Research article

Community composition and phyto-diversity assessment of ganda roba and ganda shabbo sites in Damota natural vegetation, eastern Ethiopia

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**ABSTRACT**

Anthropogenic activities like overexploitation of natural vegetation and plantation of exotic species in degraded areas are commonly occurring in the natural vegetation of Ethiopia. Natural forests conserve plant species and provide a number of ecosystem services to society. This study focuses on the tree species composition and regeneration possibility of Ganda Roba and Ganda Shabbo in Natural Vegetation of Damota, Eastern Ethiopia. The sample of tree species were collected from 40 plots of 20 m × 20 m, while seedlings and saplings were collected from 160 plots of 5 m × 5 m and 320 plots of 1 m × 1 m, respectively from elevations ranging from 2039-3023 m. There were 47 tree species identified, belonging to 32 genera and 21 families, with Fabaceae being the most prominent family with the most species. The mean species richness of adult trees was 39 ± 2.4, for saplings 38 ± 6.5, and for seedlings, it was 34.5 ± 5.3. The average seedling density was 21850 ± 1131.37 individuals ha−1, for saplings 17162.5 ± 972.27 individuals ha−1 and of mature trees 12450 ± 2050.61 individuals ha−1. The mean basal area for trees, saplings, and seedlings were 267.65 ± 30.78 m² ha−1, 68.6 ± 4.12 m² ha−1 and 45.83 ± 2.86 m² ha−1, respectively. Good regeneration was seen in 41% of total species in the Ganda Roba site while in Ganda Shabbo fair regeneration was seen in 44% of species. In Ganda Roba and Ganda Shabbo sites, 7% and 6% of species exhibited no regeneration respectively. Diameter-density distribution curve exhibited a consistent reduction in tree densities with an rise in DBH patterns. The current study provides baseline information for foresters and policymakers to better manage the forest for sustaining tree diversity and regeneration patterns and formulate better strategic conservation plans for the future.

1. Introduction

The integration of diverse abiotic and biotic elements, such as the environment and biotic impacts, keeps forest communities dynamic in nature (Ao et al., 2021; Tripathi et al., 2016). In general, natural forest areas are depleting over the world due to anthropogenic activities, particularly in tropical regions (Ao et al., 2020; Devi et al., 2018; Singh et al., 2015). Aspects of the community including variety, regeneration, and forest stability are being adversely affected by changes in the density of seedlings, saplings, and mature species of trees (Ao et al., 2021; Paul et al., 2019). Under the influence of many environmental elements and soil conditions, species diversity and regeneration is an significant element for tree species survival in a plant community (Huo et al., 2022; Singh et al., 2015). The tree species diversity and regeneration in Ethiopia, particularly in afro-alpine and tropical forest ecosystems, are largely determined by three factors, for example, the recruitment of new seedlings at various altitudes, the capacity of saplings and seedlings to withstand a variability of microclimatic conditions, and their ability to be converted into a mature individual (Ao et al., 2021; Atsba et al., 2019; Ayanaw Abunie and Dalle, 2018). Across Ethiopia's geography, several tree species are suffering from a lack of appropriate regeneration (Balelay and Siraj, 2021; Temesgen and Warkineh, 2020). As a result, an understanding of a forest community's diversity and regeneration status is required for the proper management, restoration, and long-term stability of the community (Dibaba et al., 2020; Gebeyehu et al., 2019).

The Natural Vegetation of Damota, Eastern Ethiopia’s largest vegetation covered with an area of around 1692 ha, is recognized as a naturalist wonderland due to its diverse habitats that support a high floral diversity (Belayneh and Demissew 2011; Sintayehu 2018). All of eastern Ethiopia’s representative forest communities are represented in the area (Belayneh and Demissew, 2011). Ecosystems of acacia-commiphora forest, semiarid scrubland, and evergreen shrub were all found in the area’s

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vegetation. *Acacia robusta, Acokanthera schimperi, Oncoba spinosa, Capra*Paris tomentosa and *Tamarindus indica* are among the woodland species found in Damota, according to more recent sources (Belayneh and Demissew 2011). The Damota, where this study was done, has the eastern parties of the country’s largest and most important vegetative cover.

