**Woody Species Diversity, Structure and Regeneration Status of Gara Duro Natural Forest Oromia Region, Ethiopia**

**Abstract**

This study was conducted at Gara Duro Natural Forest Oromia Region, Ethiopia to **determine Woody Species Diversity, Structure, and Regeneration Status**. The data was collected form a total of 47 plots having 20x20m dimension systematically at every 100m interval along five transect lines. All woody species in these plots were recorded and their Diameter at Breast Height (DBH) was measured with tree caliper at 1.3 m above ground. Data on seedlings and samplings were collected from five subplots of 1m × 1m (1m2) located at the four corners and center of the main plot. All the data obtained were analyzed using descriptive statistics. Forty (40) of the woody were characterized to thirty-eight (38) genera and thirty-one (31) families. The most frequent species were *Maesa lanceolata*, *Rubus apetalus, Croton macrostachyus*,and *Podocarpus falcatus.* The highest importance value index(IVI)were found in *Maytenus addat*, *Maesa. lanceolata*, *Podocarphus falcatus*, *Croton. macrostachyus* and *Pittosporum viridiflorum* while  *Ficus vasta, Brucea antidysenterica, Schefflera abyssinica, Hypericum revolutum* and *Erica arborea* were species with lowest IVI. Based on the evaluation of the diameter class, overall structure of woody species structure showed an inverted J-shaped curve. The population structure and regeneration status of the forest indicated that there have been high forest degradation and severe anthropogenic disturbances in the area and, therefore, conservation of species, ecosystem restoration, and sustainable use of the forest genetic resources are highly recommended. Therefore the forest lands should be reversed and local authorities and all concerned institutions should work together for designing and implementing *in-situ* conservation of the forest giving priority to identified plant species and promoting ecosystem services through forest sustainable management system.

**Key words:** Woody Species Diversity, Population Structure, Regeneration status, Natural Forest

**Introduction**

Ethiopia is considered as one of the top twenty five biodiversity richest countries in the world (WCMC, 1994). It is estimated to around 6000 species of higher plants, of which about 10% endemic plants) (Ensermu and Sebsebe, 2014).A wide ranges of ecological, edaphic factors and climate conditions that account for the huge diversity of its biological resources both in terms of flora and fauna wealth; between 6500 and 7000 higher plant species, out of which about 19 percent are endemic to Ethiopia (Kelbessa *et al*. 1992; Shibru and Martha 1995; IBC 2009; Kebede *et al.* 2012). The vegetation of Ethiopia is complex. There is a variation from region to region; some regions of the countries (Southern and South Western parts of the countries) are relatively richer in biodiversity as compared to other parts of the countries. The complexities of vegetation arise from the great variation in altitude employing equally great spatial difference in moisture regime as well as temperature and also depend on rainfall and altitude variation (Zerihun Woldu, 1999).However, wood plant species diversity and Importance Value Index (IVI) were limited and no data was available for Gara Duro Mountain Ecosystem. Therefore, the aim study was conducted to determined data on woody species diversity, structure, and regeneration status of some species. Scientific data on wood plant species, vegetation structure and regeneration status of a given forest ecosystem are highly needed for determining the current status and future trend of a given forest and its ecosystem services including biodiversity conservation. Furthermore, such data are critical for designing and implementing appropriate forest conservation and sustainable management methods. Therefore, the aim of this study was to contribute to filling gap in scientific data on diversity and structure of woody plants, in Gara Duro natural forest.

**Material and Methods**

**Site description**

The study was conducted in Gara Duro natural forest, located in Nagelle Arsi Disrcit, West Arsi zone, Oromia regional state. It is one of the most threatened remnant forest in Ethiopia as a result of unregulated Agricultural expansion and settlements. Gara Duro Forest is sources of many important rivers such as Huluka and Dhadhaba that flow into Central Rift Valley Lakes. It is approximately located between 38°4ʹ and 8°32ʹ E and 7°3ʹ and 2°20ʹ N and extends over an altitudinal range from 2300–2900 m with the total area of 449.6 ha And soil type covers about 52.2% of Negele Arsi, while Nitosols cover the remaining 47.8% Oromia Regional State government (ORS, 2012). The soils parent materials consist of volcanic lavas, ashes and pumices from quaternary volcanic activities in the Rift Valley. Soil type of the study area was classified as Mollic Andosol (Tolera *et al*. 2008). The rainfall in the area has bimodal distribution. The mean annual rainfall is 1200mm and the annual mean temperature is about 200C (Tolera *et al*. 2008)). The total area of the District was about 1396 km2 of which 52% is arable, 30% water bodies, 5% forest and 13% grazing. Nagelle Arsi is characterized by crop-livestock based farming systems (Lemenih *et al*. 2004).



Figure 1 Map of the study Area Gara Duro natural forest Area

**Sampling Design**

Systematic sampling design was used to collect wood species data from the study site. Appropriate transect lines and sampling quadrats were made based on the total area of the study site for wood species data collection. Five transect lines were laid following the altitudinal gradient and quadrats of size 20m × 20m (400m2)was used (Austin 2005; Senbeta and Denich 2006; Gurmessa *et al*. 2013).) Were established systematically at every 100m interval. The transect lines were arranged systematically to each other throughout entire natural forest and a total of forty seven Sample plot size of 20 m x 20 m (400m2) To collect data on seedlings and saplings, five sub quadrats of 1m × 1m (1m2 ) size located at the four corners and center of the main quadrats were used. In each quadrat, heights of trees and shrubs with DBH > 2.5 cm were measured using clinometer and their diameter at breast height (DBH) was measured using diameter tape. For trees and shrubs that were branched around the stamp height, the circumference was measured separately and averaged c= πd.

**Wood species Data Collection**

All the woody plant species encountered in each sample quadrats were recorded and coded with vernacular and local names whenever possible. Woody species a total of forty seven sample plots was used for natural forest uses. To collect data on seedlings less than 2.5cm and saplings less than 1m, five sub quadrats of 1 m × 1m (1m2) size were located at the four corners and center of the main quadrat. The regeneration status of the woody plant species was assessed using data from the sub-quadrats that were established. In general, a total of five transects, 47 quadrates and 235 sub-quadrates were used to collect the inventory data from the Gara Duro natural vegetation. The plant species occurring outside sample quadrats but inside the forest were recorded only as present but not used in the subsequent vegetation data analysis. These species and the rest plant specimens were collected, pressed, dried, and brought to the National Herbarium of Ethiopia (ETH), Department of Plant Biology and Biodiversity Management.

**Diameter at Breast Height (DBH).**

DBH measurement was taken at about 1.3 m from the ground using a diameter tape. Trees and shrubs with DBH > 2.5 cm were measured and recorded for diameter at breast height (DBH). Trees/shrubs with multiple stems or fork below 1.3 m height were also treated as a single individual (Kent and Coker, 1992). For trees and shrubs that are branched around the breast height, the circumference was measured separately and averaged. Diameter class frequency distribution of selected tree species in the area was classified into ten classes: (1) 2.5-5cm, (2) 5.1-10cm, (3) 10.1-15cm, (4) 15.1-20cm, (5) 20.1-25cm, (6) 25.1-30cm, (7) 30.1-35cm, (8) 35.1-40cm, (9) 40.1-45cm, (10) >45cm.

**Height.**

Height is a straightforward parameter used for direct measurement purposes. The total tree heights (to the top of the crown) were measured using Hypsometer. Height class frequency distribution of trees in the area was classified into in to seven groups as: **A** (≤ 5 m); **B** (5.1–10 m); **C** (10.1-15m); **D** (15.1-20m); **E** (20.1-25m); **F** (25.1-30m); **G** (>30.1m).

**Data Analysis**

The diameter at breast height (DBH), basal area, tree density, height, frequency regeneration status, and important value index were used for description of vegetation structure (Kent and Coker, 1992).

**Analysis of Population Structure**

$$Frequency \left(\%\right)=\frac{Number of quadrants in which the species occures}{Total Number of quadrants studied}\*100…………eq \left(1\right)$$

$$Relative frequency \left(\%\right)= \frac{Number of occurance of the species}{Number of occurance of all species}\*100………..……eq \left(2\right)$$

$$Relative dominance \left(\%\right)= \frac{Total basal area of the species}{Total basal area of all species}\*100………………..…..eq (3)$$

$$Relative abundance \left(\%\right)= \frac{Total number of individual species in all quadrants }{Total number of quadrants in which the species occured}\*100….eq(4)$$

$$Basal Area \left(BA\right)= \frac{πD^{2}}{4}………….. eq \left(5\right)$$

Where: BA= Basal Area (m2), DBH= Diameter at Breast Height (cm), $π$=3.14

Importance Value Index (IVI) = Relative abundance + Relative dominance + Relative frequency (Curtis 1959, Kent and Coker 1992).

