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Ecological Performance of Economically Prioritized Indigenous Tree Species in Munessa-Shashemene Natural Forest, Ethiopia

Gemedo Furo[1,2], **Guo Jiao**[1] **and Mi Feng**[1*]

[1]*Beijing Forestry University, P.O. Box 100083, P.R. China*

[2]*Ethiopian Environment and Forest Research Institute, Hawassa Center, P.O. Box 1832, Hawassa, Ethiopia*

[*]**Corresponding author:** Mi Feng, Beijing Forestry University, P.O. Box 100083, P.R. China, E-mail: mifengsun@163.com

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Abstract

The Munessa-Shashemene forest is one of the dry Afromontane forests and is dominated by ecologically and economically important tree species that are being degraded at an alarming rate. Therefore, research on the structural status of preferable indigenous tree species is essential for providing information that can be used in the implementation of sustainable forest management. Different timber-based forest products and species-specific removal impact the ability of the forest to maintain functions valuable to both biology and humanity, including the future provision of forest products and services. The objectives of this study were to identify economically important indigenous tree species and to analyze their ecological performances. In 33 plots with areas of 30 m × 30 m each, all woody species, the number of stumps, the Diameter at Breast Height (DBH) of all woody species greater than 2.3 cm and their height were recorded. Tree prioritization was analyzed using matrix ranking procedures and some ecological variables (importance value index, Shannon Wiener's diversity index, stand density indexand basal area ha^{-1}) were computed. A Multiple linear regression model was used to investigate the impact of the economic preference of tree species and other ecological variables on stem density ha^{-1}. The results revealed that Myrsineme lanophloeos, Haginea abysinica, Juniperus procera, Podocurpus falcatus and Maytenus arbutifolia were the top five economically important tree species. The Economic preference of tree species has a statistically significant ($p<0.05$) negative impact on the stem density ha^{-1} of that species. At the Beseku site, a DBH class distribution of Myrsine melanophloeos repealed distinct inverted J-shape curves, which indicates good regeneration status. However, the DBH class distribution at the Heben and Shopha sites exhibit an interrupted Gauss type curve. The stand density ha^{-1}, relative density, relative frequency, and importance value index of economically prioritized tree species varied between three studied forest sites and their structural distribution were significantly different from those of inferior tree species.

Keywords: Ecological performance; Prioritization; Indigenous tree; Structural distribution

Introduction

Forests play a great role in the poverty alleviation of millions of rural smallholders in developing countries. It is therefore evident that humans depend on forest products and services for their daily livelihoods and this dependence might change the forest stand structure and ecosystem services [1,2]. However, efforts to conserve the forest reserve area via the restriction of access can provide challenges for the people whose daily lives rely on collecting forest resources [3]. Moreover, policies maintained in the forest reserves that focus on restricting forest access by the poor contribute to the overexploitation of the forest resources, while other development and forest management opportunities are ignored [4-7].

Many forest landscapes in tropical regions are declining into patches of land due to agricultural land expansion, poor conservation interventions, urbanization, and other indirect drivers. Therefore, the forest ecosystem functions and services that both, directly and indirectly, support the livelihoods of local people are declining [8-10]. Conservation interventions and agricultural land expansions are both positively and negatively affected by influencing forest products that are harvested by local people [11]. Thus, the ways in which forests contribute to the livelihoods of rural people, the interaction between the forests and the people and the influence exercised on forest contributions via ongoing landscape transformations are the key focus of some researchers [12-14]. However, species-specific economic utilization may lead to the declining that species in natural forests. One of its most common consequences is also forest degradation i.e, a reduction in the overall biomass and species richness of forests [15]. Therefore, the removal of different timber-based forest products impacts the regeneration capacity and sustainability of valuable functions of forest including the future provision of forest products and services.

In the forested landscapes of Ethiopia, the livelihoods of the people living in or near forests are strongly linked to the forest ecosystem services. These people depend on the forests for a variety of forest products including food, fodder, agricultural tools, housing, as well as an array of marketable minor forest products. In fact, the unsustainable use of forest products can result in forest degradation; firewood collection, illegal logging, charcoal production, overgrazing on forest land (releasing livestock into forests for feeding and browsing)and extracting materials for construction are the primary causes of forest degradation [1,16,17]. Some endemic trees and shrubs including *Hagenia abysinica, Cordia africana, Podocarpus falcalus,* and *Juniperous procera* are widely-used, high-value timber tree species. The demand for wood furniture and wooden construction using the timber and timber products of these species has increased over time. However, the supply has not kept up with the demand and reforestation of these species is negligible. This causes a rapid depletion of high-value tree species particularly in dry Afromontane forests [18,19].

The Munessa-Shashemene forest is one of the dry Afromontane forests of Ethiopia and is dominated by ecologically and economically significant tree species that are degrading at an alarming rate. There is an information gap in existing research on the structural status of economically preferable indigenous tree species in the forest. Due to the declining over time of economically important indigenous tree species, some tree species with similar wood characteristics have been used as substitutions for the preferred species in the creation of various forest products. In fact, all tree species provide a critical role in the livelihoods of the local people. However, people prefer some tree species over others for specific forest products and this may impact the stem density ha^{-1} of these species in nearby natural forests. The analysis of the effect of people's economic preferences of tree species on stem density was conducted by both socio-economic and vegetation survey research which are both crucial for creating forest management policy and strategies that may ensure sustainable forest management. The result of this study will demonstrate the ecological performance of economically preferred tree species, as well as provide insight on how preference for high-value timber tree species may impact the stem density ha^{-1}.