Recent research conducted in different regions of the world including the Damota primary forests have emphasized the role of excessive human-made disruptions on the structure and functioning of the forests (Surfiyan and Abdala, 2021; Manpoong et al., 2020; Singh et al., 2020; Yinga et al., 2020; Singha et al., 2020; Sintayehu et al., 2020; Abdala and Fentahun, 2017; Fentahun, 2017; Seifu and Beyene, 2014). Major factors reported for the loss of biodiversity and ecosystem functioning in these regions includes habitat degradation, slash & burning agriculture, overexploitation, and the introduction of monoculture species (Wapongnungsang et al., 2021; Lahiri and Dash, 2021; Wapongnungsang et al., 2020; Singh et al., 2020; Manpoong et al., 2020; Grogan et al., 2012). Natural ecosystems are profoundly impacted by both anthropogenic and natural disasters in terms of composition, density, structure, diversity and ecological processes (Antongiovanni et al., 2020; Mori et al., 2018; Ouyang et al., 2021; Tripathi et al., 2008, 2012).

It is necessary to prioritize distinct conservation areas based on useable trees, their death or regeneration, as well as other ecological qualities including quantity, distribution, and dominance (Paul et al., 2019). Through various provisions for life sustenance, tree populations, especially at higher elevations, play a major contribution to the conservation of essential habitats, biogeochemical cycles, and ecosystem functions for human communities (Lahiri and Dash, 2021). In the tropical forests of eastern Ethiopia, insights on the compositional characteristics of vegetation, such as species diversity and population structure and, is widely available (Atsbha et al., 2019; Balemi et al., 2022; Balemlay and Siraj, 2021; Woldearegay et al., 2018; Yahya et al., 2019), but in the Damota Natural Vegetation, complete assessments of forest status, diversity, structure, and regeneration, particularly in tropical forests, are rare (Aynekulu et al., 2016; Chazdon and Guariguata, 2016; Gebeeyehu et al., 2019; Melese and Ayele, 2017; Tadesse et al., 2014). As a result, credible information about these fragile ecosystems’ health is required to comprehend the complication of ecosystem activities and to develop an

![Map of research area.](image-url)
integrated conservation strategy. With all of this in mind, the main objective this was assessing the diversity of species, regeneration status and community structure of the tropical forest of the Damota Natural Vegetation.

2. Materials and methods

2.1. Study site

The study was carried out in East Hararghe’s Damota Natural Vegetation (DNV) between 2020 and 2021, situated between 09° 23’ 30” and 09° 27’ 00” N, and 41° 59’ 00” and 42° 06’ 30” E (Figure 1). The region covers 1692 acres and is representative of the tropical vegetation of eastern Ethiopia. Its heights range from 2039 to 3023 m. a.s.l.

The principal species in the tropical forest of DNV include Acacia seyal, Euphorbia adjurana, Acacia tortilis, Acacia nilotica, Acacia brevispica, Acacia bussei and Acacia eubaica (Table-1). Around 85% of the entire area's topography is composed of flat to gentle slopes, with the remaining 15% made up of intricate valleys and deep gorges. Based on altitude, the study area is classified into two parties viz. Ganda Roba (2039–2500 m) and Ganda Shabbo (2501–3023 m). The mean annual temperature between 200 and 2020 ranged from 10.24 to 24.51 °C while the annual rainfall during the same period ranged from 465.25mm to 1078.38mm.

2.2. Methodology

Field visits were undertaken regularly from January 2020 to July 2021. Using the quadrat approach, phytosociological research for three tree growth stages such as mature trees, seedlings, and saplings were conducted. Stratified random sampling was used to lay the quadrats. For this research, 40 sample plots (i.e., 20 plots at each site of size 20 m × 20 m for trees, 160 quadrats (i.e., 80 quadrats at each site of size 5 m × 5 m for saplings, and 320 quadrats of size 1 m × 1 m for seedlings) were laid out on the forest floor (i.e., in 40 tree plots, 8 = 320 quadrats nested within each tree plot). The best sample size was determined by finding a point where adding more quadrats did not result in a substantial rise in the number of new species. Individual tree species with circumferences greater than 30 cm at breast height (DBH, 1.37 m above ground) were regarded as mature and assessed species by species. Individuals with a DBH of less than 10 cm were classified as seedlings. While those with a DBH in the middle of the two classifications were classified as saplings (Malik and Bhatt, 2015). π² was used to compute circumference at breast height (dbh = 1.37 m) (where r denotes the radius). The basal area (m²/ha⁻¹) of a tree species was used to calculate its relative dominance.