**Results**

**Species diversity and Structure**

**Woody species diversity**

From the study Gara Duro a total of 40 plant specimens were collected; belonging to 38 genera and 31 families (See Annex 1). The most frequent species in the forest were *Maesa* (Myrsinaceae), *Rubus* (Rosaceae)*,* *Croton (*Euphorbiaceae), and *Podocarphus* (Podocarphaceae) respectively. On the other hand the families of these genera are also the most frequent and diverse in the inventoried woody species. From each respective genera, *Maesa lanceolata*, *Croton macrostachyus* and *Podocarphus falcatus; Maytenus addat,* and *Trichilia emetica* were found to be good diverse woody plant species. The distribution of the plant species in terms of the growth forms or habits was resulted as Trees,17 in number of species (43.6 %), Shrubs, 20 in number of species (51.2 %) and climber or Lianas, 2 in number of species which accounts to 5.1 % whole growth habits of woody species composition.

**Floristic richness by Aspect**

The result of the study shows that the species distribution varies with aspects. About 2% of the species were recorded from the northeast, 29.4 % from West, 20.6 % from South, 17.6 % from Southwest, 14.7 % from North, 11.8 % from Southeast, and 5.9 % on East direction of the woodland topographic feature (Figure 2). In terms of the individual species, maximum number of woody plant species was inventoried on the west direction followed by south and southwest aspects respectively.

**Figure 2** Number of species recorded as per the topographic aspects

**Floristic richness by slope gradients**

The species occurrence analysis by slope gradient revealed that 91.2 % of the total woody plant species inventoried was recorded from slope gradient class **B;** 5.9 % from class **A;** 2.9 % from **C** and finally no species was recorded from slope gradient class **D** (Figure 3). As illustrated in Figure 3, the number of woody plant species composition or distribution was higher at slope gradient class **B** (3-10)

As illustrated in Figure 3, the relationship between the species richness and slope gradient was non-linear and this is explained by 42% (R2 = 0.421). It is a bell-shaped type of distribution.

**Figure 3** Woody plant species distribution by slope gradient classes

**Structure**

**Size class Distribution**

The measurements of woody plant species that include maximum DBH/DSH, mean DBH/DSH, maximum total height, mean total height and number of stems per species were presented in (Annex 2). The maximum height attained in the forest was 35m while the maximum DBH/DSH was 160cm represented by the *Maytenus addat* tree species. This tree species had mean height of 18.33m and mean DBH/DSH of 59.2 cm.

The second maximum height attained in the forest was 32m while the maximum DBH/DSH was 140cm represented by the *Pittosporum viridiflorum* tree species. Interms of mean height and mean DBH/BSH this species was greater than *Maytenus addat*, having mean height (21.63m) and mean DBH/DSH (72.13 cm).

As described in Annex 2, the maximum numbers of stems sampled and measured were for those tree species that were the most diverse or frequently appearing in the studied woodland. On the other hand, the least size of DSH/DBH and total height recorded was 2.5 cm and 2.5 m, respectively.

**Species frequency**

The result of the study showed that the variation of the species frequency ranged between 2.13 – 80.8 %. This implies that there was some heterogeneity in species distribution in the Garaduro forest. Among these, *Maesa lanceolata* (80.8 %), *Croton macrostachyus* (76.6 %), *Podocarpus falcatus* (72.3%) and *Maytenus addat* (63.8 %) were the most frequently appearing or the most widely distributed woody plant species. On the other hand, *Hagenea abyssinica, Schefflera abyssinica, Dovyalis abyssinica, Erica arborea, Buddleja polystachaya, Manilkara butugi, Ekebergia capensis, Olea capensis,* *Hypericum revolutum,* and *Ficus vasta* had lowest frequency (Annex 3). Hence, there was a high variation in species distribution between the above-mentioned groups of species that showed the highest and the lowest frequency. Nonetheless, the majority of the species fall between the frequency range of 4.26 –29.8 %. In other words, when the distribution of species were interpreted in terms of frequency classes, as indicated in Annex 3, it was only one species, *Maesa lanceolata* (13.8 %),which belonged to the A frequency class (80-100 %). Three species *Croton macrostachyus*, *Podocarpus falcatus* and *Maytenus addat* about 36.5% were in a frequency class B (61-80 %). Further, as illustrated in Figure 8, about 6.93 % one species was included under frequency class C (41-60 %); 18.24 % under frequency class D (21-40 %) while 24.38 % of the species were categorized under frequency class E (1-21 %). Therefore, the falling of highest percentage (or number of species) under low value frequency class implies as the distribution of the species is in the woody species is not generally high.

**Figure 4** The number of species by frequency class.

**Species density**

The species density in the forest ranges between 0.43–141.28 per ha. (See Annex 4). The variation of the relative density of the species was also between 0.07 – 22.36 %. The least species density was for *Schefflera abyssinica, Olea capensis, Manilkara butugi, Hypericum revolutum* and *Hagenea abyssinica* while the highest species density (> 100 per ha) was for *Maesa lanceolata* (141.28) and *Podocarpus falcatus* (115.32). This result Pointed out that there was a significant variation among the individual tree/shrub species in density per ha. In the studied forest, the total species density per ha was 627.68. To summarize, the species density was organized by density classes as shown in Table 1. Here, the majority of the species (44.1 %) was belonged to density class D.

**Table 1**. Species density class and the distribution of species

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species density class** | **Total density** | **Relative density** | **Number of species** | **Proportion****(%)** |
| A (>100) | 256.6 | 40.9 | 2 | 5.9 |
| B (50.1–100) | 95.74 | 15.3 | 1 | 2.9 |
| C (20.1–50) | 199.57 | 31.8 | 6 | 17.6 |
| D (1–20) | 69.79 | 11.1 | 15 | 44.1 |
| E (<1) | 5.98 | 1.0 | 10 | 29.4 |
| **Total** | **627.68** | **100** | **34** | **100** |

The species densities per ha with the diameter size greater than 10 cm DSH/DBH and greater than 20 cm DSH/DBH were 325.6 and 197.5, respectively and their ratio was 38.1

**Size class distribution**

**DBH distribution**

For ease of the comparison and interpretation, the diameter class was formed in to eight groups as: **A** (2.6–7.5 cm); **B** (7.6–12.5 cm); **C (**12.6–17.5 cm); **D** (17.6–22.5 cm); **E** (22.6–27.5); **F** (27.6–32.5 cm); **G** (32.6–37.5 cm), **H** (37.5–42.5 cm) and **I** (>42.5cm). The species density distribution by diameter class was tabled in Annex 5. The result of the analysis of the diameter class data indicated that about 35.3 % (N=20) of the tree/shrub species are those species which have fallen in diameter class **A**; 14.0 %(N=16) in diameter class **B**; 10.9 %(N=15) in diameter class **C**; 10.4 %(N=12) in diameter **D**; 7.9 %(N=12) in diameter class **E**; 8.7 %(N=14) in diameter class **F**; 4.5 %(N=9) in diameter class **G**; **0.9**%(N5) in diameter class **H** and **7.5**%(N14) in diameter class **I** respectively (See Figure 5)**.**

**Figure 5**. Number and total species density by diameter class

**Height distribution**

In determining the height distribution , the height class was formed in to seven groups as: **A** (≤ 5 m); **B** (5.1–10 m); **C** (10.1-15m); **D** (15.1-20m); **E** (20.1-25m); **F** (25.1-30m); **G** (>30.1m). The species density distribution by height class was listed in Annex 6. The result of the analysis of the height profile data indicated that about75.2% (N=15) of the tree/shrub species are those species which have fallen in height class **A**; 24.8 % (N=7) in height class **B** and no species recorded in **C** diameter class (See Figure 6)**.**

**Figure 6** Number and total species density by height class

**Basal Area and Dominance of woody plant species**

The total basal area for the inventoried woodland was 7.1 m2 per ha. As listed in (Annex 7), the biggest basal area recorded was for *Pittosporum viridiflorum* (2.52 m2 ha-1) while the largest dominance and relative dominance was for *Pittosporum viridiflorum* (17.12 and 31.51 % respectively). The top five dominant woody plant specieswere *Pittosporum viridiflorum, Millettia ferruginea,* *Olea capensis, Hagenea abyssinica* and *Maytenus addat,* respectively within the range of 2.52 – 0.35.Here the number of stems of a species plays a crucial role for a certain species is dominant or not besides the mean basal area of the species.The DBH of the majority of the species was in the lowest diameter class (2.5-5.5 cm) this implies that the basal area of the lower diameter class range between 0.0015 – 0.0064.

