Article

Diversity, structure and regeneration status of woody species in Wacho forest, South-Western Ethiopia

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Abstract
Wacho forest is on the verge of degradation. Thus, the study was conducted to quantify the vegetation status of Wacho forest. The field data was collected through a systematic random sampling technique from 20 m × 20 m of 73 sample plots. The matured strata were collected from 20 m × 20 m of the main plot, while saplings were collected from 5 m × 5 m of subplots. Seedlings were additionally collected from each of the five 1 m × 1 m of subplots. The species richness, Shannon wiener diversity index, and Shannon evenness were computed to examine the diversity of the study forest. The structures of woody species were determined using diameter at breast height class, density, frequency, basal area, and important value index. The number of trees and shrubs, saplings, and seedlings were counted across all sample plots to determine the regeneration status of the study forest. The result showed that about 82 woody plant species with 38 families were identified within the study forest. Wacho forest had 2.75 of Shannon Wiener diversity index and 0.95 of Shannon evenness, which shows a medium Shannon Wiener diversity index and proportional distribution of woody species across all quadrants. The structural analysis of the study forest indicates that the majority of the woody species had a larger number in the lower diameter at breast height category and a lower number in the higher diameter at breast height category, which shows an inverted J-shaped structure, and therefore the regeneration status of the study forest is situated under fair condition.

Key words regeneration; species richness; species evenness; Wacho forest.

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1 Introduction

The loss of plant diversity is a growing concern in the global world, which has become the principal threat affecting the existence of human kind (Brook et al., 2006). Tropical plant diversity is being lost at an ominous rate because of increasing population growth and subsequent demands for land use and land cover changes (Behera et al., 2017).

Forest fragmentation and coupled edge effects are the foremost threats to plant diversity, and the impact is sever in the tropical forests where human evoked strain is excessive and forests are being removed at an alarming rate((Laurance et al., 2006). Forest degradation in Sub-Saharan African countries has widely taken place because people get a short-term economic return from the forest and related economic activities (Mogaka, 2001). In the same way, expanded deforestation and wooded area fragmentation to satisfy the food and energy requirements of the increasing population growth are principal ecological issues in the Federal Democratic Republic of Ethiopia (Friis et al., 2001). In the Federal Democratic Republic of Ethiopia, most of the vegetation victims are taking place wherever the livelihoods of the communities are linked to wooded area sources (UNFAO, 2010). These human-evoked threats to vegetation cause changes in plant species range, plant species structure, and plant species regeneration (Driba et al., 2014). In particular, the diversity of Ethiopian dry Afro montane forest is vulnerable to momentous deforestation, forest fire, forest fragmentation, and penury ecosystems because of its expediency for human tenancy accompanied by sedentary agriculture and widespread cattle herding (Teketay, 2001). Population increment has resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forest land for fuel wood, fodder, and construction materials. Because of such motives, the forest area of Ethiopia has been curved from 40% to 11.40%, resulting in momentous ecological deprivation (FAO, 2015).

Wacho forest is one of the remnant dry Afro montane forest found in South Western Ethiopia. The forest is facing a problem principally by charcoal production, and selective logging by adjoining communities, which results in the exhaustion of indigenous plant varieties in the study area (Field observation, 2019/2020). This triggered the researchers to study the diversity, structure, and regeneration status of Wacho forest.

Previous authors like Tadele et al. (2014), Gedefaw and Soromessa (2014), Geneme et al. (2015), Hailemariam and Teman (2018) have attempted to study woody species diversity, structure, and regeneration status of Zengena forest, Tara Gedam forest, Komba-Dega forest, and Gole Natural forest, respectively. Yet, no study has been conducted on the Wacho forest. Therefore, this study fills the underprovided scientific quantitative statistics vegetation status of wacho forest. This study is planned to address the following research objectives such as (1) To assess and identify the diversity pattern of Wacho forest (2) To assess the structures of woody plants found in Wacho forest and (3) To examine the regeneration status of Wacho forest.

2 Material and Methods

2.1 Description of the study area

Wacho forest is found in Hawa Gelan district, Oromia Region, South-Western Ethiopia. It is located at about 630 km to the South-West of the capital city of Ethiopia, Addis Ababa. Geographically, it is found between 8°42'32"N-8°42'34"N and 40°52'49"E-40°53'55"E (Fig. 1). The study forest had about 720 hectares of land.

According to the statistics obtained from the National Meteorological Service agency (1986–2018), the mean maximum and minimum temperatures of the study area were 30.84°C and 16.38°C, respectively. The mean annual rainfall was also 1,645 mm (Fig. 2).

The altitudinal assortment of the study area also ranges from 1435 to 1704 m above mean sea level. The study area is divided into four land use types, such as forest land, shrub land, farm land, and grazing land. The study area is dominated by the woody plant species of *Ehretia cymosa, Prunus africana, Acacia abyssinica, Carissa edulis, Albizia gumifera, Syzygium guineense, Leucas stachydiformis,* and *Calpurnia aurea.*

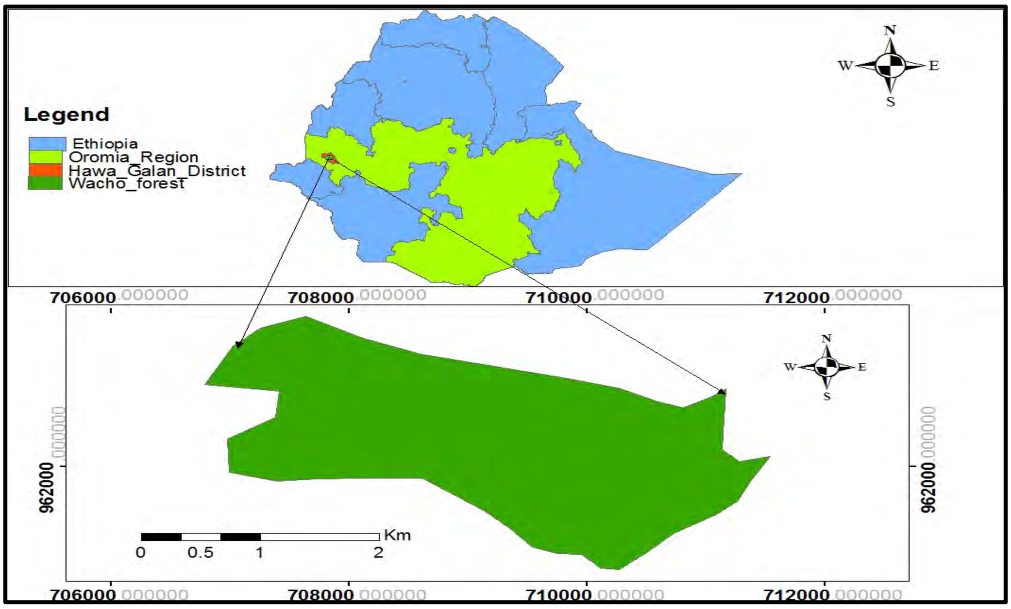

Fig. 1 Location map of the study area.

