Scientific Research Publishing

Open Journal of Ecology, 2024, 14, 789-813
https://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Regeneration Status, Population Structure and Floristic Composition of Woody Plant Species in *Sheleko Medicinal* Natural Forest, South Gondar Zone, North West Ethiopia

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How to cite this paper: Alemayehu, T.G., Muche, K.H., Rao, C.B. and Chitra, D.S.V. (2024) Regeneration Status, Population Structure and Floristic Composition of Woody Plant Species in *Sheleko Medicinal* Natural Forest, South Gondar Zone, North West Ethiopia. *Open Journal of Ecology*, **14**, 789-813.
https://doi.org/10.4236/oje.2024.1410045

Received: June 29, 2024
Accepted: October 28, 2024
Published: October 31, 2024

Abstract

Ethiopia is one of the countries in the world endowed with rich biological resources. However, due to human impacts, the forest cover in Ethiopia has been decreasing rapidly. The study was carried out with the purpose of finding out the Regeneration Status, Population Structure and Floristic composition of Woody Plant Species in Sheleko Medihanialem Natural Forest in Gondar, North West Ethiopia, from October 2019 to September 2020. The systematic vegetation sampling method was used to collect data from Fifty plots of 20 m × 20 m (400 m^2) along five line transects. In addition, five, 5 m × 5 m subplots were laid within the main plot to sample seedlings and saplings. The floristic composition and population structure of woody individuals of trees and shrubs with a diameter at breast height (DBH) ≥ 2.5 cm and height ≥ 2 m were measured. DBH ≤ 2.5 cm and less than 1 m height were considered as seedlings and DBH ≥ 2.5 cm and height of 1 - 2 m as saplings. Vegetation data of density, frequency, basal area, and importance value index were computed. A total of 65 woody plant species in 54 genera and 34 plant families were recorded. Fabaceae, Moraceae and Euphorbiaceae were the dominant families in terms of species richness. Woody species densities for mature individuals were 2202.5 stems·ha^{-1}, seedling 2419.2 stems·ha^{-1} and sapling 1737.6 stems·ha^{-1}. The forest was dominated by small-sized/young trees and shrubs, indicating the status of secondary growth and/or regeneration.

Keywords

Population Structure, Regeneration Status, Sheleko Medhanialem Forest, Woody Plant Species

1. Introduction

In the Horn of Africa, Ethiopia is a biodiversity hotspot, with a diverse woody flora and a substantial number of unique species. Loss of forest cover and biodiversity due to anthropogenic activities is a growing concern in many parts of the world [1]. Africa's forest cover is estimated to be 650 million hectares, constituting 17% of the world's forests including a number of global biodiversity hotspots [2].

Forests do, in general, harbor the majority of the Earth's terrestrial species [3]. Forests are also crucial for Ethiopia's terrestrial ecological diversity. Even though there are some exceptions, such as agro forestry systems [4]-[6]. Despite the fact that anthropogenic activities have reduced the overall vegetation cover of woodlands in Ethiopia [7], it remains a key source of woody species diversity.

The deterioration of vegetation cover is one of the most severe environmental issues faced by humankind today [8]. In this respect, Ethiopia is fronting severe land degradation in both the highlands and the lowlands due to deforestation, agricultural land expansion, and continuous heavy grazing [9], which strongly negatively affect ecosystem services of the area. The regeneration of a species is affected by both natural and anthropogenic factors [10]. Regeneration is critical in a forest because it determines future species composition and stocking. The lack of adequate forest regeneration is an issue recognized by both foresters and ecologists [11].

In Ethiopia, as elsewhere in the globe, anthropogenic impacts are the most significant threats to natural vegetation. Ethiopia has seen a significant improvement as a result of the collaborations of the communities, government, and non-governmental organizations in the restoration of degraded areas [12].

Sacred groves are community-preserved, often small, forest patches in which certain spiritual, cultural, or religious values contribute to the conservation of biodiversity and ecosystem services [13]-[15]. Ethiopian church forests, a type of sacred forest, represent a third, hybrid approach to forest protection that incorporates elements of both the top-down Bparks and bottom-up common property models. Sacred forests—also known as sacred groves and fetish forests—are a worldwide phenomenon where, broadly speaking, forests are protected because they have both cultural and spiritual significance to the people who live around them [15] [16]. Conservationists celebrate them because they play a key role in maintaining both cultural and biological diversity in areas affected by land system change [17]-[20]. *Juniperus procera* was the most common species in Ethiopian church forests, with a frequency of 94.12%, followed by *Olea europaea*, *Maytenus* *arbutifolia*, *Osyris quadripartite*, *Acacia abyssinica*, *Dodonaea viscosa*, *Allophylus abyssinicus*, *Calpurnia aurea*, *Rhus glutinosa*, and *Clutia aby* [21]. Despite this, the church forest is threatened by fragmentation and a scarcity of viable seeds. Human motion in the church environment trampling seedlings and reducing the recruitment of woody species [22]. The sacred church woodlands protected with a wall showed much higher seedling species richness than forests without a fence at the same heights, according to the same survey.

Natural regeneration is influenced by a number of elements, including canopy gap size, degree of disturbance, soil condition, moisture, seed source and quality, and forest structure [23] [24]. However, much of the present research on Ethiopia's woody species diversity and regeneration metrics [21] [25] [26], for example, is focused on seedling and sapling density. This does not assist us in grasping the entire process of woody species regeneration, and it indicates a research vacuum in the country's woody species regeneration studies.

The diversity, structure and regeneration status are crucial elements to clearly visualize the human activities as well as environmental factors affecting the vegetation of an area. Sheleko Medihanialem natural forest has a rich biodiversity. However, its rich biodiversity resources are being destroyed at an alarming rate largely due to human related activities and a lack of integration of the local people living around the forest.

No other study has been conducted on the diversity of woody plant species, their structure, and their regeneration status in Sheleko Medihanialem natural forest. Thus, the study of woody plant species diversity, structure and regeneration status is very important for conservation and management of the forest for sustainable use. Therefore, this study was initiated to provide primary information on the diversity of woody plant species, as well as the structure and regeneration status of the forest, to call for immediate and timely scientific solutions to support the conservation of this natural forest from further depletion.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Sheleko Medhanialem forest, which is found in Fogera woreda, South Gondar Zone, Amhara Region. Fogera woreda is one of the 169 districts of the Amhara Regional State, found in South Gondar Zone. It is situated at 11˚46' to 11˚59' latitude North and 37˚33' to 37˚52' longitude East. Woreta is the capital of the woreda and is located 625 km from Addis Ababa and 55 km from the regional capital, Bahir Dar (**Figure 1**). The woreda is bordered by Libo Kemkem Woreda in the North, Dera Woreda in the South, Lake Tana in the West and Farta Woreda.