This paper applies the matrix ranking technique proposed by Keegan et al. [20] to prioritize the economically important tree species and various ecological variables were computed to evaluate their ecological performances. This research also uses a multiple linear regression model to evaluate the effect of tree species-specific use on the stem density ha^{-1} of targeted tree species. Additionally, this research employed both diameter class and cluster analysis using an importance value index and other indices. Principal components analysis was applied to investigate the structural distribution and ecological importance of economically important tree species at three forest sites.

Methods and Materials

Study area

This study was conducted in the Munessa-Shashemene natural forest (Figure 1). The area is located at 7°35'13.3" N and 38°59'57.31" E with an elevation range from 2010 m to 2700 m above sea level. The climatic condition is a bimodal rainfall distribution with a mean annual rainfall of 1200 mm and a mean temperature of 15°C [21]. The soils are classified as Mazic Vertisol in the lower altitude and Humic Umbrisol in the higher altitude [22]. The natural forest belongs to a tropical dry Afromontane forest [23]. The plantation forests are composed of exotic species, primarily the Cupressus lusitanica, Pinus patula and Eucalyptus species.

Household sampling

A total of 100 households were selected from three sub-districts that have a common boundary with the Munessa-Shashemene forest to identify and prioritize tree species that are considered more economically valuable. The list of households was obtained from the village administrative offices. Five percent (5%) of the respondent households were then randomly selected from those near the forest boundary. We interviewed each respondent household and the key informant regarding species-specific use. The key informants included forest guards, elders, and village leaders. We also asked them to rank five tree species from high importance to low importance in terms of their use for lumber, firewood, charcoal, house construction, fodder, and different farm tools. Six Group discussions were also conducted to confirm and cross-check the validity of the collected data. Each group contained six and eight households. The group members were selected from households that were not considered for an individual interview.

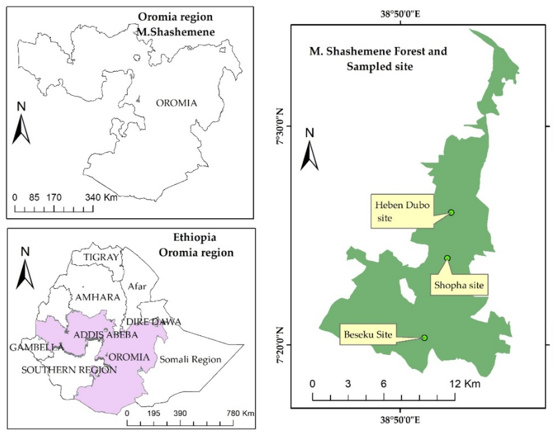

Figure 1: The study area location.

Vegetation sampling

A total of 33 plots were systematically established in three forest management sites following Muller and Ellensburg [24] and Kent et al. [25]. The size of each plot was 30 m × 30 m (900 m^2). Eleven plots were considered at each forest site (Beseku, Heben Duboand Shopha). The plots were established at 300 m apart along the transect lines in each site. The Beseku site belongs to the Gambo forest and wildlife district. Whereas the Heben dubo and Shopha sites belong to the Dagaga forest and wildlife district. In each plot, the number of stumps which represented the specific species after they were cut, was counted. For all plots, the diameter at breast height (DBH) i.e., 1.3 m above ground level, of all tree species greater than 2.3 cm was measured using a caliper. For large trees with a DBH greater than 100 cm, the circumference was measured using a measuring tape and then the diameter was computed using Eq. (1).

Seedlings and sapling were not considered in this study due to constrained resources. However, 2.3 cm was considered as the lower threshold size for DBH to include the small size trees in the data analysis.

$$DBH = \frac{C}{\pi} \quad (1)$$

In the above equation, DBH is the diameter at breast height, C is the circumference and is 3.14.

The heights of all wood species found in each plot were measured using a hypsometer. Additional data, including slope, aspect, latitude, and longitude, were recorded at the center of each plot. The scientific names of the tree species were obtained by referring to a field guide [26,27]. Some species that were difficult to identify at the field level were identified at Addis the Ababa national herbarium.

Data analysis

The matrix ranking procedure was used to prioritize the tree species because the ranking and scoring procedure is effective for weighing pros and cons across multiple criteria [20]. Values from 1 to 5 were then assigned for the listed tree species for each product during data coding and entry. Higher scores indicated that the tree species in the study area were economically important. The relative preference of tree species for overall products was calculated based on mean scores obtained by Equation (2) as follows:

$$Mean\ Score = \frac{\sum_{k=1}^{n} Sifi}{n} \qquad (2)$$

Where is the frequency of the respondents for the ith item, S is the score of the ith item, i=1, 2, 3, 4 or 5and n is the total number of respondents.