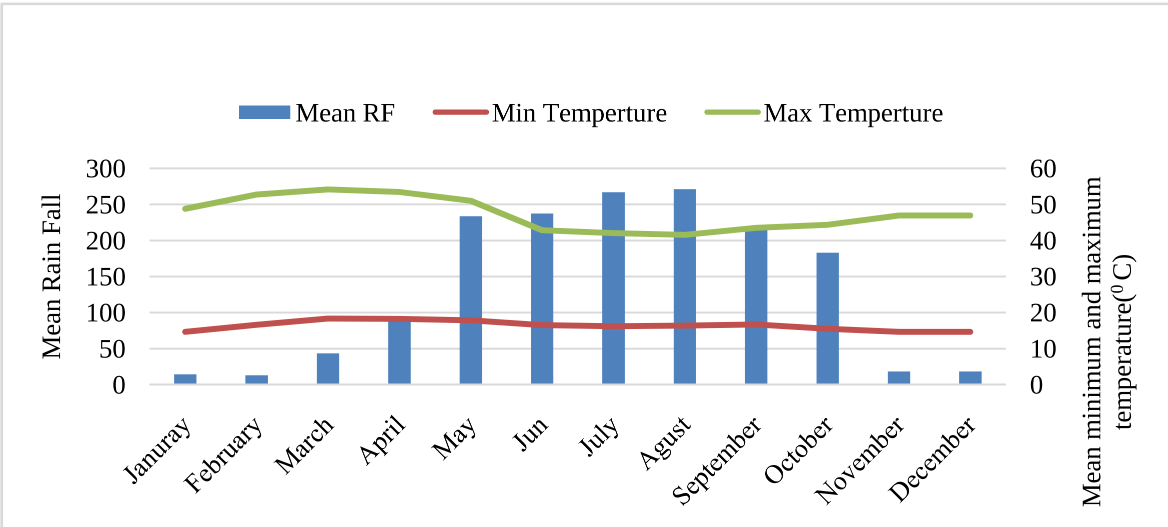

Fig. 2 Mean rain fall, minimum and maximum temperature of the study area.

2.2 Sampling technique

Sample plot of 20 m × 20 m was laid in the course of a systematic random sampling technique at every 200 m interval between each sample plot and 400 m intervals between each transect line. Finally, a total of 73 sample plots and seven transect lines were used for sampling of woody plants in the study area.

2.3 Vegetation data collection

All the woody plant species of fresh plant specimens were collected and pressed properly for identification of their names in the published volume Flora of Ethiopia and Eritrea that prepared by Bekele (1993). The number and height of trees/shrubs, seedlings, and saplings were recorded to determine the regeneration status of the study forest. The height and diameter at breast height (DBH) of trees/shrubs having ≥ 2.5 cm were measured from the main plots using hypsometer and DBH tape respectively. The height and diameter at ground level of seedlings and saplings were measured using a meter and a venerable caliper, respectively. Young woody plants were recorded as saplings having a height of > 50 cm and ≤ 2.5 coral diameters. Moreover, young woody plants were recorded as seedlings having ≤ 50 cm and ≤ 2.5 cm coral diameter, as recommended by Wale et al. (2012). Saplings were collected from 5 m x 5 m sub plot positioned at the midpoint of the main plot, while seedlings were collected from each of the five 1 m × 1 m areas of sub plots, which situated at the four corners and one at the midpoint of the main plot, following the methodology used by Singhal (1996).

2.4 Data analysis

2.4.1 Analysis of woody species diversity

The woody diversity of the study forest was estimated by using species richness, Shannon-Wiener diversity index, and Shannon evenness as follows:

Richness=N……………………………………………………………………….….Equation (1)

where N= Number of species found in the study area.

$H=\sum pi \ln Pi$……………………………………………………………………………Equation (2)

where H: Shannon-Wiener Index, Pi: proportion of individual tree species.

Shannon’s Evenness=$\frac{H'}{Hmax}$…………………………………..……………………..……..Equation (3)

where H' = Shannon diversity index, Hmax = the maximum level of diversity within a given population, which equals with Ln number of species.

2.4.2 Structural analysis of woody plants

The structure of woody plants was analyzed by DBH class, density, frequency, basal area, dominance, and important value index. The DBH/coral diameter of each woody species was measured, ranging from a minimum of 1 cm to the most important DBH of the tree at 170 cm. The DBH and coral diameter distribution of every woody species was categorized into five classes as (≤ 10 cm), (> 10 cm – 20 cm), (> 20 cm – 30 cm), (> 30 cm – 40 cm) and (> 40 cm). The following equations were used to scrutinize the remaining vegetation structural variables:

$\text{Density(stem/ha)} = \frac{\text{Number of individuals}}{\text{Sum of all plot areas}}$…………………………………..………...…Equation (4)

$\text{Frequency(\%)} = \frac{\text{Number of quadrants in which a species occur}}{\text{Total number of quadrants thrown in the study area}} \text{x100}$……......................Equation (5)

$BasalArea(m^2) = \frac{\pi(Dimateratbreat \quad eig \quad t)^2}{4}$……….……….…………………...…….Equation (6)

$\text{Important Value Index(\%)} = \frac{\text{RDO+RD+RF}}{\text{Frequency of all species}}$ ……...…………………………......Equation (7)

2.4.3 Analysis of the regeneration status of woody plants

The regeneration status of each woody plant species was determined by counting the total number of seedlings, saplings, and mature strata across all sample plots of the study area following the methodology used by Shankar (2001) as shown below.

1. Good, if the number of seedlings > saplings > mature strata
2. Fair, if the number seedlings >or ≤ saplings ≤ mature strata
   If seedlings ≤ saplings >mature strata
   If seedlings ≥ saplings and the species had no mature strata
3. Poor, if a species survives only in the sapling stage (even though saplings may be <, >or = mature)

4. None, if a species is absent both in sapling and seedling stages, but present as mature strata.
5. New, if a species has no mature, but only sapling and or seedling stages.

2.5 Statistical analysis

Descriptive statistics were used to summarize the data, including the maximum, minimum, mean, and standard deviations of richness; Shannon evenness; Shannon Wiener diversity index; and structure of woody plants, such as density, frequency, basal area, and important value index of woody plants in the study area. The statistical analysis was carried out with the help of the Statistical Package for Social Science (SPSS) software version 26.