2.2. Temperature and Rainfall

The area has a uni-modal rainfall distribution pattern. The climate diagram of the study area was drawn based on 10 years of data. The mean annual rainfall in the study area was about 1401 mm, and its peak period was from July to October. There was a decreasing rainfall trend from November to December and none or very little from January to May. The mean minimum and maximum temperatures of the area were 21˚C, 13.5˚C and 29.8˚C respectively (Amhara Metrological Service Center from 2010 to 2019) (Figure 2).

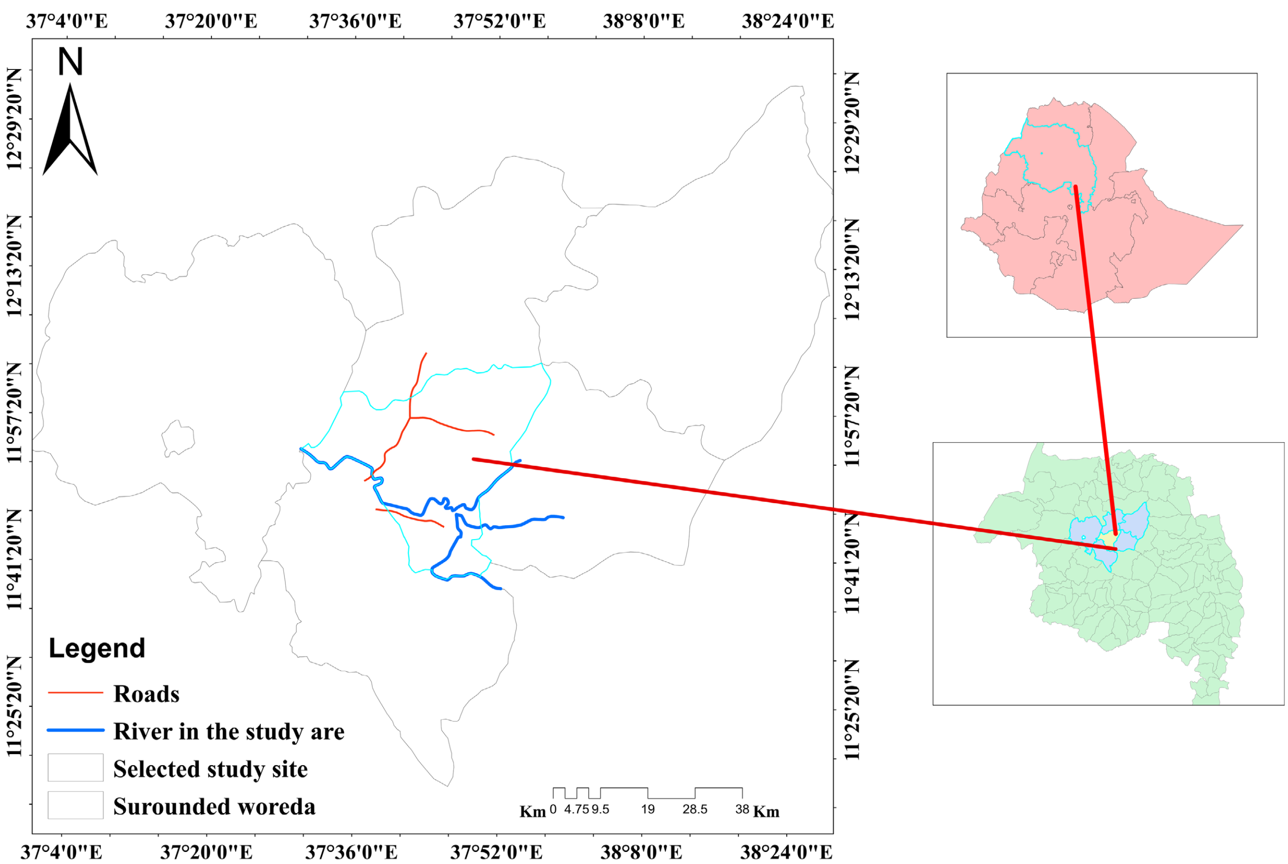

Figure 1. Map of the study area.

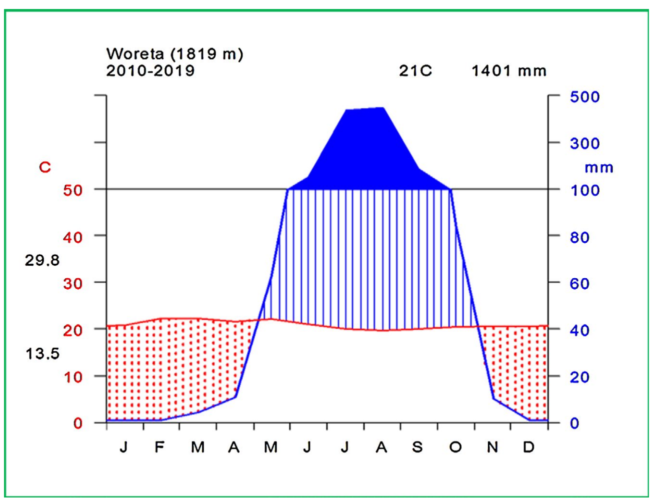

Figure 2. Climate diagram for Woreta town showing rainfall distribution and temperature variation from 2010 to 2019. [Data source: Amhara Meteorological Service Center (AMSC, 2020)]

3. Methods

3.1. Preliminary Survey

Preliminary survey was done on the first week of November 2019 across the forest to get an overview of the forest to select sampling points and determine the sample size. During the preliminary survey, contact was made with relevant and concerned authoritative bodies and with the people living around the forest. The survey was useful in providing a general understanding of the existing conditions of the study forest.

Sampling design

Systematic random sampling design was applied in this study. Sheleko Medhanialem church forest has an area of 250 hectares. Among this area of the forest 20, 000 m^2 area was sampled. Five parallel line transects were systematically laid at every 200 m distance between consecutive transects in the North to South direction. The first line transect started at 50 meters distance away from the edge of the forest to avoid "edge effect". A total of 50 sample plots having an equal size of 20 m × 20 m (400 m^2) were laid along transect lines, to collect data on matured alive woody species at a horizontal distance of 100 m from each other. Within the main plot 5 m × 5 m subplots were laid four at the corners and one in the middle for seedling and sapling data collection.

Woody plant species data collection and identification

The actual data collection was conducted from December 2019 to January 2020. All woody plant species encountered in each plot were recorded by their local (vernacular) names. Local names of the woody plant species were provided by informants who were born, brought up, and lived around the study forest area throughout their lives. Woody plant species occurring outside the plots but inside the forest within 10m distance from plots were also recorded only as 'present', but not used in the subsequent data analysis [27]. To avoid confusion, colored chalk and tally sheet were used to mark and record woody plants respectively. Taxonomic identification was made by referring to the published volume of the flora of Ethiopia and Eritrea [28] as well as personal expertise. For the purpose of regeneration assessment, the seedlings and saplings from the five subplots were counted for each species. In this study, a seedling was considered a woody individual with a DBH < 2.5 cm and a height of 1 - 2 m.