Important value Index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989).The important value index of the species indicates how dominant is the species in a certain area and hence helps to compare ecological importance of the species in vegetation’s (Curtis and McIntosh, 1951). This reveals that in this forest the species relative frequency, density and dominance differ accordingly. The IVI of woody species in Gara Duro Forest varied between 0.44–42.63 as shown in As it was listed in Table 3, the majority of the species (*ca* 50 %) are appearing in the IVI class **A** and **A** contributing around 5.43 % to the total IVI and there is no species record in IVI class **D**. The next dominant species are categorized to the IVI class **B** consisting about 15.58 % from the whole IVI. *Maytenus addat Maesa lanceolate* only by its own contributed 28.33 % to the total IVI, and hence it is the most frequent and dominant species in the forest. On the contrary, since *Erica arborea, Hypericum revolutum, Schefflera abyssinica, Brucea antidysenterica* and *Ficus vasta* possess the lowest IVI, they do not frequently exist and are the most minor or rare species in the forest. In principle, when a certain species receives the lowest IVI, it entails as it demands high priority for endangered species. As presented in Table 3 IVI was lowest for *Erica arborea* and *Hypericum revolutum* and highest for *Maytenus addat*.

Table 2 summarizes the IVI class and proportion of woody species in the study area.

|  |  |  |  |
| --- | --- | --- | --- |
| Species IVI class | Number of species | Total IVI | Proportion (%) |
| A (<2) | 17 | 16.29 | 5.43 |
| B (2.1– 10) | 9 | 46.76 | 15.58 |
| C (10.1–20) | 3 | 42.04 | 14.01 |
| D (20.1–30) | 0 | 0 | 0 |
| E (>30.1) | 5 | 194.92 | 64.97 |
| Total | 34 | 300 | 100 |

Table 3 Importance Value Index of woody species in Gara Duro Forest, Oromia, Ethiopia

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  Species Scientific name | RD | RDO | RF | IVI | Percent | Rank |
| No |
|  | *Bersama abyssinica* | 0.20 | 0.01 | 0.73 | 0.95 | 0.32 | 24 |
|  | *Brucea antidysenterica* | 0.40 | 0.01 | 1.46 | 1.87 | 0.62 | 18 |
|  | *Brucea antidysenterica* | 0.13 | 0.04 | 0.36 | 0.54 | 0.18 | 30 |
|  | *Celtis Africana* | 0.27 | 0.15 | 1.09 | 1.52 | 0.51 | 20 |
|  | *Citrus aurantiifolia* | 7.54 | 0.13 | 2.19 | 9.86 | 3.29 | 10 |
|  | *Croton macrostachyus*  | 15.15 | 7.64 | 13.14 | 35.93 | 11.98 | 4 |
|  | *Discopodium penninervum*  | 2.42 | 0.09 | 1.46 | 3.97 | 1.32 | 12 |
|  | *Dovialis abyssinica* | 0.34 | 0.00 | 0.36 | 0.70 | 0.23 | 27 |
|  | *Ekebergia capensis* | 0.13 | 0.39 | 0.36 | 0.89 | 0.30 | 26 |
|  | *Erica arborea*  | 0.07 | 0.00 | 0.36 | 0.44 | 0.15 | 33 |
|  | *Ficus vasta* | 0.13 | 0.13 | 0.36 | 0.63 | 0.21 | 29 |
|  | *Hagenea abyssinica* | 0.07 | 0.48 | 0.36 | 0.91 | 0.30 | 25 |
|  | *Hypericum revolutum*  | 0.07 | 0.04 | 0.36 | 0.47 | 0.16 | 32 |
|  | *Kolasaa Undefined*  | 0.27 | 0.02 | 0.73 | 1.01 | 0.34 | 23 |
|  | *Trichilia emetica*  | 4.31 | 0.61 | 6.93 | 11.86 | 3.95 | 7 |
|  | *Galiniera saxifrage*  | 0.61 | 0.16 | 1.46 | 2.23 | 0.74 | 16 |
|  | *Maesa lanceolata* | 22.36 | 6.15 | 13.87 | 42.37 | 14.12 | 2 |
|  | *Manilkara butugi*   | 0.07 | 0.22 | 0.36 | 0.65 | 0.22 | 28 |
|  | *Maytenus addat* | 6.26 | 25.42 | 10.95 | 42.63 | 14.21 | 1 |
|  | *Millettia ferruginea* | 0.94 | 13.75 | 4.38 | 19.07 | 6.36 | 6 |
|  | *Myrsine melanophloeos* | 4.38 | 1.52 | 4.01 | 9.92 | 3.31 | 9 |
|  | *Nuxia congesta* | 0.47 | 0.14 | 1.46 | 2.07 | 0.69 | 17 |
|  | *Olea capensis*  | 0.07 | 0.74 | 0.36 | 1.18 | 0.39 | 22 |
|  | *Pittosporum viridiflorum* | 1.08 | 31.51 | 3.28 | 35.87 | 11.96 | 5 |
|  | *Podocarphus falcatus*  | 18.25 | 7.46 | 12.41 | 38.12 | 12.71 | 3 |
|  | *Prunus Africana* | 0.34 | 0.88 | 1.46 | 2.67 | 0.89 | 15 |
|  | *Rytigynia neglecta* | 3.91 | 0.81 | 4.74 | 9.46 | 3.15 | 11 |
|  | *Schefflera abyssinica*  | 0.07 | 0.06 | 0.36 | 0.50 | 0.17 | 31 |
|  | *Sclerocarya birrea* | 1.14 | 0.81 | 1.82 | 3.78 | 1.26 | 13 |
|  | *Teclea nobilis* | 0.54 | 0.05 | 0.73 | 1.32 | 0.44 | 21 |
|  | *Terminalia brownie* | 0.34 | 0.37 | 1.09 | 1.80 | 0.60 | 19 |
|  | *Vernonea amygidelina*  | 5.86 | 0.14 | 5.11 | 11.11 | 3.70 | 8 |
|  | *Vernonea auritifoia*  | 0.13 | 0.04 | 0.73 | 0.91 | 0.30 | 26 |
|  | *Polysciasfulva(Hiern* | 1.68 | 0.02 | 1.09 | 2.80 | 0.93 | 14 |

**Species population structure**

The pattern of diameter size-class distribution has often been used to represent the population Structure of a forest (Khan *et al*., 1987). This is because the pattern of diameter class distribution connotes the general trends of population dynamics and recruitment process of a given species. This was depicted by the evaluation of the diameter class total species density distribution as an inverted J-shape curve (Figure 7), which shows a pattern where a total species density distribution has the highest density in the lower diameter class and a gradual decrease towards the higher classes.

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**Figure 7** Diameter class density distribution of selected tree species

**Regeneration status**

The seedling status woody species was recorded for 24 woody plant species which belong to 24 genera and 22 families. This becomes about 64.1 % when compared to the total matured woody Plant species richness inventoried. Moreover, the total seedlings density per ha was 10622.

In terms of species, *Myrsine melanophloeos, Bersama abyssinica, Vernonea auritifoia* and *Maesa lanceolata* respectively sharethe highest seedlings density in the wood plant species.And while it is the least for *Ekebergia capensis* and *Dovyalis verrucosa* woody plant species.

On the other hand, 19 woody plant species existing at the sapling stage were recoded. This is 48.71% from the total tree/shrub species inventoried. These are grouped to 19 genera and 18 families. Besides, in terms of the individual stems per ha or density, 6436 stems per ha were recorded as samplings. Nevertheless, there are about 14 species which neither appear in the seedling or sampling stages. Their seedlings and samplings, as discussed above, could be related with the forest disturbance besides the environmental catastrophes like the occurrence of recurrent drought in the area. Different species cope up with the soil moisture deficit differently.

**Discussion**

**Woody species Diversity**

A total of 40 woody plants were identified from Gara Duro natural forest which belonged to 38 genera and 31 families. The most frequent species in the forest were *Maesa lanceolata*, *Rubu* *apetaluss,* *Croton macrostachyus*, and *Podocarphus* *falcatus* respectively. The evaluation of selected individual species also revealed two main patterns of population structure These are 1) inverted J-shape curve for *Maesa lanceolate* and *Trichilia emetica*, in similar to the general trend of the diameter class total density distribution, this shows the pattern which has the highest species density distribution in the lower diameter class and a gradual decrease towards the higher classes. The pattern of diameter size-class distribution has often been used to represent the population structure of a forest (Khan et al., 1987). This pattern of DBH classes indicates a good potential of reproduction and recruitment of the forest. Similar results were reported by Ayelew Alemu (2006, Fayera Senbeta 2006), Haile Yineger (2008),Feyera Abdena (2010) Fikadu Gurmessa (2010), Fisah Gudine (2013). 2) bell-shaped curve *Podocarpus falcatus* and *Croton macrostachyus,* which is a type of density distribution in which it is high in the middle diameter classes and lower in the lower and higher diameter classes.