3 Results and Discussion

3.1 Woody species richness

About 82 woody plant species having a total of 4,634 individuals belonging to 38 families were identified within the sample plots of Wacho forest. The largest and the least number of woody species in the study forest were placed in sample plots of 15 and 41, which accounted for 64 and 5 woody plant species, respectively (Fig. 3). The variation of woody species among sample plots of Wacho forest could be due to the presence of different disturbance regimes, topography, relative weather conditions, soil type, and soil texture. The total number of woody species found in Wacho forest (82) was greater than the entire number of woody species found in Zengena forest (50) (Tadele et al., 2014), and less than the entire number of woody species found in Tara Gedam forest (113) (Zegeye et al., 2011). The variations of woody species within the above study areas could be due to the degree of human-induced disturbances, geographical location, and the degree and type of management options. But also, it could be due to the regeneration success and computation of woody species for nutrients (Chen et al. 2004). Out of 38 families, Fabaceae was the most diverse families, having 10 species. The dominance of the Fabaceae family in the study forest could be due to the adaptation potential of Fabaceae species in the study area and probably due to having efficient pollination and successful seed dispersal mechanisms of the species (Ensermu and Teshome, 2008).

3.2 Shannon- wiener diversity index and Shannon evenness

The quantitative examination of woody species diversity and woody species evenness reveals the ways of sustainable forest conservation and management (Sarkar and Devi, 2014).Woody species diversity and woody species richness are the most important elements in forest ecology, which show the health of woody plant communities, and they are positively correlated with forest steadiness (Ahmad et al., 2020). The collection of information about forest ecology, such as the richness and diversity of woody species, provides a foundation for natural habitat conservation (Ao et al., 2021).

In the present study, the Shannon-Weiner diversity index (H’) of the study forest was high in the sample plot of 15 and low in the sample plot of 41 (Fig. 4). This variation could be due to the presence of different relative weather conditions, soil type, soil texture, slope gradient, altitudinal gradient, aspect, disturbance regime, site resource availability, dispersal patterns, competition, and natural harbors. The mean (H') of the study area was estimated to be 2.7, which is lower than the (H') of Tara Gedam forest (2.9) (Zegeye et al., 2011) and greater than the (H') of Ambo forest (0.27) (Melese and Ayele, 2017). According to Cavalcanti et al. (2004), the (H’) is high when it's above 3.0, medium when it's between 3.0 and 2.0, low when it's between 2.0 and 1.0, and really low when it's smaller than 1.0. Accordingly, the Shannon-wiener diversity index of the Wacho forest was medium. The possible reasons for the medium Shannon diversity index of the Wacho forest could be anthropogenic disturbances like harvesting of woody plants for charcoal production and overgrazing. The Shannon evenness lies between 0 and 1, when the value is close to 1; the abundance of all species is equally distributed in a given area, but close to 0 refers to disproportional species. The Shannon evenness of sample plots in Wacho forest weren't uniform, which changed from one sample plot to another sample plot of the study forest. The mean Shannon evenness of the study area was estimated to be 0.95, which shows that almost all woody species were equally distributed within the study area.

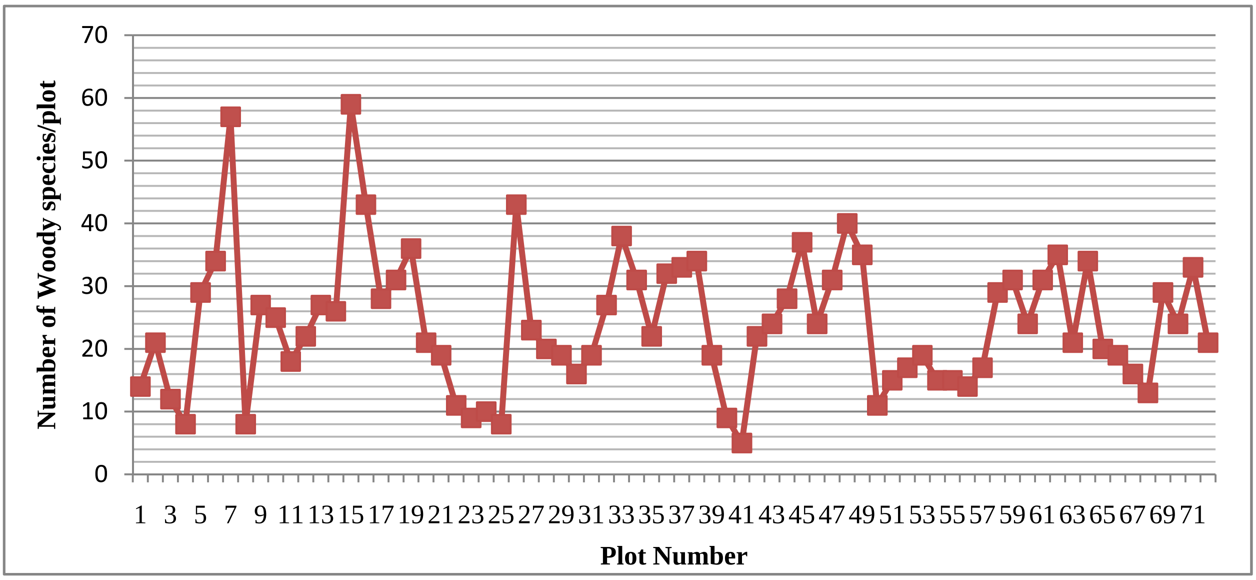

Fig. 3 Number of woody species per plot found within the study forest.