2.3. Data analysis

With the use of accessible literature, all of the dried and collected plant specimens were identified and converted to their Scientific nomenclature using published volumes of “Natural Database for Africa (ND) Version 2 (Bultum et al., 2019), Useful Trees and Shrub of Ethiopia (Bekele-Tesemma and Tengnäss, 2007), Flora of Ethiopia and Eritrea volume 6 (Edwards et al., 1997), as well as through consulting several herbaria. The voucher specimen was prepared according to the standard practice (Jain and Rao 1977) and deposited at Haramaya University Herbarium. From pooled quadrat data, the phytosociological parameters of density, frequency, abundance, and total basal area, as well as their values of relative, were determined (Misra, 1968).

By adding relative density (RD), relative frequency (RF), and relative basal area (RBA), the important value index (IVI) was calculated (Misra, 1968). A single species-dominated community was defined as a site/habitat where a species contributed >50% of the total IVI, and a mixed community was defined as a site/habitat where a species <50% of the IVI overall (Lahiri and Dash, 2021). The number of species per unit area was used to calculate species richness (Lahiri and Dash, 2021; Whittaker, 1972). The ratio of abundance to frequency determines the pattern of distribution. This ratio shows if a distribution (0.025), (0.025–0.05), and (0.05–0.05) is regular, random, and contagious respectively (Odum, 1971). The population size of seedlings and saplings were used to determine the species’ regeneration status (Khaine et al., 2018; Maua et al., 2020; Paul et al., 2019; Pradhan et al., 2019). When a particular species is in the area in mature stage saplings < saplings < seedlings, its regeneration is good; When a species is in the area in mature stage saplings < saplings < seedlings, it has fair regeneration; and Poor regeneration occurs when a species is only available as saplings instead of seedlings (Goncalves et al., 2018; Negi et al., 2018; Sharma et al., 2018; Tiwari et al., 2018). A species is considered non-regenerating if it only exists in its mature stage. If a species only has seedlings or saplings instead of adults, it is considered new.

The diversity (H) was determined by using Shannon-Wiener information index (Shannon-Wiener, 1963) as (equation 1):

\[
H = \sum_{i=1}^{S} pi \ln pi
\]

where, \( H \) was the Shannon-Wiener diversity index and \( pi \) was the species richness that forest type.

Simpson’s diversity index (Simpson, 1949) was calculated as (equation 2):

\[
D = 1 - Cd
\]

where, \( D = \) Simpson’s diversity and \( Cd = \) Simpson’s concentration of dominance = \((\sum ni/n)^2\)
Species evenness was calculated using the Shannon evenness index (Shannon and Wiener, 1963) (equation 3):

$$J = H_0 \cdot s$$ (3)

where $H_0$ is the Shannon–Wiener diversity index and $s$ is the species number (Pielou, 1966). The Shannon evenness index goes from 0 (when just) to 1 when one species is dominant and when all species are equally dominant respectively (Gatti et al., 2020; Rawat et al., 2020).

Beta diversity was calculated using the formula (Whittaker, 1972) which indicated as (equation 4):

$$\beta \text{diversity} = \frac{(S_1 - c)}{(S_2 - c)}$$ (4)

where $S_1$ is the overall species number in site 1 and $S_2$ overall species number in site 2, $c$ is the overall species number found in both $S_1$ and $S_2$.

