of

![Figure 5](https://example.com/fig5.jpg) **Figure 5.** The overview of physical difference between treated exclosure (Figure 5A) & the untreated adjacent open grazing land (Figure 5B) in the study area: Source: field observation and Photographs by the researcher (October, 2021).

![Figure 6](https://example.com/fig6.jpg) **Figure 6.** The linear relationship of woody species diversity with exclosure (a) and adjacent open grazing land (b). Source: woody species data computation result (2021).

### Table 4. Comparison of species diversity indices ($H'$) and evenness species ($E$) between exclosure and adjacent open grazing land

| Diversity indices | Compared land uses | Origin of species | Shannon's diversity index ($H'$) | Species evenness ($E$) | Species richness ($S$) |
|-------------------|--------------------|-------------------|-------------------------------|-----------------------|------------------------|
|                   | Area exclosure     | All               | 2.591 **                     | 0.867 ns              | 34                     |
|                   |                    | Native            | 3.42                         | 2.39                  | 27                     |
|                   |                    | Exotic            | 0.03                         | 0.95                  | 7                      |
|                   | Open grazing land  | All               | 0.889 **                     | 0.715 ns              | 19                     |
|                   |                    | Native            | 2.01                         | 1.60                  | 18                     |
|                   |                    | Exotic            | 0.01                         | 0.000                 | 1                      |

Source: Own species data survey computation result (2021). ** stand for significant at 5%; ns (not significant at 5%).
Table 5. Species composition similarity between exclosure and open grazing land using Sorensen’s species similarity index (%)

| Number of plant species presence/absence in each land use | Frequency |
|----------------------------------------------------------|-----------|
| Existed species in area exclosure but not existed in open grazing | 16        |
| Existed species in open grazing but not existed in area exclosure | 1         |
| Existed species common to both area exclosure & open grazing | 18        |
| Similarity index (%) | Difference coefficient index |
| 0.68 | 0.32       |

Source: Own vegetation data survey computed result (2021).

Figure 7. Focus group discussion under tree shadow (Picture 7A) and key informant interview in interviewee’s private house compound (Picture 7B). Source: interview and group discussion result. Photograph by the researcher (April, 2021).

(Melkamu and Abdella, 2019) who reported that human induced disturbance, selection tree cutting for fire wood and expansion of farming land might be caused to have a difference of plant species between exclosure and open grazing area. However, the result of this study was in contradicting with the findings of (Sinore and Dobrech et al. 2021) who forwarded that both exclosure and open grazing land were showed active regeneration due to similar natural seed germination.

3.5. Types of environmental conservation programs, community participation and local benefit of maintaining exclosure

According to the key informants, focus group discussion and office experts report, there are two types of soil and exclosure conservation programs, namely, Safety Net and free service of community campaign on conservation programs.

The first program was household participation under Safety Net program. An average of 1200 people participate every month per year and the land conservation program has continued for 6 months during the dry season (December-April) and all participants of the program have a monthly payment in cash budgeted by the Ethiopian government and supported by NGOs. According to the key informant, they have high interest to participate in Safety Net program willingly than the free service campaign due to its availability of payment.

The second program was a free service of community campaign on SWC practices. In this SWC campaign, the local communities have participated based on the order of local leaders, Natural resources management office experts and Development Agents (DAs) without their willing and incentives. In this SWC campaign, the local communities have participated based on the order of local leaders, Natural resources management office experts and Development Agents (DA’s) without their willing and incentives. According to the respondents and office experts, averages of 1500 people participate every month per year and the program had lasted only for one month work.
term in selected sites of the study district. During the field observation, the author observed that both environmental conservation programs are applied on communal land, degraded hillsides, exclosure area and rarely on individual farm plots.

As reported by the key informants (Figure 7B) and focus group discussion (Figure 7A), the study communities have benefited from exotic plant species found in exclosure area by selling fire wood and cut and carry grassess. Similarly, of the total 40 key informants and focus group discussion participants, 12(30%), 9(22.5%), 7(17.5%), 6(15%), 3(7.5%), 2(5%) and 1(2.5%) responded that the major benefits of exclosure are fire wood collection, source of income, animal fodder, medicinal value, bee harvesting, erosion control and soil fertility, respectively. The key informants also added that the medicinal plant leaves collected from the exclosure are mainly used to treat Malaria, cough, fever, headache, diarrhea and intestinal parasites by the guides of elders. This implies that community of the study area have used the medicinal plants without scientific measurement and dose which might negatively affect their health. However, the household head informants underlined that animal grazing and cutting wet trees inside the exclosure is totally forbidden. The present result is supported by Mekuria (2011) who reported that treated exclosure plant species are used for multiple purposes such as source of income, fire wood, land restoration, construction materials and soil fertility in Tigray region, Ethiopia.

3.6. The overall implications for woody species diversity conservation practices
Increasing plant species cover in and around the area in which communities live through locally sound exclosure practices have expected to enhance plant species quality and can contribute to assist in conserving biodiversity within the enclosure itself (Molla & Kewessa, 2015; Senbeta et al., 2014). Thus, land use management has to be supported by environmental education, community-based monitoring and other forms of public management required for conservation planning and implementation with cooperation of multiple stakeholders. Providing legislative institutions that strengthen conservation and management of exclosure and vegetation by governmental institutions and other local-based rules could enhance conservation strategy of plant species diversity (Srinivasan, 2014; Smith et al., 2016). Therefore, the policies should aim to strengthen, not replace, national issues and local forms of woody species protection either by establishing exclosures or using other forms of conservation approaches.

4. Conclusion
From the present study, it was concluded that exclosure area had higher woody species diversity, composition, abundance and height of trees than adjacent open grazing land. This reveals that highly degraded land scapes in the study area can be restored and regenerated in a short period of years if well managed. It is also concluded that enclosure measure is one of the best strategy and easy mechanism for restoration of previously degraded lands. Population structure of the exclosure show more or less inverted J-shape which indicated that there was good recovery of plant species. The linear regression pattern showed that woody species diversity is increasing and positively associated with adjacent open grazing land than enclosure. From management point of view and effective management practice, it is strongly recommended that restriction on cutting trees and leaves for fire wood and medicinal value purposes should be considered. Finally, the authors recommended that policy makers planners, experts, stakeholders, NGOs, individuals household farmers and other concerned bodies should give priority attention to expand more exclosure areas in accordance with local conditions, culture and interest of the local communities.

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Author details
Mengistu Meresa1
E-mail: mengistu1343@gmail.com
Menfese Tadesse2
Negussie Zeray3
1 Department of Natural Resources Management, Dilla University, Dilla Town, Ethiopia.
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