Regarding Stand Diameter and Height profile, few tree species in high diameter classes might indicate that the mature trees that attained the higher diameter size would have been selectively exploited by the local communities for different purposes like wood logging and charcoal making. This depicts that the majority of the species belongs to the lower height class in similar trend as diameter distribution. The possible reason could be similar with the justification given in the analysis of stand diameter profile that selective matured tree cutting, intensive browsing and moisture deficit or recurrent droughts were the determinants for the appearing of the majority of the tree/shrub species in the lower height class. On the other hand, since there is intensive browsing and in addition the area is regularly affected by recurrent drought and wind pressure the big trees could be fall down observed during study time, these impacts might have also hampered the growth from attaining the higher diameter class the number of stems per hectare was higher for species of smaller diameter size than for species of greater diameter size. The slope gradient class is a landscape characterized by near flat slope were usually the soil nutrient movement is slow, while aeration and infiltration is low.

At the lower slope gradient class the number of species is few and it increases towards the moderate slope class and then decreases as slope gradient rises to steep slope. This result agrees with the finding of Feyera Senbeta (2006) that pointed out the relationship between topographic features and species abundance is non-linear in afromontane rainforest areas. Therefore, this confirms that the topographic features significantly affect the species composition and distribution. In general, the regeneration status was high but the survival rate would be low and the profound reason could be the intensive trampling by livestock while browsing and grazing in the woodland. In terms of species, *Myrsine melanophloeos, Bersama abyssinica, Vernonea auritifoia* and *Maesa lanceolata, respectively* sharethe highest seedlings density in the woody species. And while it is the least for *Ekebergia capensis* and *Dovyalis verrucosa* woody plant species. The species density in the forest ranges between 0.43–141.28 per ha. The variation of the relative density of the species was also between 0.07- 22.36 %. The least species density was for *Schefflera abyssinica, Olea capensis, Manilkara butugi, Hypericum revolutum* and *Hagenea abyssinica* while the highest species density (> 100 per ha) was for *Maesa lanceolata* (141.28) and *Podocarpus falcatus* (115.32). This result Pointed out that there was a significant variation among the individual tree/shrub species in density per ha. In the studied forest, the total species density per ha was 627.68. The mean density of woody species of the study area was less than Achera forest (1034.17 individuals per hectare) (Habtam Getaneh 2012). Due to the reason that some part of the forest changes to farm land, browsing and over grazing in the forest.

The total basal area for the inventoried forest was 7.1 m2 per ha. The biggest basal area recorded was for *Pittosporum viridiflorum* (2.52 m2 ha-1) while the largest dominance and relative dominance was for *Pittosporum viridiflorum* (17.12 and 31.51 % respectively), which is almost similar to the result of previous study by Dawit Shiferaw et al. (2011), which was 9.5 m2/ha. Whereas, the total basal area was 17.12.which is much higher than that of Dawit Shiferaw et al. (2011), this may be because of the tree diameter growth of the woody plant species. According to Dawins (1959; cited in Lamprecht, 1989) the normal area of virgin tropical forest in Africa is 23-37m2/ha. Based on the report the basal area of Gara Duro is related to normal indicating the woody species. The top five dominant woody plant species were *Pittosporum viridiflorum, Millettia ferruginea, Olea capensis, Hagenea abyssinica* and *Maytenus addat*, respectively within the range of 2.52 – 0.35. The basal area of Gara Duro natural forest is less than Menagesha Suba (Beche, D 2012) and Dodola (Hundera k, 2007). With basal area 158.68 and 129.0 m2ha-1 respectively. This may be due to the presence of plant species having forest degradation, over grazing, forest disturbance and forest land changes to farm land. The DBH of the majority of the species was in the lowest diameter class (2.5-5.5 cm) this implies that the basal area of the lower diameter class ranger between 0.0015 – 0.0064. This shows that both the basal areas per species and the total were small. This could be due to the stunted diameter growth of the woody plant species in the dry land areas because of both the ecological factors (moisture deficit and high temperature) and intensive forest disturbance due to browsing, grazing and wood exploitation for Logging and charcoal making.

In this study area *Maesa lanceolata, Maytenus addat*,only by its own contributed 28.33 % to the total IVI, and hence it is the most frequent and dominant species in the forest. On the contrary, since *Erica arborea, Hypericum revolutum, Schefflera abyssinica, Brucea antidysenterica* and *Ficus vasta possess* the lowest IVI, they do not frequently exist and are the most minor or rare species in the forest. In principle, when a certain species receives the lowest IVI, it entails as it demands high priority for endangered species. On top of this, there was a physical damage on the seedlings by peeling during grazing and browsing. Important value index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989).The important value index of the species indicates how dominant is the species in a certain area and hence helps to compare ecological importance of the species in vegetation’s (Curtis and McIntosh, 1951). This reveals that in this forest the species relative frequency, density and dominance differ accordingly. On the other hand, the highest Important Value Index of a species the most dominant the species is in an area Shibru Samuel (2004).

The regeneration statues seedling woody species was recorded for 24 woody plant species which belong to 24 genera and 22 families. This becomes about 64.1 % when compared to the total matured woody plant species richness inventoried. Moreover, the total seedlings density per ha was 10,622. The number of seedlings and saplings counted from the study area were higher than the seedlings and saplings of Wof-Washa studied by Fisseha Gudina (2013) and Bibita Denu, (2007) which reported 8,796.5, and 2,555.2 respectively. In terms of species, *Myrsine melanophloeos, Bersama abyssinica, Vernonea auritifoia and Maesa lanceolata* share the highest seedlings density in the wood plant species. And while it is the least for *Ekebergia capensis* and *Dovyalis verrucosa* woody plant species. The variation could be as a result of highly regeneration statues this indicates that the regeneration potential of Gara Duro natural forest is high.

**Conclusion**

This study was conducted to determine diversity and structure of woody plants and also their regeneration status in Gara Duro natural forest. The result shows that in the study area about 40 woody plant species which belongs to 38 genera and 31 families were documented. Regarding the regeneration status, *Myrsine melanophloeos, Bersama abyssinica, Vernonea auritifoia* and *Maesa lanceolata* have high seedlings density while it is the least for *Ekebergia capensis* and *Dovyalis verrucosa*. Species with low seedling (*Ekebergia capensis* and *Dovyalis verrucosa*) should get priority in order to ensure the perpetuation of species until the seedlings reach to a stage which can tolerate the ecologically adapted of the forest. There was high human interference due to farming and overgrazing in the study site leads to forest degradation. Therefore, it was concluded that unregulated expansion of agriculture into forest land should be reversed and local authorities and all concerned institutions should work together for sustainable management of forest biodiversity while still promoting agricultural productivity through from existing farm lands using technologies and other necessary inputs. Furthermore, conservation and sustainable use of forest patch and trees and shrubs on natural forest is important So the local and regional government should have to give attention and creating awareness to the local people regarding with forest management and sustainable use of natural resources importance of conserving the forests for mitigation of climate change and ecosystem services of the forest.

**Authors Contributions**

**Kedir Beno Gedo**: Conceptualization (lead); data collection and curation (lead); formal analysis (lead); investigation (lead); methodology (lead); project administration (lead); validation (lead); writing original draft (lead); writing review and editing of the writing (lead), **Lalisa Mekonnen Jaldu**: Conceptualization (lead); data collection and curation (lead); formal analysis (lead); investigation (lead); methodology (lead); project administration (lead); validation (lead); writing original draft (lead); writing review and editing of the writing (lead), **Gemedo Dalle Tussie:** Conceptualization (lead); data collection and curation (equal); formal analysis (lead); investigation (lead); methodology (lead); project map development (lead); validation (lead); editing of the writing (lead). **Sileshi Degefa:** Conceptualization (lead); data collection and curation (equal); formal analysis (lead); investigation (lead); methodology (lead); project map development (lead); validation (lead); editing of the writing (lead), **Tura Safawo:** Conceptualization (lead); data collection and curation (equal); formal analysis (lead); investigation (lead); methodology (lead); project map development (lead); validation (lead); editing of the writing (lead), **Tesfaye Alemu:** Conceptualization (lead); data collection and curation (equal); formal analysis (lead); investigation (lead); methodology (lead); project map development (lead); validation (lead); editing of the writing (lead).