3. Result and discussion

3.1. Species diversity and richness

Two sampling sites resulted in a total of 47 tree species found to 21 families and 32 genera (Table 3). Across the study site, 42 plant species

| Species name | Ganda Roba | Ganda Shabbo |
|--------------|------------|--------------|
| Acacia seyal | 4.68       | 6.36         |
| Acacia brevica | 2.34     | 9.77         |
| Acacia bausii | 2.34       | 2.73         |
| Acacia ethaica | 7.55      | 3.41         |
| Acacia negrii | 5.22       | 3.86         |
| Acacia nilotica | 5.94      | 5.00         |
| Acacia tortilis | 7.73      | 4.32         |
| Acylpyra fruticosa | 6.12 | 6.59         |
| Aloc spreti | 1.44       | 3.18         |
| Balanites glabra | -         | 3.64         |
| Barbeya oleoides | -        | 0.45         |
| Barbeya discolor | 1.62      | 0.91         |
| Bridelia microtia | 0.54      | 0.45         |
| Cadia purpurea | 3.60       | 2.27         |
| Dedinea angustifolia | 3.06   | 1.59         |
| Drecia rubicundia | 5.76      | 10.97        |
| Euphorbia adianthum | 1.62    | 1.59         |
| Euphorbia candelabrum | 0.54   | 1.14         |
| Euphorbia polyacantha | 0.90    | 7.18         |
| Ficus vasta | 1.62       | 4.32         |
| Grewia erythraea | 3.96      | 2.73         |
| Grewia ferruginea | 0.36      | -            |
| Grewia schweinfurthii | 3.42  | 11.14        |
| Grewia tenax | 1.62       | 4.88         |
| Grewia velutina | -          | 0.23         |
| Grewia vitosa | 0.54       | 0.52         |
| Jasminum abysinicum | 0.18      | 0.23         |
| Jasminum grandiflorum | 0.18   | -            |
| Jasminum spinosum | 0.36      | 0.45         |
| Lantana camara | 11.15      | 3.86         |
| Olea europaea | 0.18       | -            |
| Opuntia ficus-indica | 3.42     | 2.05         |
| Opuntia stricta | 1.98       | 1.14         |
| Pitstophorum abysinicum | 1.08    | 0.91         |
| Rhoicissus tridentata | 0.36   | 0.68         |
| Rhus glutinosus | 1.26       | 0.68         |
| Rhus natalensis | 1.26       | 3.86         |
| Rhus napolii | 0.36       | 1.25         |
| Rhus vulgaris | 0.54       | 4.73         |
| Rumex nervosus | -          | 0.68         |
| Salvadora persica | 1.08      | 3.64         |
| Sanseveria ehrenbergii | 0.54    | 2.58         |
| Solanum nigrum | 0.72       | 0.45         |
| Withania somnifera | -         | -            |
| Ziziphus mauritiana | 0.18     | 1.12         |
| Ziziphus spinos-christi | 0.54    | 0.48         |
found to 17 families were recorded in the Ganda Roba site, which lies in the altitudinal range between 2039–2500 a.m.s.l. As per the life form distributions, climbers and trees & shrubs were 14.29 %, 42.85% and 42.86 %, respectively at the Ganda Roba site. while, 36 species plant belonging to 19 families were recorded in the Ganda Shabbo site in the altitudinal range between 2501–3032 a.m.s.l. As per the life form distributions, climbers and trees & shrubs were 8.33%, 44.44 %, and 47.22 %, respectively at the Ganda Shabbo site. Fabaceae was the dominant family, which had 9 species. Table 2 shows the combined phytosociological features and diversity indices of the forest stands examined (see Table 1).

An study of phytosociological characteristics for each site, including basal area, density, and important value index for each growth form, including trees, saplings, and seedlings (Table 2) revealed that tree species richness ranged from 36–42 (39 ± 2.4), saplings 34–42 (38 ± 6.5), and seedlings 32–37 (34.5 ± 5.3). Total tree density was lowest, ranging from 1100 to 1390 ha⁻¹ (1245 ± 205.06), sapling density was moderate, ranging from 1647.5 to 1785 ha⁻¹ (1716.25 ± 97.22), and seedling density was highest, ranging from 2105 to 2265 ha⁻¹ (2185 ± 113.19).