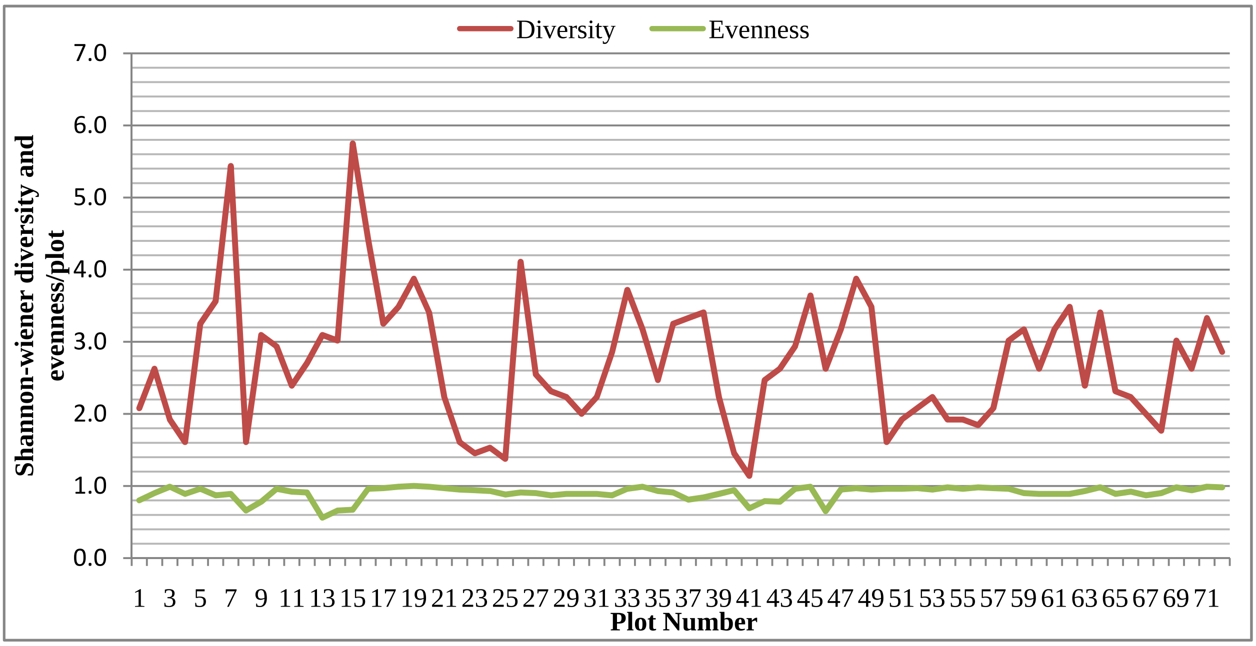

Fig. 4 Shannon wiener diversity and Shannon evenness of the study forest per plot.

3.3 Structure of woody species

3.3.1 DBH Distribution

The DBH of woody plants showed that the bulk of the woody species had a larger number in the lower DBH category and a lower number in the higher DBH category. More than half (50.6%) of the woody species were found in the first DBH category of the study forest (Fig. 5). The DBH category distribution of woody species within the Wacho forest indicated an inverted J-shaped distribution. This is a general pattern of normal population structure where the majority of the woody species had the highest number of individuals in the lower DBH category with a gradual decrease towards the higher DBH category. This shows more or less a healthy rate of regeneration and recruitment potential of young woody plants, particularly seedlings. The DBH class distribution of Wacho forest was in line with the DBH class distribution of Alesaga forest (Masresha et al., 2015) and Hallideghie wildlife reserve (Indris et al., 2017). The factors of altitudinal gradient, photoperiodic effects and thermo-periodic effects can affect the DBH of woody species (Kozlowski, 1964). Site factors and climatic conditions shape the DBH and growth of woody plants in the forest ecosystem (Houghton et al., 2001). The possible average increase in precipitation influences the growth and DBH of trees (Raich et al., 1997).

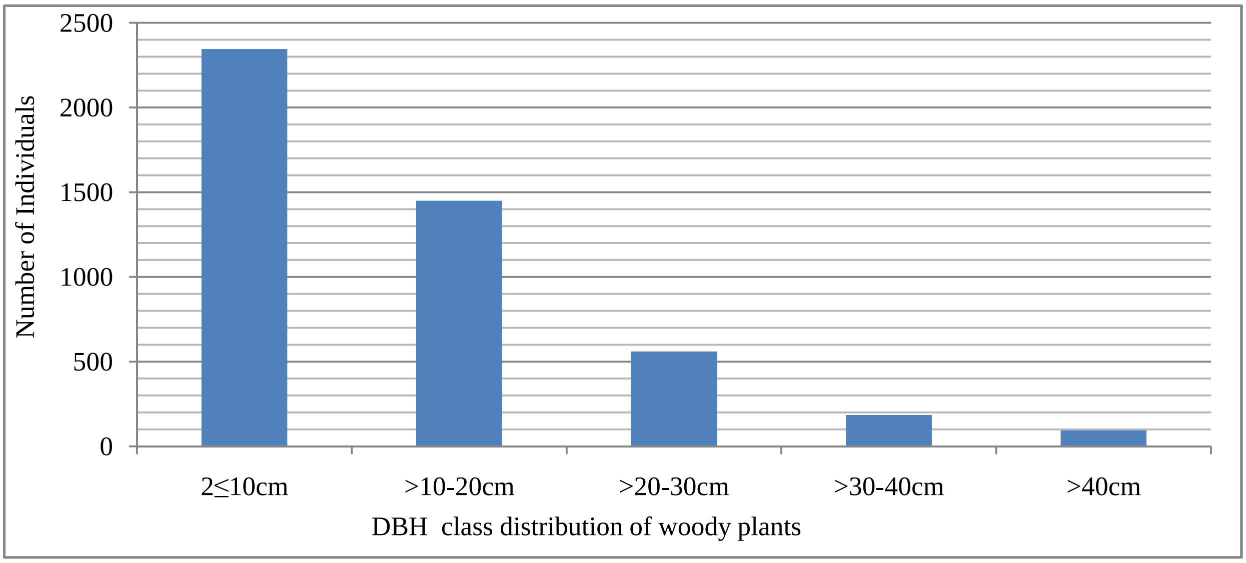

Fig. 5 Distribution of woody plants in DBH class.

3.3.2 Density

The variations in tree density are attributed to forest community type, tree species composition; forest age class, tree size class, site history, edaphics, and other factors (Saikia et al., 2017). Wacho forest had a total number of 1610 woody plants per hectare of land. The highest density of woody species was occupied by *Ehretia cymosa* (75 stems/ha), *Prunus africana* (75 stems/ha), followed by *Acacia abyssinica* (65 stems/ha), *Carissa edulis* (55 stems/ha), and *Albizia gumifera* (52 stems/ha). The largest and the least density of woody plants were found in sample plots 47 and 51, which accounted for about 103 and 25 stems/plot, respectively (Fig. 6). This variation could exist due to the presence of different disturbance regimes and topographic factors. Except for the above six densely listed woody species, other woody species in the study area were below 50 stem/ha (Appendix 1).