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**Disclaimer (Artificial intelligence)**

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**ANNEXES**

Annex 1. List of plant species Documented from Gara Duro Natural Forest during this study, with their family, local name and growth habits.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Scientific names** | **Local names**  | **Family**  | **Habit** |
|  | *Asparagus africanus* Lam. | Sariitii  | Asparagaceae  | Liana |
|  | *Bersama abyssinica* Fresen. | Koreqqaa | Melianthaceae  | Shrub  |
|  | *Brucea antidysenterica* J. F. Mill. | Ciirotaa | Simarubaceae  | Shrub  |
|  | *Buddlejapolystachaya*   | Bulchaana  |  Loganiaceae |   |
|  | *Celtis africana* Burm f. | Hirqamu | Ulmaceae | Tree  |
|  | *Arundinaria alpina* k schum | Leman  | Poaceae | Shrub  |
|  | *Croton macrostachyus* Del. | Makanisa | Euphorbiaceae | Tree  |
|  | *Discopodium penninervum* Hochst. | Maraarro  | Solanaceae | Shrub  |
|  | *Dovyalis verrucosa* (A.Rich.) |  Dhangagoo | Flacourtiaceae  |   |
|  | *Ekebergia capensis* Sparrm. | Ononuu  | Meliaceae | Tree  |
|  | *Erica arborea* L. | Satro  | Ericaceae | Shrub  |
|  | *Ficus vasta* Vahl. | Oda  | Moraceae | Tree  |
|  | *Hagenea abyssinica* (Bruce) G.F. Gmel. | Hexoo | Rosaceae | Tree  |
|  | *Hypericum revolutum* Vahl | Garamba  | Guttiferae | Shrub  |
|  | *Unidentified*  | Kolasaa |  |  Tree |
|  | *Trichilia emetica*  |   |   |   |
|  | *Galiniera saxifrage* (Hochst.) | Korraallaa |  Rubiaceae |   |
|  | *Maesa lanceolata* Forssk.  | Abayii | Myrsinaceae | Shrub  |
|  | *Manilkara butugi Chiov.* |   |   |   |
|  | *Maytenus addat* (Loes.) Sebsebe | Kombolcha | Celastraceae | Tree  |
|  | *Schefflera volkensii (*Engl)Harms | Ansha  | Fabaceae | Tree  |
|  | *Myrsine melanophloeos(* L) R.Br. | Tuullaa | Myrsinaceae | Shrub  |
|  | *Nuxia congesta* Fresen. | Biixanna | Loganiaceae | Tree  |
|  | *Olea capensis*  | Siigeda | Oleaceae | Tree  |
|  | *Olinia rochetiana* | Gunaa  | Oliniaceae | Shrub  |
|  | *Pittosporum viridiflorum* Sims | Amshiiqa  | Pittosporaceae | Tree/shrub  |
|  | *Podocarphus falcatus*  | Birbirsa | Podocarphaceae | Tree |
|  | *Prunus africana* (Hook. f.) Kalkm | Sukee  | Rosaceae | Tree  |
|  | *Rubus apetalus* Poir. | Goraa  | Rosaceae | Shrub  |
|  | *Rumex nervosus* | Dhangaggoo | Polygonaceae | Shrub  |
|  | *Rytigynia neglecta* (Hiern) Robyns | Wonte fulesa | Rubiaceae | Shrub  |
|  | *Schefflera abyssinica* Harms | Gatame | Araliceae | Tree  |
|  | *Sclerocarya birrea* (A. Rich.) Hochst. | Didessa  | Anacardiaceae | Shrub  |
|  | *Solanum marginatum* L.f. | Hiddii | Solanaceae | Shrub  |
|  | *Teclea nobilis* Del. | Hadheessaa |   | Shrub  |
|  | *Terminalia brownii* Fresen. | Araa | Combertaceae | Tree  |
|  | *Polysciasfulva(Hiern)* | Worqicha jaldesa | Araliaceae | Shrub |
|  | *Vernonea amygidelina* Del. | Ebicha  | Asteraceae | Shrub  |
|  | *Vernonea auritifoia* Hiern | Rejii  | Asteraceae | Shrub  |
|  | *Pentas sp.*  | Unidentified | Rubiaceae | Shrub |

Annex 2. Species Dimensions of Gara Duro forest

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No | Scientific name | Max DBH/DSH(cm) | Mean DBH/DSH(cm) | Max Height (m) | Mean Height (m) | Stems sampled |
|  | *Bersama abyssinica* | 14.00 | 7.67 | 10.00 | 6.00 | 3 |
|  | *Brucea antidysenterica* | 6.00 | 3.67 | 5.00 | 3.50 | 6 |
|  | *Buddlejapolystachaya*   | 18.00 | 17.00 | 9.00 | 8.50 | 2 |
|  | *Celtis Africana* | 35.00 | 22.00 | 20.00 | 12.50 | 4 |
|  | *Citrus aurantiifolia* | 5.00 | 4.30 | 5.00 | 3.34 | 112 |
|  | *Croton macrostachyus*  | 48.00 | 20.91 | 35.00 | 13.76 | 225 |
|  | *Discopodium penninervum*  | 16.00 | 5.83 | 8.00 | 3.83 | 36 |
|  | *Dovialis abyssinica* | 3.00 | 3.00 | 3.00 | 3.00 | 5 |
|  | *Ekebergia capensis* | 78.00 | 48.00 | 20.00 | 15.00 | 2 |
|  | *Erica arborea*  | 9.00 | 9.00 | 3.00 | 3.00 | 1 |
|  | *Ficus vasta* | 32.00 | 32.00 | 35.00 | 35.00 | 2 |
|  | *Hagenea abyssinica* | 88.00 | 88.00 | 12.00 | 12.00 | 1 |
|  | *Hypericum revolutum*  | 25.00 | 25.00 | 9.00 | 9.00 | 1 |
|  | *Kolasaa Unidentified*  | 12.00 | 7.50 | 8.00 | 5.75 | 4 |
|  | *Trichilia emetica*  | 32.00 | 10.30 | 25.00 | 8.25 | 64 |
|  | *Galiniera saxifrage*   | 32.00 | 15.17 | 18.00 | 8.33 | 9 |
|  | *Maesa lanceolate* | 46.00 | 14.40 | 30.00 | 9.05 | 332 |
|  | *Manilkara butugi*   | 60.00 | 60.00 | 20.00 | 20.00 | 1 |
|  | *Maytenus addat* | 160.00 | 59.28 | 35.00 | 18.33 | 93 |
|  | *Millettia ferruginea* | 125.00 | 73.07 | 30.00 | 20.86 | 14 |
|  | *Myrsine melanophloeos* | 87.00 | 12.74 | 19.00 | 7.11 | 65 |
|  | *Nuxia congesta* | 27.00 | 16.29 | 15.00 | 9.14 | 7 |
|  | *Olea capensis*  | 110.00 | 110.00 | 25.00 | 25.00 | 1 |
|  | *Pittosporum viridiflorum* | 140.00 | 72.13 | 32.00 | 21.63 | 16 |
|  | *Podocarphus falcatus*  | 40.00 | 19.23 | 30.00 | 11.97 | 271 |
|  | *Prunus Africana* | 88.00 | 45.60 | 25.00 | 16.20 | 5 |
|  | *Rytigynia neglecta* | 45.00 | 11.59 | 8.00 | 4.24 | 58 |
|  | *Schefflera abyssinica*  | 32.00 | 32.00 | 14.00 | 14.00 | 1 |
|  | *Sclerocarya birrea* | 65.00 | 24.88 | 22.00 | 14.18 | 17 |
|  | *Teclea nobilis* | 14.00 | 9.63 | 9.00 | 5.13 | 8 |
|  | *Terminalia brownie* | 65.00 | 28.80 | 22.00 | 13.40 | 5 |
|  | *Vernonea amygidelina*  | 25.00 | 16.00 | 8.00 | 6.50 | 87 |
|  | *Vernonea auritifoia*  | 28.00 | 4.18 | 8.00 | 3.74 | 2 |
|  | *Polysciasfulva(Hiern)*  | 9.00 | 3.48 | 8.00 | 4.08 | 25 |

Annex 3. The woody plant species distribution in Gara Duro forest

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  No |   | Species Frequency | Relative frequency | Frequency class | Frequency Rank |
| Scientific name |
|  | *Bersama abyssinica* | 4.26 | 0.73 | E | 22 |
|  | *Brucea antidysenterica* | 8.51 | 1.46 | E | 15 |
|  | *Buddlejapolystachaya*  | 2.13 | 0.36 | E | 30 |
|  | *Celtis Africana* | 6.38 | 1.09 | E | 19 |
|  | *Citrus aurantiifolia* | 12.77 | 2.19 | E | 12 |
|  | *Croton macrostachyus*  | 76.60 | 13.14 | B | 2 |
|  | *Discopodium penninervum*  | 8.51 | 1.46 | E | 18 |
|  | *Dovialis abyssinica* | 2.13 | 0.36 | E | 28 |
|  | *Ekebergia capensis* | 2.13 | 0.36 | E | 32 |
|  | *Erica arborea*  | 2.13 | 0.36 | E | 29 |
|  | *Ficus vasta* | 2.13 | 0.36 | E | 35 |
|  | *Hagenea abyssinica* | 2.13 | 0.36 | E | 26 |
|  | *Hypericum revolutum*  | 2.13 | 0.36 | E | 34 |
|  | *Kolasaa (Unidentified)*  | 4.26 | 0.73 | E | 24 |
|  | *Trichilia emetica*  | 40.43 | 6.93 | C  | 5 |
|  | *Galiniera saxifrage*  | 8.51 | 1.46 | E | 17 |
|  | *Maesa lanceolata* | 80.85 | 13.87 | A | 1 |
|  | *Manilkara butugi*   | 2.13 | 0.36 | E | 31 |
|  | *Maytenus addat* | 63.83 | 10.95 | B | 4 |
|  | *Millettia ferruginea* | 25.53 | 4.38 | D | 8 |
|  | *Myrsine melanophloeos* | 23.40 | 4.01 | D | 9 |
|  | *Nuxia congesta* | 8.51 | 1.46 | E | 16 |
|  | *Olea capensis*  | 2.13 | 0.36 | E | 33 |
|  | *Pittosporum viridiflorum* | 19.15 | 3.28 | E | 10 |
|  | *Podocarphus falcatus*  | 72.34 | 12.41 | B | 3 |
|  | *Prunus Africana* | 8.51 | 1.46 | E | 14 |
|  | *Rytigynia neglecta* | 27.66 | 4.74 | D | 7 |
|  | *Schefflera abyssinica*  | 2.13 | 0.36 | E | 27 |
|  | *Sclerocarya birrea* | 10.64 | 1.82 | E | 13 |
|  | *Teclea nobilis* | 4.26 | 0.73 | E | 25 |
|  | *Terminalia brownie* | 6.38 | 1.09 | E | 20 |
|  | *Vernonea amygidelina*  | 29.79 | 5.11 | D | 6 |
|  | *Vernonea auritifoia*  | 4.26 | 0.73 | E | 22 |
|  | *Polysciasfulva(Hiern)* | 6.38 | 1.09 | E | 21 |