Environmental data collection

The latitude, longitude and altitude were taken from the center of each main plot (Appendix 5) and measured using global position system (GPS) (Garmin 64 GPS). The center of the main plot was found by stretching two ropes from horizontally and vertically stretched ropes and assisted by GPS. Aspect was recorded as N = 0; E = 2; S = 4; W = 2.5; NE = 1; SE = 3; SW = 3.3 and NW = 1.3 using compass. The type of disturbance was also visually evaluated and recorded for each plot. Disturbances were recorded using the scales 1 - 5 based on the Ethiopian Biodiversity Institution (EBI) field manual. Thus 0 = Negligible, 1 = Very light, 2 = Light, 3 = Moderate, 4 = Intensive and 5 = Very intensive.

3.2. Data Analyses

Vegetation Data analyses

Structural and diversity data analyses

The structure and composition of forests was determined following [29]. The importance value index (IVI) was calculated as R (ni/N) ln (ni/N), where *ni* is the importance value index of a single species and *N* is the sum of the *IVI* values of all species. The *IVI* of each species was calculated by adding the relative values of their *frequency*, *density*, and *basal area*. Canonical correspondence analysis (CCA) was done to analyze the relationship between the environmental variable and vegetation data by fitting the data into the ordination scatter plot. Data analysis of the Sorensen's similarity coefficient in species composition of Sheleko Medihanialem forest was made with six other Afromontane forests found in Ethiopia.

Regeneration data analyses

The regeneration status of woody plant species was determined based on the population sizes of seedlings, saplings, and adults. Regeneration status of the forest was analyzed by comparing saplings and seedlings with the matured trees according to [30], the status was good regeneration, if seedlings > saplings > adults; fair regeneration, if seedlings > or ≤saplings ≤ adults; Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be or = adults); and if a species is present only in an adult form it is considered as not regenerating.

4. Results and Discussions

4.1. Floristic Composition and Woody Plant Species Richness of the Study Forest

A total of 65 woody plant species in 55 genera and 34 plant families were identified from Sheleko Medhanialem forest (Appendices 1 & 2). Four species were observed outside the plot but within the forest and used to make the complete list of woody plant species in Sheleko Medhanialem forest. These were *Eucalyptus camaldulensis* Dehnh, *Ficus ingens* Miq., *Olea europaea* subsp. Cuspidate (Wall. ex G. Don) Cif and *Vernonia amygdalina* Del.

The species richness of the forest was higher than some other forests of Ethiopia, e.g. Ambo state forest with 58 species located in South Gondar Zone [31], and Wogello natural forest with 20 species in North Gonder [32]. On the other hand, the species richness of Sheleko Medhanialem forest was less than that of several other dry Afromontane forests like Woynwuha natural forest with 69 species in East Gojjam [33], Sesa Mariam forest with 113 species in Northwest Ethiopia [34]. The variations in the species richness of different forests might be due to several reasons like climate, soil PH and variations in the intensities of human caused disturbances. Forests with a high degree of human interference and disturbance due to livestock grazing for prolonged periods show relatively lower species richness than others [35].

The major families recorded in this study were Fabaceae represented by 14 species (21.54%) followed by Moraceae with 6 species (9.23%), and Euphorbiaceae with 4 species (6.15%), Oleaceae with 3 species (4.62%), Asteraceae, Acanthaceae, Celastraceae, Lamiaceae, Apocynaceae, Malvaceae, Combretacae, Myrtaceae each with 2 species (24.62% each). Each of the remaining 22 families was represented by one species (33.85%) (Appendix 2). The most diverse genus was *Ficus* with 6 species (9.23% of the total species number recorded) followed by *Vernonia*, *Maytenus*, *Senna*, *Senegalia* and *Vachellia* containing 2 species (3.08% each contributing to the species richness recorded in this study) and the rest genera contain 49 species (87.69%). Among the 65 recorded woody plant species 32 (49.23%) were shrubs, 29 (44.62%) were trees and 4 (6.15%) were lianas.

Different studies [36] [37] from his study of Gedo Dry Evergreen Montane Forest, West Shewa Zone of Oromia National Regional State, Central Ethiopia, reported the dominance of Fabaceae, Poaceae and Asteraceae in Afromontane vegetation type, but only family Fabaceae fulfills this report in the study area. The dominance of the families of Fabaceae and Moraceae were agreed with the result of Ambo state forest, 17 and 8 species in each respectively [32]. This dominance could be related to its ecological adaptations to its habitat conditions. The dominance of Fabaceae was also reported in similar vegetation studies [38]. The dominance may indicate the suitability of the environmental conditions for Fabaceae.

4.2. Density and DBH Class Distribution of Woody Plant Species

The overall density of mature woody species with DBH > 2.5 cm in Sheleko Medhanialem forest was 2202.5 stems·ha^{-1}. This was classified into seven density classes (**Figure 4**) 1) < 5, 2) 5.01 - 20, 3) 20.01 - 35, 4) 35.01 - 50, 5) 50.01 - 65, 6) 65.01 - 80, 7) > 80 stems ha^{-1}. Only nine plant species contributed 79.25% of the total density from the density class 7 which was due to the dominance of species *Carisa spinarum*, *C. aurea*, *M. obscura*, *G. ferruginea*, *C. tomentosa*, *P. schimperi*, *R. glutinosa*, *P. stellatum* and *C. macrostachyus*. From density class 1 *S. kunthianum*, *F. sycomorus*, *Ficus palmata*, *Dichrostachys cinerea*, *Acokanthera schimperi*, *Entada abyssinica*, *F. sur*, *P. thonningii* and *Bridelia micrantha* contributed only 0.23% of the total density, and those which are represented with less number of species and thus need conservation attention (Appendix 3).

The distribution of matured woody plant species of the study area was classified into seven DBH classes. Class A = 2.5 - 5 cm, B = 5.01 - 10, C = 10.01 - 15 cm, D = 15.01 - 20 cm, E = 20.01 - 30 cm, F = 30.01 - 40 cm, G ≥ 40 cm. The first class had the highest distribution of species density per hectare (1326.5 ha^{-1}, 60.23%), the second takes (624 ha^{-1}, 28.33%) and the 3rd, 4th, 5th and 6th takes (196.5 ha^{-1}, 8.92%), (25 ha^{-1}, 1.14%), (21 ha^{-1}, 0.95%), (2.5 ha^{-1}, 0.11%), finally the last class takes (7 ha^{-1}, 0.32%) (**Figure 3**).

In the present study, the density of trees individuals in Sheleko Medhanialem forest with DBH greater than 2.5, 10 and 20 cm (**Figure 4**). The density of trees with DBH greater than 2.5 was 1950.5 ha $^{-1}$. The number of stems with DBH > 10 cm was found to be 221.5 ha^{-1} and those with DBH > 20 cm was 30.5 ha^{-1}. The ratio of DBH >10 cm to DBH > 20 cm is very high (7.26).