The Ganda Roba location had the highest tree basal area maximum (89.42 m² ha⁻¹) whereas the Ganda Shabbo site had the lowest (45.88 m² ha⁻¹). Trees, saplings, and seedlings had average basal areas of 67.65 ± 30.78 m² ha⁻¹, 46.9 ± 6.21 m² ha⁻¹, and 25.73 ± 3.47 m² ha⁻¹, respectively. The values found in this study are similar to those obtained in previous Ethiopian investigations of similar environments.

Yirga et al. (2019) reported seedling, sapling and tree densities of 805.7, 4, 757.2 and 664.4 individuals ha⁻¹, respectively in Wof-Washa forest dominated by the Juniperus procera community in the highlands of Ethiopia. Atsba et al. (2019) reported density values of trees, saplings, and seedlings 1838, 2334.29, and 3114.29 individuals ha⁻¹ from Gra-Kahsu natural vegetation, of southern Tigray of Ethiopia. Smaller values reported by other workers showed that the forests are suffering from the high sapling mortality rate in the forest of sub tropics which might as a result of the heavy canopy cover.

The total basal area ranged from 89.42 m² ha⁻¹ in Ganda Roba to 45.88 m² ha⁻¹ in Ganda Shabbo. Ganda Roba values are greater than the same research conducted in Kenech Forest, Southwest Ethiopia, with a basal area of 56.8 m² ha⁻¹ as reported by (Balemlay and Siraj, 2021); 79.3 ± 4.6 m² ha⁻¹ as reported by (Temesgen and Warkineh, 2020). The higher value of the research site is a result of the significant floral diversity there, notably the broad-leaved plants in eastern Ethiopia. This further supports the observation that in the tropical forests of DNV, the middle storey contains the highest variety, whereas the top storey contains the fewest species, due to the high density of low girth class tree species. Aside from altitudinal variation, the tree species basal area is affected by species composition, age structure, and forest successional stage. The concentration of dominance (cd) of tree ranged from 0.40 and 0.41 in Ganda Roba and Ganda Shabbo respectively (Table 2). The first three relatively important species have a significant impact on the community’s dominance concentration across the entire landscape in the current study. This is because species richness and diversity are inversely correlated with dominance concentration.

### 3.2. Pattern of species distribution

The majority of tree species in all growth stages had contiguous distribution patterns, according to the tree stratum’s abundance to frequency ratio (Figure 2). *Acacia tortilis* was the dominant species of tree in the research sites of Ganda Roba and Ganda Shabbo with important value index of 24.15 and 22.77 respectively (Table 2). The other dominant species in Ganda Roba were *Acacia seyal* (IVI: 21.67) followed by *Acacia ebeica* (IVI: 16.32), *Euphorbia adjurana* (IVI: 13.52), *Acacia bussei* (IVI: 13.42) and in Ganda Shabbo *Acacia brevispica* (IVI: 17.97) followed by *Acacia nilotica* (IVI: 17.85), *Acacia seyal* (IVI: 17.42), *Acacia bussei* (IVI: 16.84). In the saplings stratum, *Euphorbia adjurana* (IVI: 17.77) was the dominant species at Ganda Roba and *Acacia nilotica* (IVI: 17.07) at Ganda Shabbo (Table 4). Similarly, *Acacia bussei* had the most spread out among seedlings (IVI: 18.20) at Ganda Roba followed by *Acacia seyal* (IVI: 16.58), *Acacia tortilis* (IVI: 16.18), *Bridelia micrantha* (IVI: 13.34) (Table 5). *Acacia seyal* was the most dominant (IVI: 23.47) species at Ganda Shabbo followed by *Acacia bussei* (IVI: 17.42), *Acacia ebeica* (IVI: 15.98), *Ficus vasta* (IVI: 14.46), *Acacia nilotica* (IVI: 12.43).