Annex 4. Species density in Gara Duro forest

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No** | **Scientific name** | **Species Density per ha** | **Relative Density** | **Density >10DBH** | **Density >20DBH** | **Ratio** **A to B** |
|  | *Bersama abyssinica* | 1.28 | 0.20 | 0.43 |   |   |
|  | *Brucea antidysenterica* | 2.55 | 0.40 |   |   |   |
|  | *Buddlejapolystachaya*  | 0.85 | 0.13 | 0.85 |   |   |
|  | *Celtis Africana* | 1.7 | 0.27 | 1.28 | 0.85 | 1.5 |
|  | *Citrus aurantiifolia* | 47.66 | 7.54 |   |   |   |
|  | *Croton macrostachyus*  | 95.74 | 15.15 | 74.47 | 45.96 | 1.62 |
|  | *Discopodium penninervum*  | 15.32 | 2.42 | 0.85 |   |   |
|  | *Dovialis abyssinica* | 2.13 | 0.34 |   |   |   |
|  | *Ekebergia capensis* | 0.85 | 0.13 | 0.85 | 0.43 | 2 |
|  | *Erica arborea*  | 0.43 | 0.07 |   |   |   |
|  | *Ficus vasta* | 0.85 | 0.13 | 0.43 | 0.43 | 1 |
|  | *Hagenea abyssinica* | 0.43 | 0.07 | 0.43 | 0.43 | 1 |
|  | *Hypericum revolutum*  | 0.43 | 0.07 | 0.43 | 0.43 | 1 |
|  | *Kolasaa* (*Unidentified)*  | 1.7 | 0.27 | 0.43 |   |   |
|  | *Trichilia emetica*  | 27.23 | 4.31 | 8.51 | 2.13 | 4 |
|  |  *Galiniera saxifrage*  | 3.83 | 0.61 | 2.13 | 0.85 | 2.5 |
|  | *Maesa lanceolata* | 141.28 | 22.36 | 74.04 | 35.74 | 2.07 |
|  | *Manilkara butugi*   | 0.43 | 0.07 | 0.43 | 0.43 | 1 |
|  | *Maytenus addat* | 39.57 | 6.26 | 37.02 | 35.32 | 1.05 |
|  | *Millettia ferruginea* | 5.96 | 0.94 | 5.53 | 5.53 | 1 |
|  | *Myrsine melanophloeos* | 27.66 | 4.38 | 8.94 | 5.53 | 1.62 |
|  | *Nuxia congesta* | 2.98 | 0.47 | 2.55 | 0.85 | 3 |
|  | *Olea capensis*  | 0.43 | 0.07 | 0.43 | 0.43 | 1 |
|  | *Pittosporum viridiflorum* | 6.81 | 1.08 | 6.81 | 6.81 | 1 |
|  | *Podocarphus falcatus*  | 115.32 | 18.25 | 83.83 | 45.53 | 1.84 |
|  | *Prunus Africana* | 2.13 | 0.34 | 2.13 | 1.7 | 1.25 |
|  | *Rytigynia neglecta* | 24.68 | 3.91 | 1.7 | 0.85 | 2 |
|  | *Schefflera abyssinica*  | 0.43 | 0.07 | 0.43 | 0.43 | 1 |
|  | *Sclerocarya birrea* | 7.23 | 1.14 | 6.81 | 4.26 | 1.6 |
|  | *Teclea nobilis* | 3.4 | 0.54 | 0.85 |   |   |
|  | *Terminalia brownie* | 2.13 | 0.34 | 1.7 | 1.7 | 1 |
|  | *Vernonea amygidelina*  | 0.85 | 5.86 | 0.43 | 0.43 | 1 |
|  | *Vernonea auritifoia*  | 37.02 | 0.13 | 0.85 | 0.43 | 2 |
|  | *Polysciasfulva(Hiern)* | 10.64 | 1.68 |   |   |   |

Annex 5. Basal Area and Dominance of woody plant species

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Scientific name | Mean Basal area (M2) | Dominance(M2/ha) | Relative Dominance (%) | Rank |
|  | *Bersama abyssinica* | 0.01 | 0.01 | 0.01 | 25 |
|  | *Brucea antidysenterica* | 0.00 | 0.00 | 0.01 | 25 |
|  | *Buddlejapolystachaya*  | 0.02 | 0.02 | 0.04 | 23 |
|  | *Celtis Africana* | 0.05 | 0.08 | 0.15 | 17 |
|  | *Citrus aurantiifolia* | 0.00 | 0.07 | 0.13 | 19 |
|  | *Croton macrostachyus*  | 0.04 | 4.15 | 7.64 | 4 |
|  | *Discopodium penninervum*  | 0.00 | 0.05 | 0.09 | 20 |
|  | *Dovialis abyssinica* | 0.00 | 0.00 | 0 |   |
|  | *Ekebergia capensis* | 0.25 | 0.21 | 0.39 | 13 |
|  | *Erica arborea*  | 0.01 | 0.00 | 0 |   |
|  | *Ficus vasta* | 0.08 | 0.07 | 0.13 | 19 |
|  | *Hagenea abyssinica* | 0.61 | 0.26 | 0.48 | 12 |
|  | *Hypericum revolutum*  | 0.05 | 0.02 | 0.04 | 23 |
|  | *Kolasaa (Unidentified)*  | 0.01 | 0.01 | 0.02 | 24 |
|  | *Trichilia emetica*  | 0.01 | 0.33 | 0.61 | 11 |
|  |  *Galiniera saxifrage*  | 0.02 | 0.09 | 0.16 | 16 |
|  | *Maesa lanceolata* | 0.02 | 3.34 | 6.15 | 6 |
|  | *Manilkara butugi*   | 0.28 | 0.12 | 0.22 | 15 |
|  | *Maytenus addat* | 0.35 | 13.81 | 25.42 | 2 |
|  | *Millettia ferruginea* | 1.25 | 7.47 | 13.75 | 3 |
|  | *Myrsine melanophloeos* | 0.03 | 0.83 | 1.52 | 7 |
|  | *Nuxia congesta* | 0.02 | 0.07 | 0.14 | 18 |
|  | *Olea capensis*  | 0.95 | 0.40 | 0.74 | 10 |
|  | *Pittosporum viridiflorum* | 2.52 | 17.12 | 31.51 | 1 |
|  | *Podocarphus falcatus*  | 0.04 | 4.06 | 7.46 | 5 |
|  | *Prunus Africana* | 0.22 | 0.48 | 0.88 | 8 |
|  | *Rytigynia neglecta* | 0.02 | 0.44 | 0.81 | 9 |
|  | *Schefflera abyssinica*  | 0.08 | 0.03 | 0.06 | 21 |
|  | *Sclerocarya birrea* | 0.06 | 0.44 | 0.81 | 9 |
|  | *Teclea nobilis* | 0.01 | 0.03 | 0.05 | 22 |
|  | *Terminalia brownie* | 0.09 | 0.20 | 0.37 | 14 |
|  | *Vernonea amygidelina*  | 0.00 | 0.08 | 0.14 | 18 |
|  | *Vernonea auritifoia*  | 0.03 | 0.02 | 0.04 | 23 |
|  | Workicha jaldessa  | 0.00 | 0.01 | 0.02 | 24 |