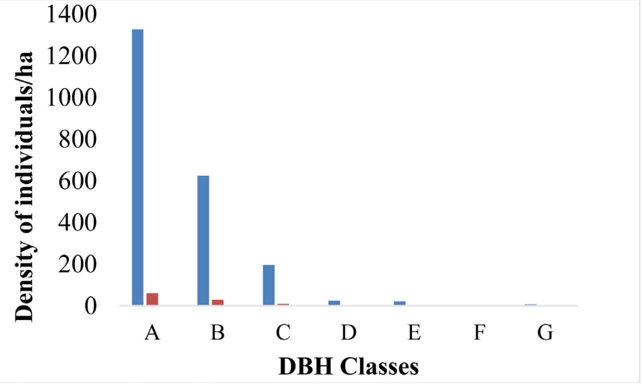

Figure 3. The distribution of matured woody plant species of the study area was classified into seven DBH classes.

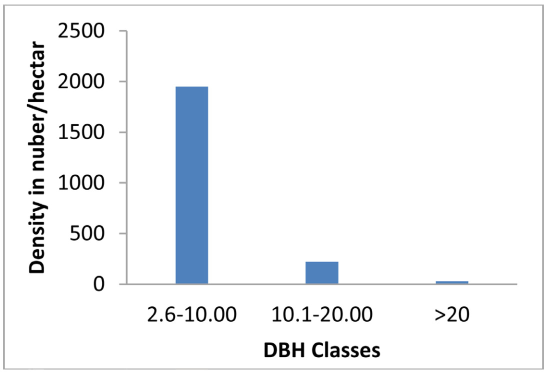

Figure 4. The distribution of all seedlings, saplings and matured woody plant species of the study area were classified into three DBH classes.

The density of seedlings, saplings and mature plants of the Sheleko Medanialem forest was 2419.2 ha^{-1}, 1737.6 ha^{-1} and 2202.5 ha^{-1} respectively. The total density of woody plant species in 36 sample plots of Chilimo-Gaji Forest was 3328.47 individuals·ha^{-1} [38]. In the same study, the total density of seedlings, saplings and trees/shrubs were 1743.7, 827.1 and 757.6 ha^{-1}, respectively (Appendix 5). The density value of seedlings and saplings is considered as an indicator of regeneration potential of the species [39] in which the presence of good regeneration indicates the suitability of the environment to the species, which is in turn affected by climatic factors and biotic interference influence.

Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults) and if a species is present only in an adult form it is considered as not regenerating [31]. The documented woody species have shown stable population structures composed of the highest density of individuals at the lowest DBH class followed by gradually declining densities of individuals with increasing DBH classes [40]. The presence of seedling recruitment is a building block in the population dynamics of many species of trees [41]. So that it is one of the important points in determining local abundance and diversity of mature trees.

The result showed that there are more seedlings than saplings and mature individuals implying the survival of seedlings to reach the sapling stage and the forest is now in a fair regeneration. The presence of a sufficient number of seedlings, saplings, and trees in a forest indicates successful regeneration [42]. The density of species regeneration is expected to vary spatially because of forest structure and physiographic conditions [11]. However, there are also species with no seedlings and saplings that may be caused by the physical condition of their microhabitat and human impacts, and urgent measurements need to be taken as they are in poor regeneration. This means there is no regeneration potential for the particular plant species or the study forest in general. The causes of failure to regenerate include lack of viable seed production, insect and animal predation, unfavorable microclimatic conditions, overgrazing, habitat changes, and biological invasions. The understanding of processes affecting the patterns of regeneration of forest-forming species is of crucial importance to ecologists and forest managers [43].

The ratio of DBH > 10 cm to DBH > 20 cm is very high (7.26). Sheleko Medhanialem forest has more trees in lower DBH classes than in the higher classes when compared to Gedo Forest [37], Chilmo and Menagesha forests [28]. The reasons behind these may be geographical location, the nature of the forest, altitude variation, age of the forest, degree of conservation and exposure to disturbance.

4.3. DBH Distribution Patterns

DBH distribution patterns indicate the general trend of population dynamics and recruitment processes for a given species. In this study, DBH class distribution of individuals in different size classes, except in the 5th class showed an inverted J shape distribution. This means that large numbers of individuals are distributed in the lower classes which later decreases in the following upper classes. Large percentage (60.23%) and (28.33%) of individuals were distributed in the 1st and 2nd DBH classes respectively whereas only 11.44% of individuals were distributed in the remaining upper classes. Analysis of some selected species in the study site revealed three general patterns. The first type of pattern was an inverted J-shape. It shows a high number of species in the lower DBH classes and a reduction in the highest DBH classes. This pattern was exhibited by the species *Pittosporum viridiflorum* Sims.

The second type of population pattern was bell-shaped and is characterized by the species *Croton macrostachyus* Del.; It shows a fairly high number of individuals of the species in the middle DBH classes but lower numbers of individuals of the species in the lower and higher DBH classes. This species has poor recruitment potential which might be due to intense competition between the other species found in its surroundings and also were use of this tree for making fencing, fuel wood, charcoal, and agricultural tools. The third type of population pattern is represented by *Acacia persiciflora* Pax.; In such a pattern, the number of individuals increases with increasing DBH up to some point and then decreases with increasing DBH. The pattern continues to decrease to some extent and increase density as DBH increases. This population structure pattern showed an irregular or zigzag type of distribution and is not healthy because of selective removal of the species for charcoal, fuel wood and making agricultural tools.

Successful management and conservation of natural forests requires reliable data on aspects such as the regeneration trends [44]. Forest stands, where there are numerous young individuals and lesser mature ones, are recognized as having an inverse J-curve diameter distribution [45].

4.4. Dominant Plant Species

The total dominance of woody species in the forest was 49.78 $m^2 \cdot ha^{-1}$. From recorded woody plant species, the most dominant species in Sheleko Medhanialem forest was *A. lahai* which contributed 16.13% followed by *S. guineense* which contributed 10.35% and *C. aurea* which contributed 7.87%. But the least dominant species were *F. sur*, *Combretum collinum*, *P. thonningii*, *Justica schimperiana*, *E. abyssinica*, *T. brownii*, *S. kunthianum*, *H. mystacinus*, *F. palmata*, *A. schimperi*, *F. sycomorus* and *D. cinerea* which contributed 0.1% of the total dominance. According to [24] the high dominance and/or abundance of a few species in a forest could be attributed to a number of factors, such as the overharvesting of the desired species, disturbance factors, succession stage of the forest and/or survival strategies of the species.