Tree species’ Shannon-Wiener diversity indices (H') ranged from 2.93 at Ganda Roba to 3.26 at Ganda Roba, for sapling H runs from 3.45 at Ganda Shabbo to 3.60 at Ganda Roba and for seedlings, it ranged from 3.35 at Ganda Shabbo to 3.58 at Ganda Roba. Lower diversity indices imply that the tropical forest of DNV is homogeneous. Different species of *Acacia tortilis* and *Acacia brevispica* predominate. Additionally, it suggests that species might not cohabit in habitats that overlap, which would reduce the stability of the forest (Madalcho et al., 2022). These H' values are higher than those from the southern Tigray region of Ethiopia’s Gra-Kahsu natural vegetation (Atsba et al., 2019), this may result from variations in the altitudinal gradient, vegetation composition, or habitat appropriateness. In the Wof-Washa highlands of Ethiopia, H value for the tree was observed at 4.02 (Yirga et al. 2019) which were more than the value in the current study. The presence of homogeneous forests in the eastern part of Ethiopia as opposed to the highland region of Ethiopia may account for the study’s lower value. As compared to the Natural forest at Belete in western Southwest Ethiopia Hα the diversity was 3.79 (Yasin et al., 2018) which was higher value than DNV.

Pielou’s equitability values ranged from 0.75 to 0.78 in the tree layer, 0.77 to 0.79 in the sapling layer, and 0.82 to 0.86 in a seedling layer at Ganda Shabbo and Ganda Roba respectively, which are larger than (0.74) of the tropical forest of Ethiopia’s South Central Highlands (Tolera et al., 2008) and natural Kafta Sheraro National Park Dry Forest woodlands, Tigray Region, Ethiopia with (0.77) value (Temesgen and Warkineh, 2020), for the same functional group; while lower than (0.79 for tree) Munessa natural forest, Southeastern Ethiopia (Ahmedin and Eliasb, 2020). This evenness index’s moderate value can be linked to the research area’s increased species richness.

The amount of species replacement and turnover along gradient in the environment in the investigated area determines the beta diversity of the area. According to the findings, tree beta diversity was 0.59, sapling beta diversity was 0.48, and seedling beta diversity was 0.51. Low differences in beta diversity values across sites suggest that different growth forms respond similarly and that species composition does not differ considerably between forest types (Legendre, 2019; Myers et al., 2013). The species composition of DNV displays a homogeneous community assembly because to their propensity to grow in pure patches or the scarcity of broad-leaved components in the tropical forest throughout the research area.
3.3. Regeneration status

Table 6 displays the regeneration status of each tree species at several study sites. Figure 3 displays the proportion of regeneration status. At Ganda Roba locations, the majority of species had good regeneration, while at Ganda Shabbo sites, the majority of species had fair regeneration status. In the density-diameter distribution, tree densities decreased as DBH classes increased. Maximum number of trees (41%) were recorded in the good regeneration area, followed by 39% of fair regeneration, 12% of poor regeneration, and 7% as not regenerating at Ganda Roba, while at the Ganda Shabbo site the maximum tree individuals (44%) were observed in the fair regeneration stage, followed by 42% of good regeneration, 8% of poor regeneration, and 6% as not regenerating (Figure 3). In the Ganda Roba site most tree individuals (48.74%) were observed in the least DBH class (< 10 cm), followed by 10 – 30 cm (40.64%) and > 30 cm (10.61%), while in the Ganda Shabbo site most tree individuals (46.13%) were observed in the least DBH class (< 10 cm), followed by 10 – 30 cm (43.86%) and > 30 cm (10.00%) (Figure 4). In the Ganda Roba site regeneration is not observed in Berchemia discolor, Cadia purpurea, and Dodonaea.
angustifolia while Rhus vulgaris and Withania somnifera were not regenerating in the Ganda Shabbo site most likely as a result of poor seed viability or an unfavorable habitat. Overall, the tropical forest in DNV has a good regeneration rate in Ganda Roba and a fair regeneration rate in Ganda Shabbo, ranging from 41% to 44%, respectively. The high density of some species that show good and fair regeneration in both the studied sites may be attributed to the optimal environmental condition for the growth of these species (Ali et al., 2019; Kujur et al., 2021; Tiwari et al., 2020).