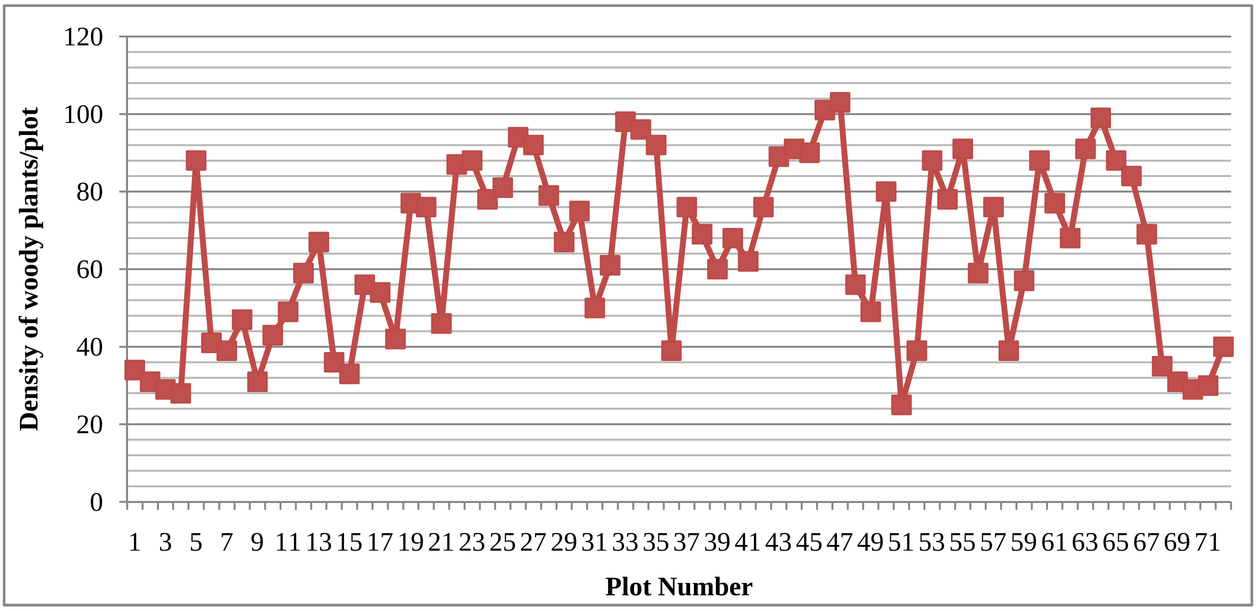

Fig. 6 Density of woody plants per plot found in the study forest.

3.3.3 Frequency

Among 82 woody species of the study forest, the largest frequency was occupied by *Acacia lahai* (77%), followed by *Acacia abyssinica* (75%), and *Carissa edulis* (73%). The frequency of each woody species within the study forest is shown in Appendix 1. The variation in the frequency of woody species within the study forest could be due to the presence of different seed dispersal mechanisms, altitudinal differences, and the degree of disturbance regime. This study was contrasted to the study of the dry Afro-Montane type of Danaba community forest (Bazezew et al., 2014), which found that *Juniperus procera* was the most frequent species in the Danaba community forest. Among the 73 sample plots of the study area, sample plot 26 and sample plot 4 had the largest and the least frequency of woody plants, which accounted for about 77 % and 3%, respectively (Fig. 7). This variation might be due to the soil structure, soil PH, and its nutrient content across sample plots of the study area.

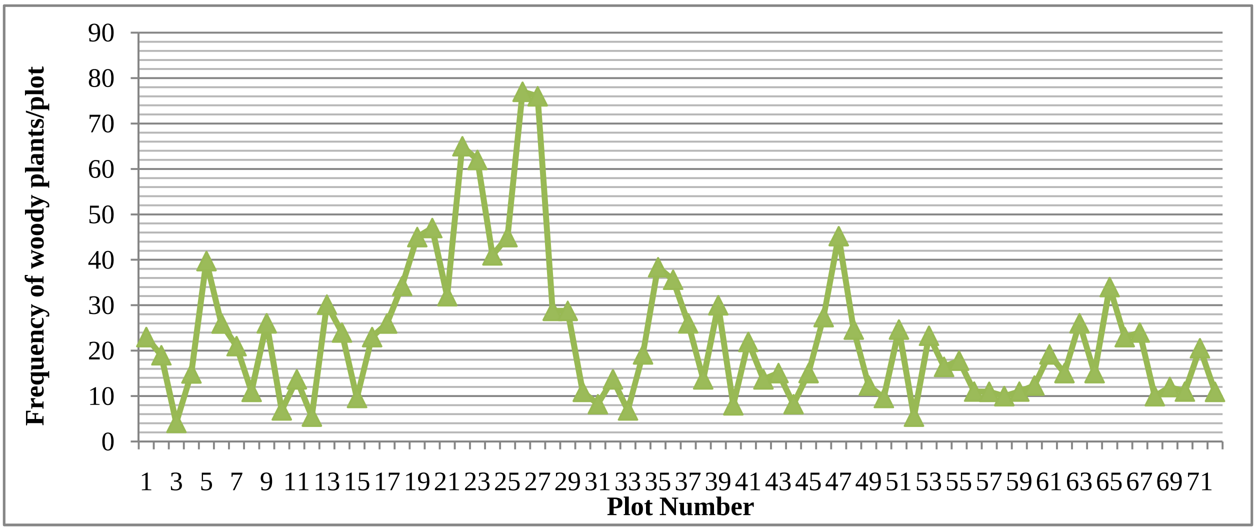

Fig. 7 Frequency of woody plants per plot found in the study forest.

3.3.4 Basal area

The total basal area of woody species in Wacho forest was 90.9 m^2/ha. Among 82 woody species of Wacho forest, only a few number of woody species such as *Ficus thonningii* (14.2 m^2/ha), *Syzygium guineense* (6.2 m^2/ha), *Ficus sur* (5.4 m^2/ha), *Myrica salicifolia* (5.2 m^2/ha), *Prunus africana* (5.25 m^2/ha), *Oncoba spinosa* (5.1 m^2/ha) were the principal contributors of basal area (Appendix 1). The basal area of Wacho forest was greater than the basal area of Alemsaga forest (75.3 m^2/ha)(Masresha et al., 2015), Jibat forest(49.8 m^2/ha) (Bekele, 1994), and lower than the basal area of Wofwasha foret (101 m^2/ha) (Teketay and Bekele, 1995) and Taragedam forest (115.4 m^2/ha) (Zegeye et al., 2011). From the 73 sample plots, the largest basal area of woody plants was found in sample plot number 36 with 14.27 m^2/plot, while the lowest least basal area of woody plants was found in sample plot number 27 with 0.01 m^2/plot (Fig. 8). The basal area of woody species can be influenced by the age of trees, girth of trees, disturbance regime, and climatic conditions (Onyekwelu and Olusola, 2014). The altitudinal difference, age structure, species composition, intensity of disturbance, and succession stage of the forest can also be another determining factor of basal area (Gogoi et al., 2020).

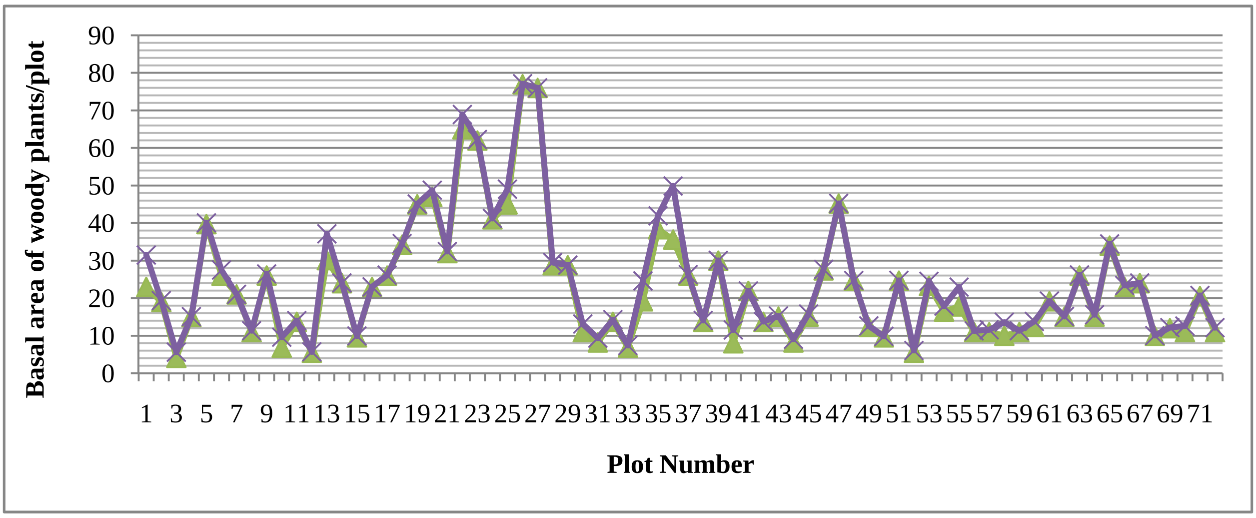

Fig. 8 Basal area of woody plants per plot found in the study forest.