To investigate the structural status of economically prioritized tree species, some ecological variables were computed the following Equations (3, 4, 5, 6, 7 and 8) using methods implemented by Curtis and McIntosh [28].

$$BA = \frac{\pi(DBH)^2}{4} \qquad (3)$$

In the above equation, BA refers to the Basal area in square meters, DBH is the diameter at breast height and π is 3.14.

$$Species\ richness = A\ total\ number\ of\ tree\ species\ found\ in\ the\ study\ area \qquad (4)$$

$$(RDM) = \frac{Basal\ area\ of\ each\ species}{Total\ basal\ area\ of\ all\ species} \times 100 \qquad (5)$$

In the above equation, RDM is a relative dominance

$$(RF) = \frac{number\ of\ plots\ in\ which\ species\ occurs}{total\ number\ of\ plots} \times 100 \qquad (6)$$

In the above equation, RF is a relative frequency

$$(RD) = \frac{Pi}{N} \times 100 \qquad (7)$$

In the above equation, RD is a relative density, P is the number of trees of ith species and N is the total number of trees recorded for all species in the plots.

$$Importance\ value\ index \quad IVI = RDM + RF + RD \qquad (8)$$

We used diameter classes to describe the structural distribution of the economically important tree species. Each tree species were classified into eleven DBH classes (Class 1: 2.3 cm to 10.5 cm; class 2: 10.6 cm to 20.5 cm, class 3:0.6 cm to 30.5 cm, class 4: 30.6 cm to 40.5 cm, class 5: 40.6 cm to 50.5 cm, continued to class 10 with 9 cm intervals and class 11: greater than 100.6 cm). Additionally, the tree species cluster was analyzed using importance value index and other indices, including stand density index, Shannon diversity index, DBH and tree height by applying Principal Components Analysis (PCA). The tree species diversity index, including the Shannon Wiener's diversity index, species evenness and richness was determined by using the Shannon-Wiener information function (H´) [28].

Finally, a multiple linear regression model was used to estimate the ceteris paribus effect of household preferences of tree species for various forest products on stem density (ha^{-1}) using both the rank of tree species and other ecological variables as explanatory variables. The question must be addressed is how the stem density ha^{-1} of economically prioritized tree species varies from that of an inferior tree species. One possibility to address this question is to include tree rank (1-5, etc.) as we would include other variables. Unfortunately, it is difficult to interpret a one unit increase in rank because ranks typically have only an ordinal meaning. Therefore, dummy variables were defined for each value of rank as follows: the first rank=1 if the tree rank=1 otherwise the first rank=0; the second rank=1 if the tree rank=2 otherwise the second rank=0and so on. The single ranking (household preference) was effectively turned into six categories to estimate the model Equation (9).

$$\begin{aligned} SDi = {} & \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \alpha_1 Y_1 \\ & + \alpha_2 Y_2 + \alpha 3 Y_3 + \alpha_4 Y_4 + \alpha_5 Y_5 + \mu_i \end{aligned} \qquad (9)$$

Where SD is stem density ha^{-1} of the th tree species, β0 is an intercept, α1, α2 α3 α4and α5 are the coefficients of the first, second, third, fourth and fifth ranks (dummy variables Y1-Y5) respectively. The coefficient of the first rank (Y1) gives the approximate proportional differential in stem density ha^{-1} between the tree species that are selected and those that that are not as the first rank while holding constant other ranks, the number of stumps, DBH, and importance value index. The values of β1, β2, β3and β4 are the coefficients of the continuous variables of tree height (X1), diameter at breast height (X2), number of stumps (X3), importance value index (X4) respectively. Finally, μ is the error term i.e., the factors not included in the model. Additionally, physical attributes like elevation, slope, and aspect can influence the distribution and growth of tree species. However, because these variables were recorded at the plot level, the values are the same for all trees found in the same plots. Therefore, these variables not considered in the models due to problems associated with perfect collinearity.

Variables	Beseku site	Heben Dubo site	Shopha site
	Mean ± SD	Mean ± SD	Mean ± SD
DBH (cm)	26.35 ± 21.16	28.07 ± 17.57	29.91 ±15.68
Height (m)	11.58 ± 11.89	9.07 ± 5.4	9.73 ± 6.12
QMD/plot*	32.60 ± 8.69	32.06 ± 5.02	33.86 ± 5.04
Stem Density (ha^{-1})	16.54 ± 23.86	27.91 ± 39.26	22.64 ± 25
Stem number/plot	55 ± 36.25	83 ± 30.34	77.81 ± 35.2
Basal area (m^2 ha^{-1})	1.483 ± 2.07	2.406 ± 2.891	1.997 ± 2.336
IVI*	37.83 ± 28.62	49.86 ± 30.8	43.12 ± 29.51
Stump number (ha^{-1})	18.50 ± 58.94	1.99 ± 6.56	4.17 ± 14.36
Elevation (m)	2448.9 ± 157.79	2490.09 ± 99.21	2448.27 ± 157.49
Slope (%)	0.65 ± 0.84	1.01 ± 0.82	0.65 ± 0.84
*Units of measurement indicated in the parenthesis, QMD: Quadratic Mean Diameter			

Table 1: Statistical summary of some variables of the stand and other attributes by forest sites.

The relationships between stem density ha^{-1} and IVI of economically important indigenous tree species were analyzed using simple linear regression model across the three forest sites. Stem density ha^{-1} was then predicted for three forest sites using the estimated coefficients of DBH, height, and IVI. Brief descriptions of some variables included in the model at the stand level among other physical attributes are summarized in Table 1 above.

Results

Ranking and prioritization of economically important tree species

Direct matrix ranking analysis of species prioritization indicates that Myrsineme lanophloeos, Haginea abysinica, Juniperus procera, Podocurpus falcatusand Maytenus arbutifolia are prioritized as the top five tree species. However, different tree species were prioritized for specific forest products (Table 2). For instance, Hagenia abyssinica, Podocarpus falcatus and pittosporum viridiflorum are prioritized for lumber production, whereas Myrsineme lanophloeos, Juniperus procera and Podocarpus falcatus are highly preferred for house construction materials. Juniperus procera is also prioritized as the most important tree species for house construction, particularly for the wall. Similarly, Hagenia abyssinica, Myrsineme lanophloeos and pittosporum viridiflorum are the preferred tree species for firewood (Figure 2). The ranking of tree species for firewood was influenced by the content of caloric value, the amount of smoke and the ease to split (Table 3).