According to the comparisons of this study forest, Sheleko Medhanialem forest, with similar studies (4 dry Afromontane forests in Ethiopia), on the basis of tree densities with DBH > 10 and 20 cm (a), DBH > 20 cm (b) and the ratio (a/b), the ratio a/b indicate that Sheleko Medhanialem forest has more tree in lower DBH classes than in the higher classes when compared to Gedo, The relatively larger value of the lower DBH class of the Sheleko Medhanialem forest than the middle and high DBH classes may indicates that this forest has a very large number of young woody plants (seedlings and saplings), and may show high regeneration potential of the study forest. The most probable reasons for these patterns could be different types. This may include past history of anthropologic disturbances [41], tree logging efficient species recruitments, forest abandonment (recent decline in the extent of anthropogenic disturbances), within-gap regeneration stages of various ages after tree fall the nature of the forest, altitude variation, age of the forest, degree of conservation and exposure to disturbance. The ratio of density of individuals with DBH > 10 cm to density of individuals with DBH > 20 cm is taken as a measure of the size class distribution Grubb *et al.* [46], cited in [47]. Moreover, the inverted J-shape distribution pattern is additional evidence or indicator of showing a higher number of individual's species in the lower DBH classes and reduction at the highest DBH classes. Such a pattern may indicate a normal or healthy structural pattern with good reproduction and recruitment capacity of a given species [24]. Diameter class distribution of selected tree species demonstrated various patterns of population structure, implying different population dynamics among species [48]. The slight reduction in diameter classes of some species may be due to selective removal of small diameter class individuals either by local dwellers for some purpose (e.g., for fencing and fuel wood), or by livestock (trampling or browsing), or maybe other biotic factors, indicating selective harvesting of individuals in the particular size classes.

4.5. Importance Value Index (IVI)

The nine most dominant woody plant species in Sheleko Medhanialem forest in Importance Value Index are *Acacia lahai* (*the highest IVI value*), *Calpurnia aurea*, *Carissa spinarum*, *Grewia. ferruginea*, *Maytenus obscura*, *Premna schimperi*, *Croton macrostachyus*, *Caparis tomentosa*, and *Rhus glutinosa* (**Table 1**).

Table 1. Importance Value Index for nine most dominant species in Sheleko Medhanialem forest. RD: relative density, RF: relative frequency, RDO: relative dominance; IVI: important value index, PC: Priority Class.

No	Botanical name	RF	RD	RDO	IVI	IVI %	PC	Habit
1	*C. spinarum*	6.5	19.3	4.04	29.9	9.97	1	SH
2	*C. aurea*	6.7	11.1	7.88	25.6	8.54	1	SH
3	*A. lahai*	4.8	3.06	16.1	24	8	1	T
4	*G. ferruginea*	6.9	10.4	4.03	21.3	7.1	1	SH
5	*M. obscura*	6.5	10.7	3.61	20.8	6.93	1	SH
6	*P. schimperi*	6.4	5.13	7.52	19	6.33	1	SH
7	*R. glutinosa*	5.3	5.02	6.69	17	5.67	1	SH
8	*C. tomentosa*	4	9.15	2.38	15.5	5.16	1	SH
9	*C. macrostachyus*	6	4.15	4.51	14.7	4.89	2	T

The Woody species in the forest were grouped into five IVI classes based on their IVI values (IVI class 5 = <1, 4 = 1 - 5, 3 = 5.1 - 10, 2 = 10.1 - 15, 1 = > 15) for conservation priority (49). The distribution of species in IVI class is shown in **Table 2**. Although the number of species in IVI class 5 is greater than the other IVI classes, their contribution to the total IVI was 2.93%. Priority class 5 (Appendix 4) should get the uppermost conservation priority since these species are at risk of local extinction. Those species with lower IVI values need high conservation efforts while those with higher IVI values need monitoring management.

Importance Value Index (IVI) is an important parameter that reflects the ecological significance of species in a given ecosystem [49]. IVI combines data from three parameters, *i.e.*, RF, RD and RDO [49]. The highest IVI shows the extent of dominance of a given species in relation to the other species in the structure of the forest stand. Those species with lower IVI values are much larger in number than the most dominant higher IVI values but very few in number, the latter need high conservation efforts while those with higher IVI values need monitoring management. Priority class 5 (Appendix 4) should get the uppermost conservation priority since these species are at risk of local extinction.

Table 2. Distribution of species in each IVI class. IVIC = Importance value index classes, NS = number of species, TIVI = total IVI.

IVIC	IVI	NS	TIVI	%
5	<1	23	8.8	2.93
4	1 - 5	22	51.6	17.2
3	5.1 - 10	6	40.1	13.4
2	10.1 - 15	2	26.3	8.77
1	>15	8	173	57.7
Total	-	61	300	100

Species with the highest importance value index are the most dominant of the particular vegetation. Similarly, IVI is used to set priority species management and conservation practices and aids in identifying their sociological status in a certain plant species as dominant or rare [49]. Based on their higher IVI value, the nine dominant and ecologically most significant shrubs and trees species in Sheleko Medhanialem Forest were *C. spinarum* (29.9), *C. aurea* (25.63), *A. lahai* (23.99), *G. ferruginea* (21.31), *M. obscura* (20.78), *P. schimperi* (19.0), *R. glutinosa* (17.02), *C. tomentosa* (15.47) and *C. macrostachyus* (14.67). These species covered 62.59 % of the total importance value index. The possible reason for species that had large importance was their high dominance or density. In contrast to this, species like *F. sycomorus*, *F. palmata*, *A. schimperi* and *S. kunthianum* were species with low IVI values that needed urgent feedback to regenerate (Appendix 4). The possible reason for this could be either the selective cutting of these species by near community or unfavorable conditions. It indicates the requirement of conservation and management of the forest as a whole.

Acknowledgements

We thank Arba Minch University, South Ethiopia, for providing us with the logistic and financial facilities required for this study. We also thank the Department of Biology as well as its staff members for giving bits of help and encouragement.

We would also like to thank Woreta Agriculture, Technic and Vocational College, Gondar, North West Ethiopia, for providing us with GPS and hypsometers for data collection. We would like to thank Ato Amsalu Meri, Ato Getamehone Tarko, W/ro Tsehay Mareye, W/rt Agernesh Tarko and Ato Gizachew Mesfin for their contributions in providing basic information during data collection.

Our special thanks also go to Ato Worku Misganew, who assisted in identifying local names in Amharic language of woody plant species, and last but not least, Ato Ewenetu Nega and Ato Ebabu Bimrew for their material support.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Appendix 1

List of woody plants collected from Sheleko Medhanialem forest; key:* = species found outside the plot, ** = endemic plant)