Annex 6. Stand diameter profile and species density distribution

|  |  |  |
| --- | --- | --- |
| No |  Scientific name | Diameter class |
| 2.6-7.5cm | 7.6-12.5cm | 12.6-17.5cm | 17.6-22.5cm | 22.6--27.5cm | 27.6-32.5cm | 32.6-37.5cm | 37.6-42.5cm | >42.5cm | Total  |
|  | *Bersama abyssinica* | 0.85 |   | 0.43 |   |   |   |   |   |   | 1.28 |
|  | *Brucea antidysenterica* | 2.55 |   |   |   |   |   |   |   |   | 2.55 |
|  | *Buddlejapolystachaya*  |   |   | 0.43 | 0.43 |   |   |   |   |   | 0.86 |
|  | *Celtis Africana* |   | 0.85 |   |   |   | 0.43 | 0.43 |   |   | 1.71 |
|  | *Citrus aurantiifolia* | 47.66 |   |   |   |   |   |   |   |   | 47.66 |
|  | *Croton macrostachyus*  | 10.21 | 13.62 | 14.47 | 20.43 | 5.53 | 16.60 | 9.36 | 2.55 | 2.98 | 95.75 |
|  | *Discopodium penninervum*  | 14.04 | 0.85 | 0.43 |   |   |   |   |   |   | 15.32 |
|  | *Dovialis abyssinica* | 2.13 |   |   |   |   |   |   |   |   | 2.13 |
|  | *Ekebergia capensis* |   |   |   | 0.43 |   |   |   |   | 0.43 | 0.86 |
|  | *Erica arborea*  |   | 0.43 |   |   |   |   |   |   |   | 0.43 |
|  | *Ficus vasta* |   |   |   |   |   | 0.85 |   |   |   | 0.85 |
|  | *Hagenea abyssinica* |   |   |   |   |   |   |   |   | 0.43 | 0.43 |
|  | *Hypericum revolutum*  |   |   |   |   | 0.43 |   |   |   |   | 0.43 |
|  | Kolasaa  | 1.28 | 0.43 |   |   |   |   |   |   |   | 1.71 |
|  | *Trichilia emetica*  | 13.19 | 6.38 | 4.68 | 0.85 |   | 2.13 |   |   |   | 27.23 |
|  | *Galiniera saxifrage*  |   | 2.13 | 0.43 | 0.43 | 0.43 | 0.43 |   |   |   | 3.85 |
|  | *Maesa lanceolata* | 44.68 | 28.94 | 19.15 | 16.60 | 13.19 | 11.49 | 5.11 | 0.43 | 1.70 | 141.29 |
|  | *Manilkara butugi*   |   |   |   |   |   |   |   |   | 0.43 | 0.43 |
|  | *Maytenus addat* | 1.28 | 1.28 | 0.85 | 0.85 | 1.70 | 2.98 | 2.13 | 0.43 | 28.09 | 39.59 |
|  | *Millettia ferruginea* | 0.43 |   |   |   | 0.43  |   | 0.85 |   | 4.68 | 5.96 |
|  | *Myrsine melanophloeos* | 15.74 | 3.83 | 1.70 | 2.13 |   | 2.55 | 0.85 |   | 0.85 | 27.65 |
|  | *Nuxia congesta* | 0.43 | 0.43 | 0.85 | 0.43 | 0.85 |   |   |   |   | 2.99 |
|  | *Olea capensis*  |   |   |   |   |   |   |   |   | 0.43 | 0.43 |
|  | *Pittosporum viridiflorum* |   |   |   |   |   | 0.85 | 0.85 | 0.43 | 4.68 | 6.81 |
|  | *Podocarphus falcatus*  | 9.79 | 21.28 | 22.55 | 20.43 | 18.30 | 13.62 | 7.66 | 1.70 |   | 115.33 |
|  | *Prunus Africana* |   |   | 0.43 |   | 0.43 | 0.43 |   |   | 0.85 | 2.14 |
|  | *Rytigynia neglecta* | 13.19 | 4.68 |   |   | 6.38 |   |   |   | 0.43 | 24.68 |
|  | *Schefflera abyssinica*  |   |   |   |   |   | 0.43 |   |   |   | 0.43 |
|  | *Sclerocarya birrea* | 0.43 |   | 1.28 | 1.70 | 1.28 | 1.28 | 0.85 |   | 0.43 | 7.25 |
|  | *Teclea nobilis* | 1.28 | 1.70 | 0.43 |   |   |   |   |   |   | 3.41 |
|  | *Terminalia brownie* |   | 0.43 |   | 0.43 | 0.85 |   |   |   | 0.43 | 2.14 |
|  | *Vernonea amygidelina*  | 0.43 |   |   |   | 0.43 |   |   |   |   | 0.86 |
|  | *Vernonea auritifoia*  | 31.91 |   | 0.43 |   |   | 0.43 |   |   |   | 32.77 |
|  | *Polysciasfulva(Hiern)* | 10.21 | 0.43 |   |   |   |   |   |   |   | 10.64 |
|  | Total | 221.71 | 87.69 | 68.54 | 65.14 | 50.23 | 54.5 | 28.09 | 5.54 | 46.84 | 627.85 |

Annex 7. Stand Height profile and Species Density distribution

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No.  | Scientific name | <= 5 | 5\_1 - 10 | 10\_1- 15 | 15\_1 - 20 | 20\_1 – 25 | 25\_1 - 30 | > 30.1 | Total |
|  | *Bersama abyssinica* | 0.85 | 0.43 |   |   |   |   |   | 1.28 |
|  | *Brucea antidysenterica* | 2.55 |   |   |   |   |   |   | 2.55 |
|  | *Buddlejapolystachaya*  |   | 0.85 |   |   |   |   |   | 0.85 |
|  | *Celtis Africana* |   | 0.85 | 0.43 | 0.43 |   |   |   | 1.70 |
|  | *Citrus aurantiifolia* | 47.66 |   |   |   |   |   |   | 47.66 |
|  | *Croton macrostachyus*  | 11.91 | 24.26 | 26.81 | 24.68 | 4.68 | 1.70 | 1.70 | 95.74 |
|  | *Discopodium penninervum*  | 14.04 | 1.28 |   |   |   |   |   | 15.32 |
|  | *Dovialis abyssinica* | 2.13 |   |   |   |   |   |   | 2.13 |
|  | *Ekebergia capensis* |   | 0.43 |   | 0.43 |   |   |   | 0.85 |
|  | *Erica arborea*  | 0.43 |   |   |   |   |   |   | 0.43 |
|  | *Ficus vasta* |   |   |   |   |   |   | 0.85 | 0.85 |
|  | *Hagenea abyssinica* |   |   | 0.43 |   |   |   |   | 0.43 |
|  | *Hypericum revolutum*  |   | 0.43 |   |   |   |   |   | 0.43 |
|  | *Kolasaa (Unidentified)*  | 1.28 | 0.43 |   |   |   |   |   | 1.70 |
|  | *Trichilia emetica*  | 14.04 | 6.81 | 3.40 | 1.70 | 1.28 |   |   | 27.23 |
|  | *Galiniera saxifrage*  | 0.85 | 2.55 |   | 0.43 |   |   |   | 3.83 |
|  | *Maesa lanceolata* | 40.43 | 60.43 | 26.38 | 12.34 | 0.85 | 0.85 |   | 141.28 |
|  | *Manilkara butugi*   |   |   |   | 0.43 |   |   |   | 0.43 |
|  | *Maytenus addat* | 1.70 | 2.13 | 5.96 | 22.13 | 6.38 | 0.43 | 0.85 | 39.57 |
|  | *Millettia ferruginea* | 0.43 | 0.43 | 0.43 | 1.70 | 2.55 | 0.43 |   | 5.96 |
|  | *Myrsine melanophloeos* | 17.02 | 5.11 | 2.55 | 2.98 |   |   |   | 27.66 |
|  | *Nuxia congesta* | 0.43 | 1.28 | 1.28 |   |   |   |   | 2.98 |
|  | *Olea capensis*  |   |   |   |   | 0.43 |   |   | 0.43 |
|  | *Pittosporum viridiflorum* |   |   | 0.85 | 3.40 | 0.85 | 1.28 | 0.43 | 6.81 |
|  | *Podocarphus falcatus*  | 11.91 | 36.60 | 45.96 | 16.60 | 2.98 | 1.28 |   | 115.32 |
|  | *Prunus Africana* |   | 0.43 | 0.85 |   | 0.85 |   |   | 2.13 |
|  | *Rytigynia neglecta* | 20.43 | 4.26 |   |   |   |   |   | 24.68 |
|  | *Schefflera abyssinica*  |   |   | 0.43 |   |   |   |   | 0.43 |
|  | *Sclerocarya birrea* | 0.43 | 2.13 | 1.28 | 2.98 | 0.43 |   |   | 7.23 |
|  | *Teclea nobilis* | 2.55 | 0.85 |   |   |   |   |   | 3.40 |
|  | *Terminalia brownie* |   | 0.85 | 0.85 |   | 0.43 |   |   | 2.13 |
|  | *Vernonea amygidelina*  | 0.43 | 0.43 |   |   |   |   |   | 0.85 |
|  | *Vernonea auritifoia*  | 31.91 | 0.85 |   |   |   |   |   | 32.76 |
|  | *Polysciasfulva(Hiern)* | 10.21 | 0.43 |   |   |   |   |   | 10.64 |
|  | Total | **233.61** | **154.47** | **117.87** | **90.21** | **21.70** | **5.96** | **3.83** | **627.65** |