Species	Lumber	House pole	House wall construction	Charcoal	Firewood	Wild fruit	Fodder	Sum	Mean	Rank
Myrsineme lanophloeos	0	309	131	445	201	78	0	1164	1.663	1
Hagenia abyssinica	467	0	219	76	288	0	94	1144	1.634	2
Juniperus Procera	22	294	475	0	141	0	0	932	1.331	3
Podocarpus falcatus	365	239	34	0	131	0	0	769	1.099	4
Maytenus arbutifolia	0	0	0	203	93	0	211	507	0.724	5
Pittosporum viridiflorum	137	0	18	0	193	0	89	437	0.624	6
Eucalyptus spp	55	168	90	19	80	0	0	412	0.589	7
Maesa lanceolata	0	0	0	299	97	15	0	411	0.587	8
Nuxia congesta	0	0	124	33	57	0	72	286	0.409	9
Hypericum revolutum	0	0	189	0	13	0	10	212	0.303	10
Cupress lusistanica	32	65	34	20	56	0	0	207	0.296	11
Syzygium guineense	3	0	35	4	15	111	0	168	0.24	12
Galiniera saxifraga	0	61	0	8	16	47	27	159	0.227	13
Moras mesoziaga	0	0	0	0	0	148	3	151	0.216	14
Allophylus abyssinica	7	0	0	1	33	103	3	147	0.21	15
Cordia africana	96	0	6	0	15	4	0	121	0.173	16
Prunus africana	0	0	4	71	37	0	8	120	0.171	17
Croton macrostachyus	73	10	13	0	13	0	0	109	0.156	18
Ekebergia capensis	71	0	0	0	15	0	0	86	0.123	19
Dombeya torrida	0	63	6	0	10	0	0	79	0.113	20
Olinia rochetiana	22	0	25	17	2	0	0	66	0.094	21
Celtis africana	0	0	2	0	38	0	2	42	0.06	22
Ficus sur	0	0	0	0	15	24	0	39	0.056	23
rosa studinear	0	0	0	0	0	32	0	32	0.046	24
Rumex nervousus	0	0	0	0	5	15	0	20	0.029	25

Millettia ferruginea	0	0	0	0	18	0	0	18	0.026	26
Rhus vulgaris	0	0	0	4	0	9	0	13	0.019	27
Ilex mitis	0	0	6	0	2	0	0	8	0.011	28
Vernonia urticifolia	4	0	0	0	0	0	0	4	0.006	29
Carissa edulis	0	0	0	0	0	2	0	2	0.003	30
Psydrax schimperiana	0	0	0	0	0	1	0	1	0.001	31
Schefflera abyssinica	0	0	0	0	0	0	1	1	0.001	31
Numbers in column two to seven were computed as the summation of the score assigned by respondents										

Table 2: Prioritized tree species for various forest products.

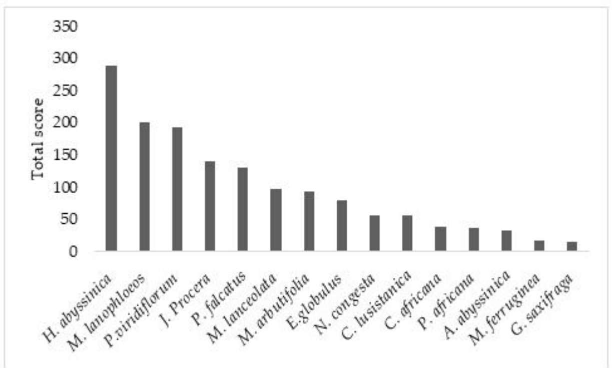

Figure 2: Fifteen most important tree species for firewood purpose using the total score obtained from summation of respondent number times score of the ith item.

Criteria of preferences	Highly preferred	Moderately preferred	Least preferred	Mean	Rank
High caloric value	100 (100)	0 (0)	0 (0)	3	1
Free from smoke	66 (66)	34 (34)	0 (0)	2.66	2
Easily burn	61 (61)	24 (24)	15 (15)	2.46	4
Easy to split	75 (75)	14 (14)	11 (11)	2.64	3
Accessibility	29 (29)	32 (32)	39 (39)	1.9	6
Take short time to dry	12 (12)	67 (67)	21 (21)	1.91	5
Numbers in parenthesis indicate the percentage					

Table 3: Reasons for prioritized tree species for firewood.

Ecological performance of prioritized tree species in the forest

Stem density (ha^{-1}) and Basal area (ha^{-1}) across three forest sites: A total of 42 tree or shrub species belonging to 31 families were recorded from all sampled plots. About 2396 trees with a DBH and height greater than 2.3 cm and 1.5 m were found within all sampled plots. Of these trees, a higher percentage (38.1%) was recorded at the Heben Dubo site than at the Shopha site (36.56%), while the Beseku site contributed a lower proportion (25.34%). Many forest disturbance indicators like the number of stumps were recorded at the Beseku site. The DBH and height of all trees ranged from 2.3 cm-184.7 cm and 1.5 m-48.52 m respectively. A maximum basal area was also found at the Heben Dubo site (25.93 m^2ha^{-1}). The mean value of the other variables for the overall tree species such as density (ha^{-1}), relative dominance, stump number, and importance value index, is illustrated in Figure 3. However, higher species richness was found at the Beseku site compared to the Heben Dubo site. The greatest number of individual trees (912.12 ha^{-1}) was found at the Heban Dubo and was followed by the Shopha site (882.828 ha^{-1}). This finding indicates that stem density ha^{-1} for Myrsine melanophloeos at the Heben Dubo site was three times higher than at the Beseku site (Table 4).