No.	Local name in Amharic	Botanical name	Family name	Habit	Collection code
1	Tnbilka grar	*Acacia lahai* Steud. & Hochst.ex Benth.	Fabaceae	T	KH 28
2	Nech grar	*Acacia persiciflora* Pax.	Fabaceae	T	KH 27
3	Debene grar	*Acacia sieberiana* DC.	Fabaceae	T	KH 15
4	Kontir grar	*Acacia venosa* Hochst.ex Benth**	Fabaceae	T	KH 59
5	Kusheshile	*Acanthus sennii* Chiov**	Acanthaceae	SH	KH 49
6	Mrenz	*Acokanthera schimperi* (A. DC.) Schweinf.	Apocynaceae	SH	KH 42
7	Sendel Zaf	*Albizia gummifera* (J.F.Gmel.) C.A.Sm.	Fabaceae	T	KH 17
8	Azamer	*Bersama abyssinica* Fresen.	Melianthaceae	SH	KH 14
9	Yeneber tifer	*Bridelia micrantha* Hochst. Baill.	Euphorbiaceae	T	KH 53
10	Digta	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	SH	KH01
11	Gmero	*Capparis tomentosa* Lam.	Capparidaceae	SH	KH 07
12	Agam	*Carissa spinarum* L.	Apocynaceae	SH	KH 04
13	Limich	*Clausena anisata* (Willd.) Benth.	Rutaceae	SH	KH 31
14	Azohareg	*Clematis simensis* Fresen.	Ranunculaceae	L	KH 58
15	Yekola Abalo	*Combretum collinum* Fresen. subsp.collinum	Combretaceae	T	KH 36
16	Wanza	*Cordia africana* Lam.	Boraginaceae	T	KH 38
17	Bisana	*Croton macrostachyus* Del.	Euphorbiaceae	T	KH 06
18	Gorgoro	*Dichrostachys cinerea* (L.)Wight &Arn.	Fabaceae	T	KH 46
19	Kitkta	*Dodonea angustifolia* L.F.	Sapindaceae	SH	KH 21
20	Sesa	*Entada abyssinica* Steud.ex A. Rich.	Fabaceae	T	KH 50
21	Kuara	*Erythrina abyssinica* Lam. ex DC.	Fabaceae	T	KH 12
22	Key bahirzaf	*Eucalyptus camaldulensis* Dehnh*	Myrtaceae	T	KH 61
23	Dedeho	*Euclea racemosa* Murr. Subsp. Schimperi (A.DC.)White	Ebenaceae	SH	KH 03
24	Tilus	*Ficus ingens* Miq.*	Moraceae	T	KH 63
25	Debas	*Ficus palmata* Forssk.	Moraceae	T	KH 48
26	Shola	*Ficus sur* Forssk	Moraceae	T	KH 30
27	Bamba warka	*Ficus sycomorus* L.	Moraceae	T	KH 60
28	Chibeha	*Ficus thonningii* Blume	Moraceae	T	KH 45
29	Warka	*Ficus vasta* Forssk.	Moraceae	T	KH 29
30	Gambilo	*Gardenia ternifolia* Schumach. & Thonn.subsp. jovis - tonantis (Welw.) Verdc.	Rubiaceae	T	KH 23

Continued

31	Lenqwata	*Grewia ferruginea* Hochst.ex A. Rich.	Tiliaceae	SH	KH 13
32	Esat abrid	*Helinus mystacinus* (Ait.)E. Mey. Ex Steud.	Rhamnaceae	L	KH 52
33	Nacha	*Hibiscus macranthus* Hochst.ex A. Rich.	Malvaceae	SH	KH 55
34	Tenbelel	*Jasminum abyssinicum* Hochst.ex DC.	Oleaceae	L	KH 20
35	Sensell	*Justicia schimperiana* (Hochst. Ex Nees) T.Anders	Acanthaceae	SH	KH 65
36	Atat	*Maytenus obscura* (A. Rich.) Cuf.	Celastraceae	SH	KH 05
37	Eshe bariya	*Maytenus undata* (Thunb.) Blakelock	Celastraceae	SH	KH 33
38	Brbra	*Millettia ferruginea* (Hochst.) Bak. subsp. Ferruginea **	Fabaceae	T	KH 40
39	Eshe	*Mimusops kummel* A. DC.	Sapotaceae	T	KH 37
40	Damakese	*Ocimum lamiifolium* Hochst. ex Benth.	Lamiaceae	SH	KH 32
41	Woyra	*Olea europaea* subsp. cuspidate (Wall. ex G. Don) Cif.*	Oleaceae	T	KH 64
42	Keret	*Osyris quadripartita* Decn.	Santalaceae	SH	KH 22
43	Senel	*Phoenix reclinata* Jacq.	Arecaceae	T	KH 43
44	Misrch	*Phyllanthus Sp.*	Euphorbiaceae	SH	KH 54
45	Endod	*Phytolacca dodecandra* L 'He'rit.	Phytolaccaceae	T	KH 51
46	Yekola Wanza	*Piliostigma thonningii* (Schumach.) Milne-Redh.	Fabaceae	T	KH 44
47	Anquwalit	*Pittosporum viridiflorum* Sims.	Pittosporaceae	SH	KH 02
48	Checho	*Premna schimperi* Engl.	Lamiaceae	SH	KH 08
49	Kentefa	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	SH	KH 19
50	Wedel Asfes	*Rhoicissus tridentata* (L. f.) wild and Drummond	Vitaceae	L	KH 10
51	Kimo	*Rhus glutinosa* A.Rich. **	Anacardiaceae	SH	KH 18
52	Arbog	*Sapium ellipticum* (Krauss) Pax.	Euphorbiaceae	T	KH 24
53	Kezkez	*Schrebera alata* (Hochst.)	Oleaceae	SH	KH 26
54	Dingay seber	*Scolopia theifolia* Gilg	Flacourtiaceae	SH	KH 47
55	Serk Abeba	*Senna didymobotrya* (Fresen)Irwin &Barneby	Fabaceae	SH	KH 11
56	Bshibsha	*Senna singueana* (Del) Lock	Fabaceae	SH	KH 25
57	Gorgegit	*Sida schimperiana* Hochst. ex A. Rich.	Malvaceae	SH	KH 56
58	Enbuay	*Solanum incanum L.*	Solanaceae	SH	KH 57
59	Zana	*Stereospermum kunthianum* Cham.	Bignoniaceae	SH	KH 35
60	Dokima	*Syzygium guineense* (Willd.) DC.	Myrtaceae	T	KH 41
61	Wenbela	*Terminalia brownii* Fresen.	Combretaceae	T	KH 16
62	Yetota merek	*Turraea holstii* Gurke	Meliaceae	SH	KH34
63	Girawa	*Vernonia amygdalina* Del.*	Asteraceae	SH	KH 62
64	Kotkoto	*Vernonia auriculifera* Hiern	Asteraceae	SH	KH 39
65	Enkoy	*Ximenia americana L.*	Olacaceae	SH	KH 09

Appendix 2

Plant families with their respective number of genera and species.