3.3.5 Importance Value Index (IVI)

The IVI of the wacho forest ranged from 0.07% to 15.64%. Among 82 woody species of the study forest, *Prunus africana, Syzygium guineense,* and *Ficus thonningii* had the largest IVI with 15.64, 11.51, and 11.08 %, respectively. The IVI of each woody species within the study forest is shown in Appendix 1. Sample plot number 36 had the largest basal area with 10.4 %, while sample plot number 71 had the least basal area with 2.5 % (Fig. 9). The variation of IVI among sample plot of the study area could be due to the difference in nutrient accessibility across the sample plot of the study area. The IVI is a smart tool for assessing and identifying vegetation characteristics of a given area, which is used to evaluate and weight the ecological significance of plant species and for proposing and applying sound conservation measures (Bekele et al., 2014). It shows the level of dominance and abundance of a given plant species, and therefore its ecological significance, relative to the other co-existing plant species within the forest (Kent and Cooker, 1992).

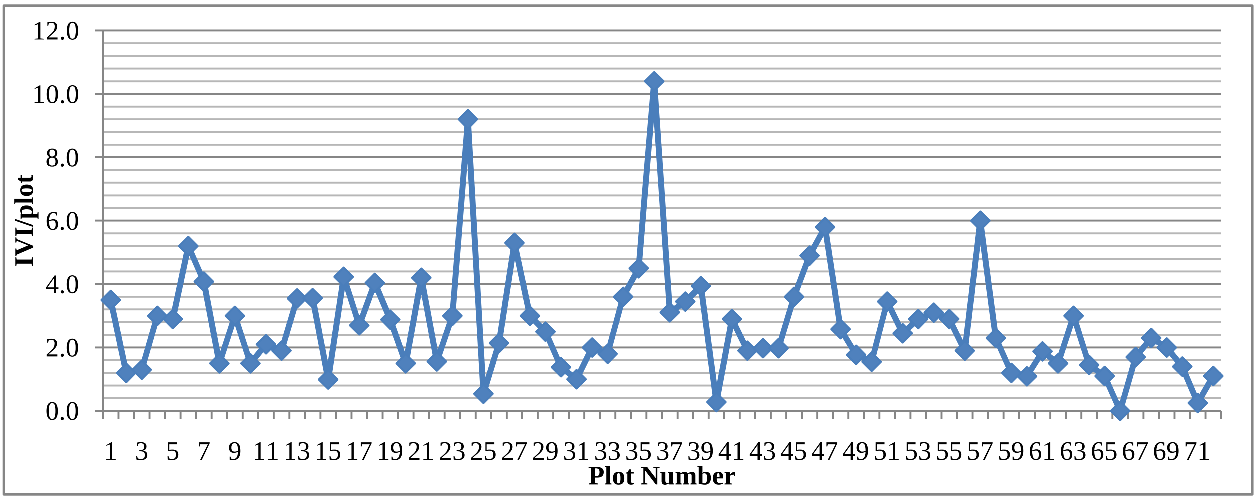

Fig. 9 IVI of the study forest per plot.

3.4 Regeneration status

In the present study, different woody species had different regeneration status (good, fair, poor, new, and none). The possible reasons for the variation of the regeneration status among woody species could be due to the preference of woody species for different activities of human beings. The browsing effect of animals could also be another factor that influences the regeneration status of woody species in the study area. Some woody species had only seedlings and saplings, which could be due to the selective cutting of the mature strata by the adjacent communities. The local communities have used the study forest for fencing, fuel wood, logging, fodder, and housing construction. Since the mature strata of some preferable woody species may be depleted by the local communities. All of the recorded stands of some woody species have existed in only mature strata, which could be due to the shading effect of the mature strata on seedlings and saplings and the viability and germination rate of seeds. Moreover, animal disturbances, seed predation, lack of sound sites for seed staffing, dormancy period of seeds, accumulation of litters, pathogens, moisture content, alternative adaptations for propagation other than seed germination could be another factor that depletes the regeneration status of seedlings and saplings in the study area (Shibru and Balcha, 2004).

The total number of seedlings, mature strata (trees and shrubs), and saplings in the Wacho forest was 1690, 1520, and 1434, respectively (Appendix 2). Since the overall regeneration status of the study forest was fair in which the number of seedling > the number of mature strata (trees and shrubs) > the number of saplings. The regeneration status of Wacho forest was in line with the regeneration status of Komba Daga natural forest (Geneme et al., 2015) and contradicts the regeneration status of Woynwuha natural forest (Mekonnen et al., 2015). The possible reasons for the variation of the regeneration status could be due to the degree of human-induced disturbance, management options, and climatic conditions within the above study area. The presence or absence of seedlings and or saplings determines the regeneration potential of woody plant species. The regeneration status of woody plant species can be predicted from the relative ratio of understory vegetation found in the total number of woody species in the forest (Khumbongmayum et al., 2006). The higher number of woody species at the seedling and sapling stage indicates the vital contribution of understory vegetation to regeneration status and biodiversity. The regeneration potential of forest in general and the densities of seedlings, saplings, and mature strata in particular can be influenced by both living and non-living factors. Moreover, anthropogenic and natural factors can also determine the regeneration status of woody plant species found in forest ecosystems (Bhuyan et al., 2003).The characteristics of the forest floor, micro-environmental variables, and diameter of woody plant species are indications of how well the forest is regenerating and is making use of site resources (Rao et al., 1990). The maintenance and conservation of biodiversity can be assured through regeneration of both understory and over-story vegetation. The good regeneration of a woody species depends on the capacity of seedlings and saplings to survive and grow. The good regeneration of woody species could be accredited to the high level of access to the restrictions imposed by the management of humans. Seedlings and saplings are more vulnerable to anthropogenic disturbances and environmental stress, thereby negatively affecting the regeneration potential of woody species (Onyekwelu et al., 2021).