Relative frequency, relative dominance and Important value index: Relative frequency analysis indicates that the most abundant tree species varied between forest sites. For instance, at the Beseku site, Maytenus arbutifolia was the species most frequently observed in sampled plots (90.91%) followed by Maesa lanceolata Forssk (81.82%) and Myrsine melanophloeos (72.73%). In contrast, the relative frequencies of Myrsine melanophloeos, Maesa lanceolata Forsskand Pittosporum viridiflorum were the same at the Heben Dubo site (81.82%). Maytenus arbutifolia and Maesa lanceolata Forssk were found in all considered plots at the Shopha site (Table 4). A simple Post Hoc test indicates that, there is no significant difference in the mean value of relative frequency for overall tree species between the shopha and the Heben Dubo sites. However, the Beseku site exhibit a statistically significant ($p<0.05$) difference of relative frequency compared to the Heben Dubo site.

Relative dominance presents the contribution of each tree species to the total basal area of all sampled trees. Podocarpus falcatus comprised the greatest (15.21%) share of the basal area at the Beseku site. The second and third greatest shares of the basal area are Maesa lanceolata Forssk (13.09%) and Maytenus arbutifolia (12.93%) respectively. At the two remaining sites, Maesa lanceolata Forssk contributed to the greatest share (Table 4). Economically valuable tree species exhibited lower basal area contribution at all three sites, particularly at the Beseku site.

Importance Value Index (IVI) provides information on the ecological importance of tree species in forest sites. Results of importance value index reveal that *Maesa lanceolata Forssk* is the most ecologically important tree species of the recorded tree species at the *Beseku and Shopha* sitesand the second most ecologically important tree species is *Maytenus arbutifolia* (Table 4). *Myrsine melanophloeos* (112.06) is the most dominance tree species at the *Heben Dubo* site and is also the most prioritized tree species for various uses.

Tree species diversity: The Shannon Wieners diversity index values of the Beseku, Heben Duboand Shopha forest sites were 2.99, 2.92 and 3.17 respectively (Table 5). The species evenness and richness were 0.83, 0.84 and 0.87 for the Beseku, Heben Dubo, Shopha sites respectively, with the numbers in parenthesis representing species richness.

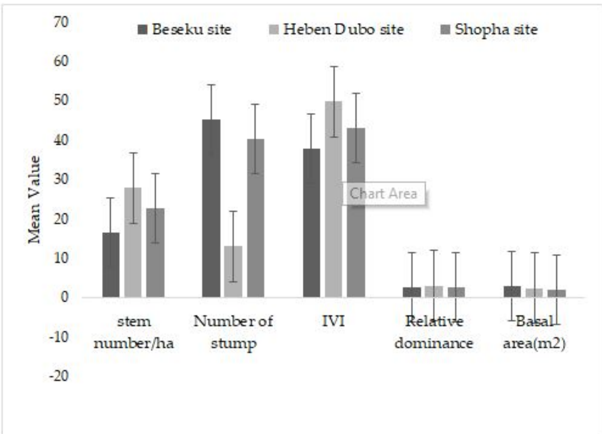

Figure 3: Mean of stem density (ha^{-1}) relative dominance, stump number, basal area and IVI of overall tree species across three forest sites.

Principal components analysis based on stem density (ha^{-1}), importance value index, stand density index and diversity indices: Principal Components Analysis (PCA) indicated that the ecological performances of the recorded tree species vary from one site to another. For instance, based on the result of PCA of the density (ha^{-1}), stand density index, importance value index, Shannon Weiner's diversity index, average height and DBH, the top five tree species at the Beseku site in terms of ecological performance are Maesa lanceolata Forssk, Maytenus arbutifolia, Podocarpus falcatus, Myrsineme lanophloeos and Croton macrostachyus. At the Heben Dubo site, the best-performing tree species are Myrsineme lanophloeos, Maesa lanceolata Forssk, Juniperus procera, Croton macrostachyusand Schefflera abyssinica. The top five ecologically best-performing tree species at the Shopha forest site are Maesa lanceolata Forssk, Myrsineme lanophloeos, Maytenus arbutifolia, Podocarpus falcatus and Vernonia Amygdalina. These results indicate a difference in the order of ecological dominance of tree species at the three forest sites when considering various ecological variables.

The value of the Shannon diversity index and species richness at the Beseku site are greater than those at the Heben Dubo site. The last column of Table 4 provides Shannon diversity indices of the top ten economically important tree species.