The impact of numerous environmental factors including topography, species mix, soil characteristics, slope angle, regional climate, and human disruptions, can be attributed to variations in phytosociological attributes in different Damota Natural Vegetation Forests (Birhanu et al., 2021; Kothandaraman et al., 2020). Variations in forest features can be attributed to both locale and landscape-level variations in successional stages, resulting in spatial heterogeneity (Camargo et al., 2020; Liu et al., 2021). In this study, I discovered that the species richness of trees, saplings, and seedlings was highest at the Ganda Roba site, and that tree

Table 5. Phytosociological characteristics of seedling of DNV.

| Species name                  | Ganda Roba | Ganda Shabbo |
|-------------------------------|------------|-------------|
|                               | RD RF RDO | IVI         | RD RF RDO | IVI |
| Acacia seyal                 | 3.97 3.94  | 8.68 16.58  | 4.51 4.91  | 14.05 23.48 |
| Acacia brevica               | 3.86 2.68  | 1.05 7.60   | 4.04 2.65  | 1.15 7.83   |
| Acacia baugae                | 4.19 3.76  | 10.25 18.20 | 4.51 5.67  | 7.24 17.42  |
| Acacia eburnea               | 2.65 2.50  | 2.36 7.52   | 2.97 4.35  | 8.67 15.99  |
| Acacia negra                 | 3.09 3.40  | 1.33 7.82   | 2.49 2.65  | 1.45 6.59   |
| Acacia nilotica              | 3.20 3.76  | 3.21 10.17  | 2.61 3.21  | 6.61 12.43  |
| Acacia senegal               | 2.43 3.22  | 0.59 6.24   | 4.28 4.35  | 1.90 10.52  |
| Acacia tortilis              | 2.54 3.40  | 10.25 16.19 | 2.61 2.27  | 2.76 7.64   |
| Acydraca fruticosus          | 2.65 2.50  | 1.48 6.63   | 2.97 3.40  | 1.72 8.09   |
| Aloe prretie                 | 3.09 3.94  | 0.57 7.60   | 2.85 2.84  | 1.01 6.69   |
| Balanites glabra             | - - -      |             | 3.09 3.40  | 2.84 9.34   |
| Barbeha oloides              | - - -      |             | 2.61 3.40  | 1.36 7.37   |
| Berchemia discolor           | 2.76 3.22  | 1.98 7.96   | 2.85 2.65  | 5.81 11.30  |
| Bridelia micrantha           | 2.54 3.58  | 7.23 13.35  | 3.44 2.46  | 4.03 9.93   |
| Calia purpurea               | 2.21 3.04  | 0.92 6.17   | 2.38 2.08  | 1.90 6.36   |
| Dodonaea angustifolia        | 2.98 4.11  | 0.76 7.85   | 3.21 3.21  | 1.42 7.84   |
| Dregia rubicunda             | 2.43 3.04  | 1.05 6.52   | - - -      |             |
| Euphorbia adjurana           | 2.98 2.50  | 5.31 10.80  | 3.21 2.27  | 1.90 7.38   |
| Euphorbia candelabrum        | - - -      |             | 2.97 3.40  | 1.98 8.35   |
| Euphorbia polyacantha        | - - -      |             | - - -      |             |
| Ficus vasa                   | 3.20 3.58  | 3.69 10.47  | 2.49 2.08  | 9.90 14.47  |
| Grewia erythreae             | 2.43 2.86  | 1.71 7.00   | 2.73 2.27  | 1.26 6.26   |
| Grewia ferruginea            | 2.43 2.33  | 1.64 6.39   | - - -      |             |
| Grewia schweinfurthii        | - - -      |             | 2.61 3.78  | 1.86 8.26   |
| Grewia tenax                 | - - -      |             | - - -      |             |
| Grewia velutina              | - - -      |             | 2.97 3.97  | 1.12 8.06   |
| Grewia villosa               | 2.10 2.15  | 2.36 6.61   | - - -      |             |
| Jasminum abyssinicum         | - - -      |             | - - -      |             |
| Jasminum grandiflorum        | 2.76 3.04  | 0.59 6.39   | - - -      |             |
| Jasminum schimperi           | 1.99 1.43  | 0.41 3.83   | 3.80 3.02  | 0.56 7.39   |
| Lantana camara               | 2.43 1.07  | 1.33 4.83   | 4.39 4.16  | 2.01 10.56  |
| Olea europaea                | 2.87 2.33  | 4.74 9.93   | - - -      |             |
| Opunia ficus-indica          | 2.10 1.97  | 1.71 5.77   | 3.44 3.78  | 2.12 9.34   |
| Opunia stricta               | 3.09 2.68  | 1.74 7.51   | 3.09 3.21  | 2.08 8.38   |
| Pittosporum abyssinicum      | 1.77 1.61  | 1.30 4.68   | 2.85 2.27  | 2.12 7.24   |
| Rhoicosus tridentata         | 1.32 0.89  | 0.51 2.73   | 2.73 2.65  | 1.42 6.80   |
| Rhus glutinosa               | 1.99 2.68  | 4.74 9.41   | - - -      |             |
| Rhus natalensis              | 2.87 2.50  | 0.80 6.18   | 2.97 3.02  | 2.04 8.03   |
| Rhus nuspoli                 | 3.53 3.04  | 2.36 8.93   | - - -      |             |
| Rhus vulgaris                | 3.64 3.04  | 4.20 10.88  | - - -      |             |
| Rumex nervos                 | - - -      |             | 2.73 3.21  | 1.92 7.86   |
| Salvadorea persica           | 1.99 1.43  | 1.98 5.40   | 2.61 1.32  | 1.98 5.91   |
| Saracenia ehrembergii        | 2.54 1.97  | 1.10 5.61   | - - -      |             |
| Solanum nigrum               | 2.43 2.33  | 1.48 6.23   | - - -      |             |
| Withania somnifera           | - - -      |             | - - -      |             |
| Ziziphus mauritana           | 2.32 2.50  | 2.77 7.59   | - - -      |             |
| Ziziphus spina-christi       | 2.65 1.97  | 1.00 5.61   | 2.97 2.08  | 1.83 6.88   |
density, species richness, and basal area decreased with increasing altitude (from Ganda Roba to Ganda Shabbo). Trees, saplings, and seedlings had the greatest basal area at lower altitude (Ganda Roba) and the smallest at higher altitude (Ganda Shabbo).