4 Conclusion

Wacho forest had a medium Shannon Wiener diversity index and a proportional distribution of woody species across all quadrants. The structural analysis of the study forest indicates that the majority of the woody species had a larger number in the lower DBH class and a lower number in the higher DBH class, which shows an inverted J-shaped structure, and therefore the regeneration status of the study forest is situated under fair condition.

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Appendix 1 Structure of woody species in Wacho forest.

No.	Species (Scientific Name)	Family	DBH (cm)	Density (stem/ha)	Frequency (%)	Basal area (m^2/ha)	IVI (%)
1	*Acacia abyssinica*	Fabaceae	6	65	75.34	28.26	8.24
2	*Acacia lahai*	Fabaceae	6	28	76.71	0.35	6.02
3	*Acacia nilotica*	Fabaceae	5	5	4.11	1.51	0.62
4	*Acanthus pubescence*	Acanthaceae	2.4	14	28.77	0.11	2.44
5	*Albizia grandibracteata*	Fabaceae	6	28	39.73	0.35	4.05
6	*Albizia gumifera*	Fabaceae	17	52	65.75	1.52	8.07
7	*Allophylus abyssinicus*	Sapindaceae	2	33	36.99	0.03	4.08
8	*Apodytes dimidiate*	Icacinaceae	3	6	10.96	0.39	1.02
9	*Azadirachta indica*	Maliaceae	6	23	26.03	0.43	2.97
10	*Bercium gradiflorim*	Lamiaceae	9	8	6.85	2.76	1.23
11	*Bersama abyssinica*	Melianthaceae	4	13	13.7	0.33	1.63
12	*Bridelia micrantha*	Euphorbiaceae	1.8	4	5.48	0.23	0.55
13	*Buddleja polystachya*	Loganiaceae	6	33	30.14	0.3	3.82
14	*Calpurnia aurea*	Fabaceae	3.2	38	43.84	0.07	4.78
15	*Capparis tomentosa*	Capparidaceae	3.1	7	9.59	0.36	1.01
16	*Carissa edulis*	Apocynaceae	3	56	72.6	0.04	7.41
17	*Clutia abyssinica*	Euphorbiaceae	1.7	5	12.33	0.16	0.98
18	*Combretum molle*	Combretaceae	5.5	26	34.25	0.31	3.62
19	*Conyza hypoleuca*	Asteraceae	2.7	23	21.92	0.09	2.66
20	*Cordia africana*	Boraginaceae	6	6	9.59	1.77	1.03
21	*Croton macrostachyus*	Euphorbiaceae	7	31	39.73	0.44	4.26
22	*Cupressus lusitanica*	Cuppressaaceae	5	2	4.11	3.93	0.44

23	*Dichrostachys cinerea*	Fabaceae	4.4	19	23.29	0.28	2.53
24	*Dodonaea angustifolia*	Sapindaceae	5	28	17.81	0.25	2.8
25	*Dombeya torrida*	Sterculiaceae	6	2	4.11	4.04	0.54
26	*Dovyalis abyssinica*	Flacourtiaeae	3.1	19	16.44	0.13	2.14
27	*Ehretia cymosa*	Boraginaceae	2	75	41.1	0.01	6.89
28	*Ekebergia capensis*	Meliaceae	8	23	28.77	0.76	3.26
29	*Embelia schimperi*	Myrisnaceae	2	29	28.77	0.04	3.34
30	*Erica arborea*	Ericaceae	8	8	10.96	2.18	1.38
31	*Erythrina brucei*	Fabaceae	5	6	8.22	1.15	0.92
32	*Eucalyptus camaldulensis*	Myrtaceae	7	23	13.7	0.58	2.38
33	*Euphorbia ampliphylla*	Euphorbiaceae	4.8	11	6.85	0.57	1.16
34	*Ficus sur*	Moraceae	22	24	19.18	5.43	4.74
35	*Ficus sycomorus*	Moraceae	16	19	38.36	3.59	4.44
36	*Ficus thonningii*	Moaeracea	40	31	35.62	14.27	11.08
37	*Galiniera saxifrage*	Rubiaceae	3.9	15	26.03	0.27	2.42
38	*Grevillea robusta*	Proteaceae	5.9	25	13.7	0.38	2.45
39	*Grewia ferruginea*	Tiliaceae	3	30	36.99	0.08	3.91
40	*Hagenia abyssinica*	Rosaceae	3	1	1.37	3.53	0.16
41	*Hibiscus ludwigil*	Malvaceae	2	31	21.92	0.03	3.14
42	*Hypericum revolutum*	Hypericaceae	2	13	13.7	0.08	1.55
43	*Ilex mitis*	Aquifoliaceae	3	12	15.07	0.2	1.61
44	*Jasminum grandiflorum*	Oleaceae	3.8	5	8.22	0.87	0.79
45	*Juniperus procera*	Cuppressaceae	8	24	15.07	0.73	2.59
46	*Lepidotruchilia volkensii*	Meliaceae	4.5	20	27.4	0.27	2.84
47	*Leucas stachydiformis*	Lamiaceae	2.6	39	45.21	0.05	4.88
48	*Lippia adoensis*	Lamiaceae	2	20	24.66	0.06	2.58
49	*Maesa lanceolata*	Myricaeae	3.8	14	12.33	0.29	1.57
50	*Markhamia lutea*	Bignoniaceae	2.8	8	9.59	0.26	1.07
51	*Maytenus arbutifolia*	Celasteraceae	2.9	29	24.66	0.08	3.18
52	*Maytenus obscura*	Celastraceae	3.7	6	5.48	0.6	0.75
53	*Milletia ferruginea*	Fabaceae	9	18	23.29	1.22	2.74
54	*Myrsine africana*	Myrsinaceae	8	12	16.44	1.48	1.91
55	*Myrica salicifolia*	Myricaceae	17	15	17.81	5.16	3.22
56	*Ocimum lamiifolium*	Lamiaceae	2.1	4	8.22	0.31	0.7
57	*Olea africana*	Oleaceae	5	10	10.96	0.65	1.35
58	*Olea capensis*	Oleaceae	8	5	5.48	3.59	0.89
59	*Olinia rochetiana*	Oliniaceae	2	3	2.74	0.35	0.36
60	*Oncoba spinosa*	Flacourtiaceae	7	9	12.33	1.48	1.45
61	*Osyris quadripartite*	Santalceae	2	16	19.18	0.07	2.07
62	*Podocarpus falcatus*	Rubiaceae	2	17	15.07	0.06	1.91
63	*Pavetta abyssinica*	Rubiaceae	3.9	27	26.03	0.15	3.18
64	*Phytolacca dodecandra*	Phytolaccaceae	4.2	9	15.07	0.53	1.45
65	*Protea gaguediEngl*	Proteaceae	2	2	6.85	0.45	0.54
66	*Prunus africana*	Rosaceae	38	75	82.19	5.25	15.64
67	*Pteroloblum stellautm*	Fabaceae	2	28	28.76	0.04	3.32
68	*Rhus vulgaris Meikle*	Anacadriacceae	2	29	27.4	0.04	3.31