No.	Family	Genera	Genera in %	Species	Species in %
1	Fabaceae	10	18.52	14	21.54
2	Moraceae	1	1.85	6	9.23
3	Euphorbiaceae	4	7.41	4	6.15
4	Oleaceae	3	5.56	3	4.62
5	Lamiaceae	2	3.70	2	3.08
6	Combratiaceae	2	3.70	2	3.08
7	Myrtaceae	2	3.70	2	3.08
8	Apocynaceae	2	3.70	2	3.08
9	Acanthaceae	2	3.70	2	3.08
10	Celastraceae	1	1.85	2	3.08
11	Malvaceae	2	3.70	2	3.08
12	Asteraceae	1	1.85	2	3.08
13	Sapotaceae	1	1.85	1	1.54
14	Melianthaceae	1	1.85	1	1.54
15	Sapindaceae	1	1.85	1	1.54
16	Meliaceae	1	1.85	1	1.54
17	Rutaceae	1	1.85	1	1.54
18	Boraginaceae	1	1.85	1	1.54
19	Rubiaceae	1	1.85	1	1.54
20	Anacardiaceae	1	1.85	1	1.54
21	Capparidaceae	1	1.85	1	1.54
22	Phytolaccaceae	1	1.85	1	1.54
23	Vitaceae	1	1.85	1	1.54
24	Rhamnaceae	1	1.85	1	1.54
25	Flacourtiaceae	1	1.85	1	1.54
26	Ranunculaceae	1	1.85	1	1.54
27	Ebenaceae	1	1.85	1	1.54
28	Tiliaceae	1	1.85	1	1.54
29	Santalaceae	1	1.85	1	1.54
30	Arecaceae	1	1.85	1	1.54
31	Pittosporaceae	1	1.85	1	1.54
32	Solanaceae	1	1.85	1	1.54
33	Bignoniaceae	1	1.85	1	1.54
34	Olaceaceae	1	1.85	1	1.54
	Total	54	100.00	65	100.00

Appendix 3

Density per hectare of mature tree and shrub species, sapling and seedling, in Sheleko Medhanialem Natural Forest. Key: DMTSs+ = Density of matured trees and shrubs, DS = Density of Saplings, **DSE** = Density of Seedlings.

No.	Botanical name	DMTSs	DSAP	DSE
1	*Acacia lahai*	67.5	24	59.2
2	*Acacia persiciflora*	11	8	14.4
3	*Acacia sieberiana*	7	17.6	12.8
4	*Acacia venosa*	2	6.4	4.8
5	*Acanthus sennii*	18.5	28.8	44.8
6	*Acokanthera schimperi*	0.5	0	0
7	*Albizia gummifera*	1.5	0	0
8	*Bersama abyssinica*	6.5	22.4	28.8
9	*Bridelia micrantha*	0.5	0	0
10	*Calpurnia aurea*	243.5	230.4	316.8
11	*Capparis tomentosa*	201.5	148.8	180.8
12	*Carissa spinarum*	426	244.8	355.2
13	*Clausena anisata*	9.5	4.8	6.4
14	*Clematis simensis*	0	9.6	0
15	*Combretum collinum*	2	12.8	1.6
16	*Cordia Africana*	2.5	3.2	0
17	*Croton macrostachyus*	91.5	73.6	67.2
18	*Dichrostachys cinerea*	0.5	0	0
19	*Dodonea angustifolia*	14.5	19.2	20.8
20	*Entada abyssinica*	0.5	0	0
21	*Erythrina abyssinica*	1	0	0
22	*Euclea racemosa*	60	46.4	78.4
23	*Ficus palmate*	0.5	0	0
24	*Ficus sur*	0.5	0	0
25	*Ficus sycomorus*	0.5	0	0
26	*Ficus thonningii* Blume	3	0	0
27	*Ficus vasta*	1	0	0
28	*Gardenia ternifolia*	10.5	11.2	19.2
29	*Grewia ferruginea*	229.5	160	232
30	*Helinu mystacinus*	2	8	3.2
31	*Hibiscus macranthus*	0	0	1.6
32	*Jasminum abyssinicum*	21.5	28.8	54.4

Continued

33	*Justica schimperiana*	5	19.2	19.2
34	*Maytenus obscura*	234.5	164.8	304
35	*Maytenus undata*	26.5	11.2	6.4
36	*Millettia ferruginea*	1.5	9.6	0
37	*Mimusops kummel*	2.5	0	0
38	*Ocimum lamiifolium*	11.5	20.8	30.4
39	*Osyris quadripartita*	14	20.8	24
40	*Phoenix reclinata*	2	11.2	9.6
41	*Phyllanthus Sp.*	0	0	1.6
42	*Phytolacca dodecandra*	6	12.8	0
43	*Piliostigma thonningii*	0.5	1.6	0
44	*Pittosporum viridiflorum*	41	14.4	32
45	*Premna schimperi*	113	88	156.8
46	*Pterolobium stellatum*	95.5	48	84.8
47	*Rhoicissus tridentate*	7.5	14.4	4.8
48	*Rhus glutinosa*	110.5	64	124.8
49	*Sapium ellipticum*	1	0	0
50	*Schrebera alata*	2.5	3.2	1.6
51	*Scolopia theifoli*	8.5	14.4	19.2
52	*Senna didymobotrya*	0	0	1.6
53	*Senna singueana*	17	16	33.6
54	*Sida schimperiana*	0	19.2	0
55	*Solanum incanum*	0	0	6.4
56	*Stereospermum kunthianum*	1	0	0
57	*Syzygium guineense*	10	0	0
58	*Terminalia brownii*	20	12.8	9.6
59	*Turraea holstii*	8.5	25.6	6.4
60	*Vernonia auriculifera*	5.5	20.8	11.2
61	*Ximenia americana*	20	16	28.8
	Total	2202.5	1737.6	2419.2

Appendix 4

Importance Value Index.

No.	Botanical name	RF	RD	RDO	IVI	IVI in %	Priority class
1	*Carissa spinarum*	6.52	19.34	4.04	29.90	9.97	1
2	*Calpurnia aurea*	6.69	11.06	7.88	25.63	8.54	1
3	*Acacia lahai*	4.80	3.06	16.13	23.99	8.00	1
4	*Grewia ferruginea*	6.86	10.42	4.03	21.31	7.10	1
5	*Maytenus obscura*	6.52	10.65	3.61	20.78	6.93	1
6	*Premna schimperi*	6.35	5.13	7.52	19.00	6.33	1
7	*Rhus glutinosa*	5.32	5.02	6.69	17.02	5.67	1
8	*Capparis tomentosa*	3.95	9.15	2.38	15.47	5.16	1
9	*Croton macrostachyus*	6.00	4.15	4.51	14.67	4.89	2
10	*Syzygium guineense*	0.86	0.45	10.34	11.65	3.88	2
11	*Euclea racemosa*	3.26	2.72	3.84	9.82	3.27	3
12	*Pterolobium stellatum*	2.06	4.34	1.88	8.27	2.76	3
13	*Pittosporum viridiflorum*	2.92	1.86	1.18	5.96	1.99	3
14	*Ficus vasta*	0.34	0.05	5.04	5.43	1.81	3
15	*Acacia sieberiana*	1.37	0.32	3.63	5.32	1.77	3
16	*Acacia persiciflora*	2.57	0.50	2.24	5.31	1.77	3
17	*Ximenia americana*	1.03	0.91	2.33	4.27	1.42	4
18	*Senna singueana*	2.06	0.77	1.01	3.84	1.28	4
19	*Jasminum abyssinicum*	2.23	0.98	0.57	3.78	1.26	4
20	*Gardenia ternifolia*	2.23	0.48	0.99	3.70	1.23	4
21	*Ficus thonningii*	0.69	0.14	2.62	3.44	1.15	4
22	*Terminalia brownii*	2.23	0.91	0.01	3.15	1.05	4
23	*Maytenus undata*	0.86	1.20	1.07	3.13	1.04	4
24	*Osyris quadripartita*	1.72	0.64	0.69	3.04	1.01	4
25	*Dichrostachys cinerea*	2.57	0.02	0.00	2.60	0.87	4
26	*Dodonea angustifolia*	1.37	0.66	0.45	2.48	0.83	4
27	*Rhoicissus tridentate*	1.54	0.34	0.15	2.03	0.68	4
28	*Acanthus sennii*	0.86	0.84	0.27	1.97	0.66	4
29	*Vernonia auriculifera*	1.54	0.25	0.07	1.86	0.62	4
30	*Ocimum lamiifolium*	0.86	0.52	0.30	1.68	0.56	4
31	*Scolopia theifoli*	1.03	0.39	0.23	1.65	0.55	4
32	*Turraea holstii*	0.51	0.39	0.59	1.49	0.50	4