This may be due to the difference in human disturbances. While the cluster analysis of economically important tree species exhibits no clear separation at all considered forest sites. It indicates a slight separation at the Beseku site (Figure 4). This cluster structural distribution was attained by using the first two principal components (PCs). For the Beseku site, the correlation matrix provided the first PC with a total variance contribution of 59.723% which is nearly equally weighted by density (ha^{-1}), Shannon Weiner's diversity index, importance value index and stand density index variables. The second PC with a total variance of 25.872% is dominated by the variables of average height and DBH. Together, the first two PCs account for 85.6% of the variation in variables at Beseku site. At the Heben Dubo and Shopha sites, the variance contribution of the first two PCs are about 89.04% and 87% respectively and the first PC is dominated by the variables of density (ha^{-1}), Shannon Weiner's diversity index, the importance value index and stand density index. The second PC is dominated by the average height and the DBH.

Beseku site						
Tree Species	**Density ha^{-1}**	**Relative Density**	**Relative frequency**	**Relative Dominance**	**IVI**	**H'**
Myrsine melanophloeos	57.58	9.41	72.73	5.39	87.53	0.22
Hagenia abyssinica	17.17	2.81	36.36	5.19	44.36	0.1
Juniperus procera	20.2	3.3	54.55	6.59	64.44	0.11
Podocarpus falcatus	25.25	4.13	72.73	15.21	92.06	0.13
Maytenus arbutifolia	39.39	6.44	90.91	12.94	110.29	0.18
Pittosporum viridiflorum	12.12	1.98	27.27	2.41	31.66	0.08
Maesa lanceolata	133.33	21.78	81.82	13.09	116.69	0.33
Nuxia congesta	11.11	1.82	27.27	2.58	31.67	0.07
Hypericum revolutum	5.05	0.83	18.18	0.5	19.5	0.04

Syzygium guineense	1.01	0.17	18.18	0.11	18.46	0.01
Heben Dubo site						
Myrsine melanophloeos	216.16	23.46	81.82	6.78	112.06	0.34
Hagenia abyssinica	22.22	2.41	54.55	5.38	62.34	0.09
Juniperus procera	43.43	4.71	63.64	7.42	75.77	0.14
Podocarpus falcatus	33.33	3.62	54.55	2.59	60.76	0.12
Maytenus arbutifolia	25.25	2.74	63.64	2.23	68.6	0.1
Pittosporum viridiflorum	44.44	4.82	81.82	3.61	90.26	0.15
Maesa lanceolata Forssk	97.98	10.64	81.82	18.33	110.78	0.24
Nuxia congesta	35.35	3.84	54.55	6.44	64.82	0.13
Hypericum revolutum	2.02	0.22	9.09	0.18	9.49	0.01
Syzygium guineense	0	0	0	0	0	0
Shopha site						
Myrsine melanophloeos	97.98	11.1	63.64	6.55	81.28	0.24
Hagenia abyssinica	8.08	0.92	27.27	2.02	30.21	0.04
Juniperus procera	37.37	4.23	54.55	4.24	63.02	0.13
Podocarpus falcatus	32.32	3.66	54.55	9.63	67.84	0.12
Maytenus arbutifolia	47.47	5.38	100	6.29	111.66	0.16
Pittosporum viridiflorum	31.31	3.55	63.64	4.02	71.2	0.12
Maesa lanceolata Forssk	107.07	12.13	100	14.74	126.87	0.26
Nuxia congesta	29.29	3.32	63.64	4.46	71.41	0.11
Hypericum revolutum	1.01	0.11	9.09	0.05	9.26	0.01
Syzygium guineense	0	0	0	0	0	0
IVI: Importance Value Index, H': Shannon Weiner's Diversity Index						

Table 4: Stem density ha^{-1}, relative density, relative frequency, relative dominance, IVI, and Shannon Diversity Index (SHDI) for economically prioritized top ten tree species.

Diversity indices	Beseku site	Heben Dubo site	Shopha site
Shannon Weiner's diversity index (H')	2.99	2.92	3.17
Shannon Weiner's equitability (species evenness)	0.83	0.84	0.87
Species richness	37	33	39

Table 5: Diversity indices of Beseku, Heben Dubo, and Shopha forest sites.

Structural distribution of top five economically important tree species by diameter class: To analyze the size distribution patterns of economically important indigenous tree species, diameter values were classified into eleven classes. Figures 5-7 present the DBH class distribution patterns of four economically valuable and one ecologically important, tree species. The top-ranked economically important tree species (Myrsine melanophloeos) was analyzed separately for each site. Figure 5 reveals that the DBH class distribution pattern of Myrsine melanophloeos varies between sites. The DBH class distribution pattern of Myrsine melanophloeos at the Beseku site reveals distinct inverted J-shape curves. Whereas, it almost exhibits an interrupted Gauss type pattern at the Heben and Shopha sites. As Figures 6 and 7 show, the lower DBH classes of Hagenia abyssinica, Podocarpus falcatusand Juniperus Procera are smaller than the middle classes. This indicate that the future sustainability of all economically prioritized tree species is not a promising trend in these study areas. In Particular, the seedlings of Hagenia abyssinica were not observed in the study area during vegetation data collection. The DBH class distribution of Maesa Lanceolata Forssk which is an ecologically important tree species, reveals a Gauss type distribution pattern across all sites.