69	*Rosa abyssinica*	Rosaceae	3	20	36.99	0.12	3.29
70	*Rumex nervosus*	Polygonaceae	2	12	23.29	0.1	1.98
71	*Rydingia integrifolia*	Lamiaceae	3.1	14	20.55	0.19	1.99
72	*Sapium ellipticum*	Euphorbiaceae	6	10	10.96	1.01	1.36
73	*Schefflera abyssinica*	Araliaceae	8	13	19.18	1.36	2.12
74	*Seteganotaenia araliaceae*	Bignoniaceae	15	34	38.36	1.82	5.18
75	*Solanecio mannii*	Asteraceae	2	3	9.59	0.39	0.71
76	*Syzygium guineense*	Myrtaceae	35	48	54.79	6.92	11.51
77	*Vangueria madagascariensis*	Rubiaceae	2	3	2.74	0.39	0.34
78	*Teclea nobilis*	Rutaceae	3	5	4.11	0.47	0.59
79	*Terminalia laxiflora*	Combretaceae	2	2	2.74	0.45	0.32
80	*Vepris dainellii*	Rutaceae	2	7	5.48	0.17	0.72
81	*Vernonia amygdalina*	Asteraceae	2.2	31	30.14	0.04	3.54
82	*Vernonia auriculifera*	Asteraceae	2	14	16.44	0.08	1.79

Appendix 2 Regeneration status of Wacho forest.

No	Botanical name	Total No. of woody plants	No. of seedling	No. of sapling	No. of mature strata	Regeneration status
1	*Acacia abyssinica*	320	115	100	105	Fair
2	*Acacia lahai*	100	45	29	26	Good
3	*Acacia nilotica*	108	49	27	32	Fair
4	*Acanthus pubescence*	60	22	18	20	Fair
5	*Albizia grandibracteata*	70	30	19	21	Fair
6	*Albizia gumifera*	100	40	29	31	Fair
7	*Allophylus abyssinicus*	90	37	33	20	Good
8	*Apodytes dimidiate*	19	0	0	19	None
9	*Azadirachta indica*	55	0	0	55	None
10	*Bercium gradiflorim*	80	37	13	30	Fair
11	*Bersama abyssinica*	220	100	58	62	Fair
12	*Bridelia micrantha*	87	45	20	22	Fair
13	*Buddleja polystachya*	220	100	57	63	Fair
14	*Calpurnia aurea*	40	0	0	40	None
15	*Capparis tomentosa*	30	18	4	8	Fair
16	*Carissa edulis*	6	0	0	6	None
17	*Clutia abyssinica*	102	5	97	0	New
18	*Combretum molle*	135	58	50	27	Good
19	*Conyza hypoleuca*	11	5	2	4	Fair
20	*Cordia Africana*	2	0	0	2	None
21	*Croton macrostachyus*	58	4	54	0	New
22	*Cupressus lusitanica*	11	0	0	11	None
23	*Dichrostachys cinerea*	90	40	38	12	Good
24	*Dodonaea angustifolia*	220	85	75	60	Good
25	*Dombeya torrida*	90	60	8	22	Fair
26	*Dovyalis abyssinica*	40	29	5	6	Fair
27	*Ehretia cymosa*	9	0	0	9	None
28	*Ekebergia capensis*	5	0	0	5	None

29	*Embelia schimperi*	50	37	5	8	Fair
30	*Erica arborea*	24	13	5	6	Fair
31	*Erythrina brucei*	22	13	4	5	Fair
32	*Eucalyptus camaldulensis*	22	16	2	4	Fair
33	*Euphorbia ampliphylla*	11	5	2	4	Fair
34	*Ficus sur*	90	0	0	90	None
35	*Ficus sycomorus*	9	4	2	3	Fair
36	*Ficus thonningii*	220	90	60	70	Fair
37	*Galiniera saxifrage*	22	0	0	22	None
38	*Grevillea robusta*	30	0	0	30	None
39	*Grewia ferruginea*	6	0	0	6	None
40	*Hagenia abyssinica*	12	0	0	12	None
41	*Hibiscus ludwigil*	5	0	0	5	None
42	*Hypericum revolutum*	72	42	14	16	Fair
43	*Ilex mitis*	4	0	0	4	None
44	*Jasminum grandiflorum*	29	15	5	9	Fair
45	*Juniperus procera*	79	49	13	17	Fair
46	*Lepidotruchilia volkensii*	2	0	2	0	Poor
47	*Leucas stachydiformis*	27	17	4	6	Fair
48	*Lippia adoensis*	29	18	4	7	Fair
49	*Maesa lanceolata*	62	29	16	17	Fair
50	*Markhamia lutea*	46	0	0	46	None
51	*Maytenus arbutifolia*	2	0	0	2	None
52	*Maytenus obscura*	6	0	0	6	None
53	*Milletia ferruginea*	2	0	0	2	None
54	*Myrsine africana*	2	0	0	2	None
55	*Myrica salicifolia*	22	9	6	7	Fair
56	*Ocimum lamiifolium*	61	36	10	15	Fair
57	*Olea africana*	2	0	0	2	None
58	*Olea capensis*	2	0	0	2	None
59	*Olinia rochetiana*	2	0	0	2	None
60	*Oncoba spinosa*	42	29	6	7	Fair
61	*Osyris quadripartite*	51	26	10	15	Fair
62	*Podocarpus falcatus*	42	29	5	8	Fair
63	*Pavetta abyssinica*	40	29	5	6	Fair
64	*Phytolacca dodecandra*	35	26	4	5	Fair
65	*Protea gaguediEngl*	20	14	2	4	Fair
66	*Prunus africana*	19	13	2	4	Fair
67	*Pteroloblum stellautm*	90	0	0	90	None
68	*Rhus vulgaris Meikle*	42	25	8	9	Fair
69	*Rosa abyssinica*	33	12	10	11	Fair
70	*Rumex nervosus*	25	10	7	8	Fair
71	*Rydingia integrifolia*	33	15	8	10	Fair
72	*Sapium ellipticum*	6	0	0	6	None
73	*Schefflera abyssinica*	90	0	90	0	New
74	*Seteganotaenia araliaceae*	247	7	240	0	New

75	*Solanecio mannii*	42	18	11	13	Fair
76	*Syzygium guineense*	28	0	0	28	None
77	*Vangueria madagascariensis*	43	26	12	5	Good
78	*Teclea nobilis*	43	0	0	43	None
79	*Terminalia laxiflora*	111	4	107	0	New
80	*Vepris dainellii*	174	80	80	14	Fair
81	*Vernonia amygdalina*	34	10	23	1	Good
82	*Vernonia auriculifera*	2	0	0	2	None
	Total	4644	1690	1520	1434	

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