Continued

33	*Mimusops kummel*	0.51	0.11	0.85	1.48	0.49	4
34	*Cordia africana*	0.69	0.11	0.65	1.45	0.48	4
35	*Schrebera alata*	1.03	0.11	0.17	1.31	0.44	4
36	*Bersama abyssinica*	0.51	0.30	0.37	1.18	0.39	4
37	*Clausena anisata*	0.34	0.43	0.34	1.11	0.37	4
38	*Combretum collinum*	0.86	0.09	0.06	1.01	0.34	4
39	*Phytolacca dodecandra*	0.51	0.27	0.14	0.93	0.31	5
40	*Phoenix reclinata*	0.69	0.09	0.07	0.85	0.28	5
41	*Albizia gummifera*	0.51	0.07	0.16	0.74	0.25	5
42	*Sapium ellipticum*	0.34	0.05	0.25	0.64	0.21	5
43	*Acacia venosa*	0.34	0.09	0.11	0.54	0.18	5
44	*Erythrina abyssinica*	0.34	0.05	0.07	0.46	0.15	5
45	*Justica schimperiana*	0.17	0.23	0.03	0.43	0.14	5
46	*Stereospermum kunthianum*	0.34	0.05	0.01	0.40	0.13	5
47	*Piliostigma thonningii*	0.34	0.02	0.03	0.40	0.13	5
48	*Millettia ferruginea*	0.17	0.07	0.13	0.37	0.12	5
49	*Bridelia micrantha*	0.17	0.02	0.16	0.35	0.12	5
50	*Hibiscus macranthus*	0.34	0.00	-	0.34	0.11	5
51	*Solanum incanum*	0.34	0.00	-	0.34	0.11	5
52	*Helinu mystacinus*	0.17	0.09	0.01	0.27	0.09	5
53	*Ficus sur*	0.17	0.02	0.06	0.25	0.08	5
54	*Entada abyssinica*	0.17	0.02	0.02	0.21	0.07	5
55	*Acokanthera schimperi*	0.17	0.02	0.01	0.20	0.07	5
56	*Ficus palmate*	0.17	0.02	0.01	0.20	0.07	5
57	*Ficus sycomorus*	0.17	0.02	0.00	0.20	0.07	5
58	*Phyllanthus Sp.*	0.17	0.00	-	0.17	0.06	5
59	*Clematis simensis*	0.17	0.00	-	0.17	0.06	5
60	*Senna didymobotrya*	0.17	0.00	-	0.17	0.06	5
61	*Sida schimperiana*	0.17	0.00	-	0.17	0.06	5
	Total	100	100	100	300	100	

Appendix 5

Locations of vegetation data collection in Sheleko Medhanialem Forest.

Transects	Plots	Latitude	Longitude	Altitude	Aspect
1	1	11˚54'91"	37˚44'15.5"	1938	N
	2	11˚54'79.4"	37˚43'98"	1948	NE
	3	11˚54'67.8"	37˚43'48"	1957	NE
	4	11˚54'56.2"	37˚43'23"	1951	NE
	5	11˚54'43.5"	37˚42'92"	1948	NE
	6	11˚54'32.9"	37˚42'69"	1951	S
	7	11˚54'20.9"	37˚42'28"	1939	SE
	8	11˚54'09.6"	37˚42'04"	1927	SW
	9	11˚53'84"	37˚41'85.3"	1933	SW
	10	11˚53'86.5"	37˚41'56"	1933	W
	11	11˚53'74.4"	37˚41'38"	1946	SW
2	12	11˚53'04.3"	37˚42'55"	1941	SE
	13	11˚53'92.6"	37˚42'14"	1974	SE
	14	11˚53'79.6"	37˚41'93"	1977	SW
	15	11˚53'71.7"	37˚39'60"	1952	SE
	16	11˚53'56"	37˚41'31"	1971	SE
	17	11˚53'45"	37˚41'12"	1947	NE
	18	11˚53'33.2"	37˚40'63.6"	1936	NW
	19	11˚53'21.7"	37˚40'47"	1925	NW
	20	11˚53'09.9"	37˚40'15"	1923	NW
	21	11˚53'98"	37˚39'96"	1915	NW
	22	11˚53'86.8"	37˚39'83"	1930	S
	23	11˚53'69.2"	37˚39'41"	1953	W
3	24	11˚53'05.5"	37˚40'47"	1948	NE
	25	11˚53'95.3"	37˚40'13"	1964	NW
	26	11˚53'83.6"	37˚39'88"	1967	N
	27	11˚53'71.7"	37˚39'60"	1952	SE
	28	11˚53'56.9"	37˚39'31"	1941	NW
	29	11˚53'44.9"	37˚39'00"	1926	NW
	30	11˚53'36"	37˚38'64"	1918	N
	31	11˚54'21.3"	37˚38'55"	1917	W
	32	11˚54'10.7"	37˚37'96"	1905	SW

Continued

	33	11˚54'99.2"	37˚37'96"	1916	SW
	34	11˚54'87.6"	37˚37'95.3"	1934	SW
	35	11˚54'79"	37˚37'58"	1930	W
4	36	11˚54'11.3"	37˚38'56"	1931	NW
	37	11˚54'10.3"	37˚38'16"	1930	W
	38	11˚54'88.3"	37˚38'00"	1929	W
	39	11˚54'76.6"	37˚37'71"	1925	W
	40	11˚54'84"	37˚38'32.2"	1930	W
	41	11˚54'57"	37˚37'45"	1922	W
	42	11˚54'51"	37˚38'80"	1933	S
5	43	11˚54'94.9"	37˚34'51"	1878	SW
	44	11˚54'83.9"	37˚34'21"	1883	SW
	45	11˚54'72.7"	37˚34'35"	1886	SE
	46	11˚54'59.4"	37˚34'28"	1903	SW
	47	11˚54'46"	37˚34'07"	1913	W
	48	11˚54'32.2"	37˚34'13"	1923	S
	49	11˚54'19.9"	37˚34'06"	1935	W
	50	11˚54'05.5"	37˚34'17"	1937	S