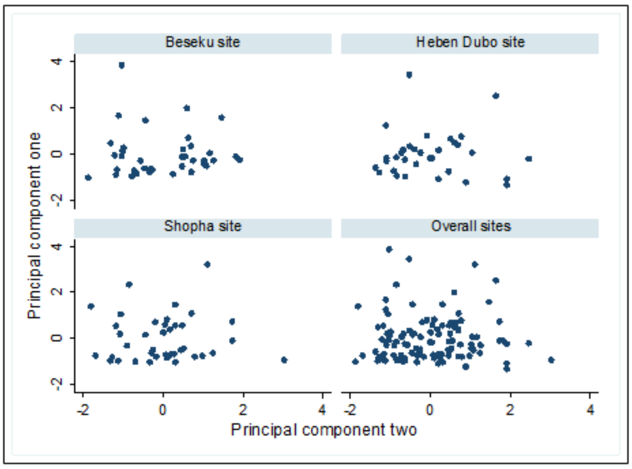

Figure 4: The structural relationships among stand density (ha^{-1}), Shannon diversity index, importance value index, stand density index, DBH average and height average for economically important indigenous tree species for three forest sites and overall sites (Beseku, Heben Dubo, and Shopha) using the first two PCs.

Effect of household preference, diameter and height growth on stem density ha^{-1} of economically important indigenous tree species: The multiple linear regression results of Equation (9) as exhibited in the Table 6, reveal that at the Beseku, Heben Dubo and Shopha sites as DBH increases by 1 cm, the stem density ha^{-1} decreases by factors of 0.087, 0.16 and 0.28 respectively. However, this reduction is not statistically significant at all three forest sites. The numbers stumps has a positive relationship with stem density ha^{-1}. The stem density ha^{-1} of the top five tree species is significantly lower than that of the tree species beyond the fifth rank, especially at the Beseku site (Table 6). When other variables remain constant, the Stem density ha^{-1} of the first-ranked tree species is 261.03 less than that of tree species ranked beyond the fifth rank. These differences are not similar across the Heben Dubo and Shopha sites.

The Importance value index has a significant positive relationship with stem density ha^{-1} at three considered sites, and its effect on each site is illustrated Figure 8. The simulation results of some variables, such as stem density ha^{-1}, DBH, height and IVI of tree species indicate that the stem density ha^{-1} of economically important tree species in the Beseku and Shopha forest sites sharply decline as the DBH and height size increase. This sharp decline may be a result of the presence of high human pressure on more economically valuable tree species (Figure 9). However, all considered variables exhibit a different degree of effect on the simulated stem density ha^{-1} at the three forest sites.

Dependent variable=Density ha^{-1}						
Independent variables	**Beseku**		**Heben Dubo**		**Shopha**	
	Coef and std. err	**P>|t|**	**Coef and std. err**	**P>|t|**	**Coef and std. err**	**P>|t|**
Average DBH (cm)	-0.087	0.772	-0.16	0.595	-0.28	0.268
	-0.28		-0.31		-0.25	
Average height (m)	-0.32	0.604	-0.45	0.598	-0.22	0.794
	-0.58		-0.83		-0.83	
Important value index	0.53	0.008*	0.6	0.000*	0.63	0.000*
	-0.12		-0.07		-0.09	
Stump number	0.84	0.001*	0.74	0.255	0.24	0.322
	-0.12		-0.63		-0.24	
First rank (dummy)	-261.03	0.001*	138.48	0.000*	-36.28	0.055*
	-35.65		-18.43		-18.16	
Second rank (dummy)	-32.55	0.011*	-6.3	0.605	-29.47	0.337
	-8.31		-12.01		-30.2	
Third rank (dummy)	-92.28	0.001*	-14.78	0.476	-1.1	0.932
	-12.02		-20.42		-12.76	
Forth rank (dummy)	-39..29	0.004*	-2.65	0.835	-26.7	0.313
	-7.67		-12.59		-26	
Fifth rank (dummy)	-21.43	0.101	-7.67	0.524	-38.03	0.074*
	(10.68		-11.85		-20.54	

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constant	-3.7	0.575	-7.7	0.297	-0.34	0.961
	-6.22		-7.22		-6.8	
	ADJ R2=98%		ADJ R2=91%		ADJR2=77.79%	
*Standard error indicated in parenthesis						

Table 6: Multiple linear regression results of stem density ha^{-1} on other independent variables.

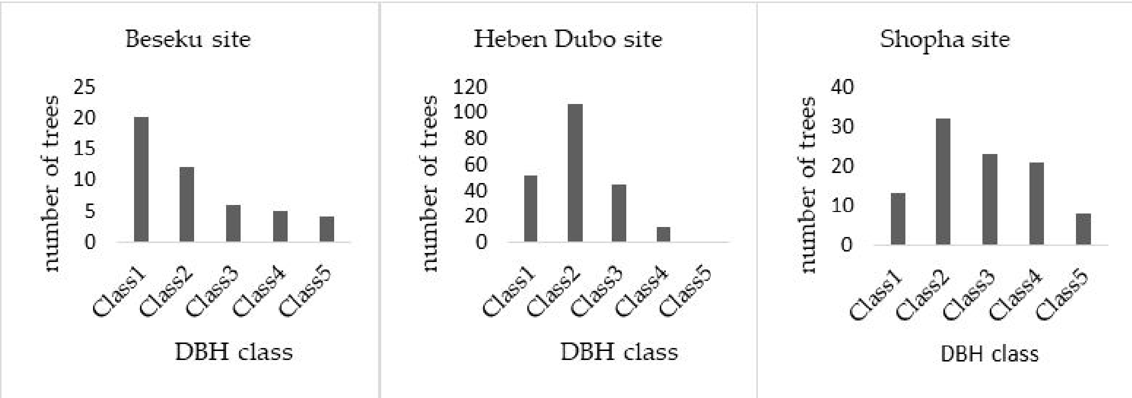

Figure 5: DBH class distribution pattern for *Myrsine melanophloeos* at three forest sites separately.