In the study region, the general regeneration pattern of tree species was good at Ganda Roba and fairly high in Ganda Shabbo. The study sites are also part of one of Eastern Ethiopia’s most diverse tropical forests, which is protected by a network of protected areas. However, due to unlawful encroachments, the inflow of tourism, irresponsible over-exploitation of medicinal plants, and extensive grazing, the area’s rich floristic resources have been significantly degraded both quantitatively and qualitatively in recent decades. During the study, plants have also been seen to be severely impacted by overgrazing and browsing by cattle from nearby communities, with several plant species suffering from low regrowth. In order to ensure the sustainability of the Damota Natural Vegetation and preserve the plant wealth, Haramaya University has already been implementing a number of conservation programs, including controlled grazing, nursery development, a complete ban on the collection of medicinal plants and fuelwood, protection of species-specific habitats, and livestock management in nearby villages. Local communities should also use non-conventional energy sources such as LPG or solar to alleviate the burden on neighboring woods.

4. Conclusion

Abiotic conditions of the study area cope up well with the existing flora that promotes fair regeneration of tree species in the research area which further allows seedling endurance. Nevertheless, five and seven species at the site either did not exhibit regeneration or poor regeneration reflecting that the climatic conditions are harsh for these species to regenerate well because survival of seedlings, germination and sprouts are largely dependent on abiotic factors. The other species, on the other hand, were noted to be regaining their health at the location, and their seedlings and sprouts were able to survive due to their superior ecological amplitude and adaptability to the climatic conditions due to stronger resilience to biotic interferences. Since it is critical to conserve forests and manage them better to ensure the survival of wildlife habitats. This study is important to maintain tree species diversity and regeneration status in the Damota Natural Vegetation. The outcome of the study is important to provide better framework for future researchers with high implications for future conservation initiatives by policymakers.