Annex 8. Important Value Index (IVI)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Scientific name | RD | RDO | RF | IVI | Percent | Rank |
| No |
| *1* | *Bersama abyssinica* | 0.20 | 0.01 | 0.73 | 0.95 | 0.32 | 24 |
| *2* | *Brucea antidysenterica* | 0.40 | 0.01 | 1.46 | 1.87 | 0.62 | 18 |
| *3* | *Buddlejapolystachaya*  | 0.13 | 0.04 | 0.36 | 0.54 | 0.18 | 30 |
| *4* | *Celtis Africana* | 0.27 | 0.15 | 1.09 | 1.52 | 0.51 | 20 |
| *5* | *Citrus aurantiifolia* | 7.54 | 0.13 | 2.19 | 9.86 | 3.29 | 10 |
| *6* | *Croton macrostachyus*  | 15.15 | 7.64 | 13.14 | 35.93 | 11.98 | 4 |
| *7* | *Discopodium penninervum*  | 2.42 | 0.09 | 1.46 | 3.97 | 1.32 | 12 |
| *8* | *Dovialis abyssinica* | 0.34 | 0.00 | 0.36 | 0.70 | 0.23 | 27 |
| *9* | *Ekebergia capensis* | 0.13 | 0.39 | 0.36 | 0.89 | 0.30 | 26 |
| *10* | *Erica arborea*  | 0.07 | 0.00 | 0.36 | 0.44 | 0.15 | 33 |
| *11* | *Ficus vasta* | 0.13 | 0.13 | 0.36 | 0.63 | 0.21 | 29 |
| *12* | *Hagenea abyssinica* | 0.07 | 0.48 | 0.36 | 0.91 | 0.30 | 25 |
| *13* | *Hypericum revolutum*  | 0.07 | 0.04 | 0.36 | 0.47 | 0.16 | 32 |
| *14* | *Kolasaa Unidentified*  | 0.27 | 0.02 | 0.73 | 1.01 | 0.34 | 23 |
| *15* | *Trichilia emetica*  | 4.31 | 0.61 | 6.93 | 11.86 | 3.95 | 7 |
| *16* | *Galiniera saxifrage*  | 0.61 | 0.16 | 1.46 | 2.23 | 0.74 | 16 |
| *17* | *Maesa lanceolata* | 22.36 | 6.15 | 13.87 | 42.37 | 14.12 | 2 |
| *18* | *Manilkara butugi*   | 0.07 | 0.22 | 0.36 | 0.65 | 0.22 | 28 |
| *19* | *Maytenus addat* | 6.26 | 25.42 | 10.95 | 42.63 | 14.21 | 1 |
| *20* | *Millettia ferruginea* | 0.94 | 13.75 | 4.38 | 19.07 | 6.36 | 6 |
| *21* | *Myrsine melanophloeos* | 4.38 | 1.52 | 4.01 | 9.92 | 3.31 | 9 |
| *22* | *Nuxia congesta* | 0.47 | 0.14 | 1.46 | 2.07 | 0.69 | 17 |
| *23* | *Olea capensis*  | 0.07 | 0.74 | 0.36 | 1.18 | 0.39 | 22 |
| *24* | *Pittosporum viridiflorum* | 1.08 | 31.51 | 3.28 | 35.87 | 11.96 | 5 |
| *25* | *Podocarphus falcatus*  | 18.25 | 7.46 | 12.41 | 38.12 | 12.71 | 3 |
| *26* | *Prunus Africana* | 0.34 | 0.88 | 1.46 | 2.67 | 0.89 | 15 |
| *27* | *Rytigynia neglecta* | 3.91 | 0.81 | 4.74 | 9.46 | 3.15 | 11 |
| *28* | *Schefflera abyssinica*  | 0.07 | 0.06 | 0.36 | 0.50 | 0.17 | 31 |
| *29* | *Sclerocarya birrea* | 1.14 | 0.81 | 1.82 | 3.78 | 1.26 | 13 |
| *30* | *Teclea nobilis* | 0.54 | 0.05 | 0.73 | 1.32 | 0.44 | 21 |
| *31* | *Terminalia brownie* | 0.34 | 0.37 | 1.09 | 1.80 | 0.60 | 19 |
| *32* | *Vernonea amygidelina*  | 5.86 | 0.14 | 5.11 | 11.11 | 3.70 | 8 |
| *33* | *Vernonea auritifoia*  | 0.13 | 0.04 | 0.73 | 0.91 | 0.30 | 26 |
| *34* | *Polysciasfulva(Hiern)* | 1.68 | 0.02 | 1.09 | 2.80 | 0.93 | 14 |

**Annex 9. Seedlings and Saplings density (per ha)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   No |   Scientific name | Seedlings | Saplings | Totals |   Rank  |
| Density  | Relative Density  | Density |  Relative Density | Density | Relative Density |
|  | *Asparagus africanus*  | 664.89 | 6.26 |   |   | 664.89 | 3.90 | 7 |
|  | *Bersama abyssinica* | 2,037.23 | 19.18 | 468.09 | 7.27 | 2505.32 | 14.69 | 2 |
|  | *Brucea antidysenterica* | 351.06 | 3.30 | 212.77 | 3.31 | 563.83 | 3.31 | 9 |
|  | *Buddlejapolystachaya*  |  |   | 132.98 | 2.07 | 132.98 | 0.78 | 18 |
|  | *Citrus aurantiifolia* |  |   | 244.68 | 3.80 | 244.68 | 1.43 | 14 |
|  | *Croton macrostachyus*  | 308.51 | 2.90 | 484.04 | 7.52 | 792.55 | 4.65 | 6 |
|  | *Discopodium penninervum*  | 207.45 | 1.95 | 292.55 | 4.55 | 500 | 2.93 | 11 |
|  | *Dodonaea angustifolia* | 10.64 | 0.10 |   |   | 10.64 | 0.06 | 24 |
|  | *Dovialis abyssinica* | 138.3 | 1.30 | 63.83 | 0.99 | 202.13 | 1.18 | 16 |
|  | *Ekebergia capensis* | 5.32 | 0.05 | 15.96 | 0.25 | 21.28 | 0.12 | 22 |
|  | *Erica arborea*  | 42.55 | 0.40 |   |   | 42.55 | 0.25 | 20 |
|  | *Hypericum revolutum*  | 351.06 | 3.30 |  |   | 351.06 | 2.06 | 13 |
|  | *Kolasaa Unidentified*  | 21.28 | 0.20 | 15.96 | 0.25 | 37.24 | 0.22 | 21 |
|  | *Trichilia emetica*  | 228.72 | 2.15 | 324.47 | 5.04 | 553.19 | 3.24 | 10 |
|  | *Maesa lanceolate* | 781.91 | 7.36 | 962.77 | 14.96 | 1744.68 | 10.23 | 4 |
|  | *Maytenus addat* | 324.47 | 3.05 | 111.70 | 1.74 | 436.17 | 2.56 | 12 |
|  | *Myrsine melanophloeos* | 2,500.00 | 23.54 | 1,287.23 | 20.00 | 3787.23 | 22.20 | 1 |
|  | *Nuxia congesta* | 15.96 | 0.15 |  |   | 15.96 | 0.09 | 23 |
|  | *Podocarphus falcatus*  | 58.51 | 0.55 | 53.19 | 0.83 | 111.7 | 0.65 | 19 |
|  | *Prunus Africana* | 111.7 | 1.05 |   |   | 111.7 | 0.65 | 19 |
|  | *Rubus apetalus* | 654.26 | 6.16 |  |   | 654.26 | 3.84 | 8 |
|  | *Rytigynia neglecta* | 404.26 | 3.81 | 478.72 | 7.44 | 882.98 | 5.18 | 5 |
|  | *Solanum marginatum* | 180.85 | 1.70 | 53.19 | 0.83 | 234.04 | 1.37 | 15 |
|  | *Teclea nobilis* | 58.51 | 0.55 | 79.79 | 1.24 | 138.3 | 0.81 | 17 |
|  | *Vernonea auritifoia*  | 1,148.94 | 10.82 | 1,058.51 | 16.45 | 2207.45 | 12.94 | 3 |
|  | *Polysciasfulva(Hiern)* | 15.96 | 0.15 | 95.74 | 1.49 | 111.7 | 0.65 | 19 |