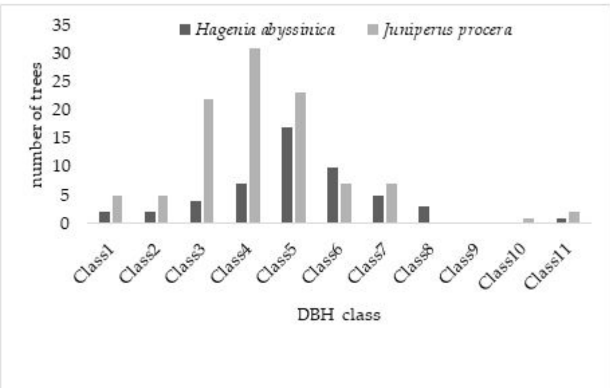

Figure 6: DBH class distribution for *Hagenia abyssinica* and *Juniperus procera* across all sites.

Discussion

Some tree species are prioritized based on different criteria for their use in various forest products. For example, Juniperus procera is durable, easy to split and light to carry out from the forest. All wood has value but different types of trees have different wood properties that are related to various uses[29].

Myrsineme lanophloeos, Maesa lanceolata and Maytenus arbutifolia are prioritized as the top three tree species for charcoal production. All member of the focus group discussion stated that there is a high demand at the local market for the charcoal produced from Myrsineme lanophloeos. However, the Acacia-dominated dry woodland and shrubl and areas provide the largest source of wood for charcoal that is used in urban centers in the country [30,31].

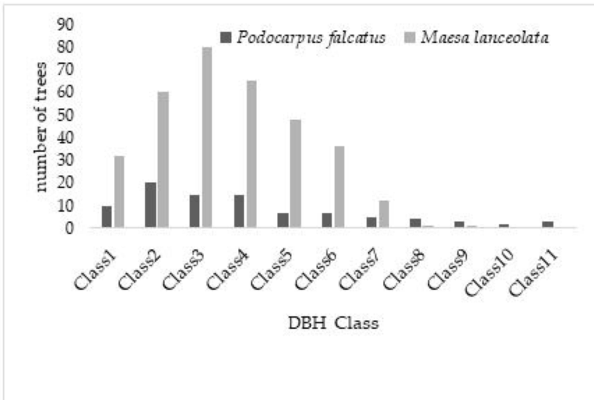

Figure 7: DBH class distribution for Podocarpus falcatus and Maesa lanceolata across all sites.

Historically, charcoal was only produced from Myrsineme lanophloeos in the study area. However, due to the decreasing amount of Myrsineme lanophloeos in the forest, now it is produced from Maesa lanceolata and Maytenus arbutifolia. This may imply forest degradation. Similarly, Sunderlin et al. [32], Mark et al. [33], Shiferaw et al. [31] and Garedew et al. [34] have reported that charcoal

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production negatively impacts forest resources as it often associated with the escalating rate of deforestation and degradation of both general and targeted species. This implies that species-specific utilization results in the degradation of these species in natural forests [34,35]. Therefore, species-specific management strategies and policy is vital to encourage sustainable forest management approaches.

The status of stem density ha^{-1}, species richness and basal area ha^{-1} of the Munessa-Shashemene forest are on satisfactory and the values stem density ha^{-1} and species richness are greater compared to those found in other studies. For example, Girma et al. [16] conducted vegetation study at the Degaga site of the Munessa-Shashemene forest and found 36 woody species belonging to 30 families. Similarly, compared to our findings Ruiz et al. [14], Bello et al. [36] found a lower species diversity in community forests of the Dolpa district in mid-west Nepal. However, some scholars found higher species diversity and stand density [1,37-39]. Similarly, Derero et al. [40] found a higher Shannon diversity index and species richness at the Masha forest in Ethiopia. Lower values of stem density ha^{-1} and more stumps were recorded at the Beseku site. This may imply that high forest disturbance has a negative impact on stem density ha^{-1}, basal area ha^{-1} and the diameter class distribution of larger trees. However, relative density, relative frequency and importance value index of economically prioritized species varied between the considered forest sites because local communities prefer different tree species for specific forest products. These values could also vary between different agro-ecologies [41].

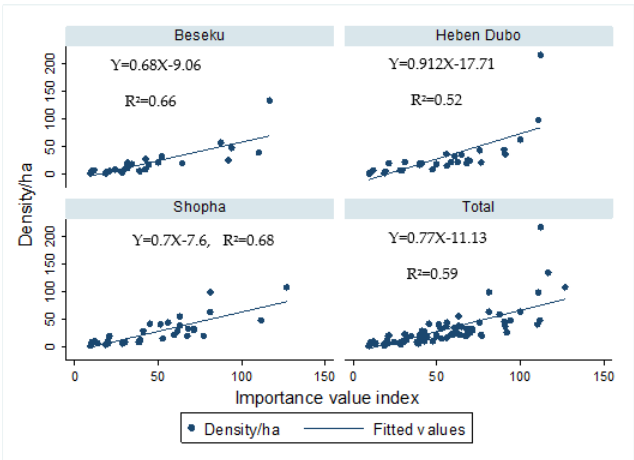

Figure 8: The relationship between stem density ha^{-1} and Importance value index for economically important tree species at Beseku, Heben Dubo, Shopha and overall sites (Y: Stand density ha^{-1} and X: Importance value index).

However, the selective felling method employed in the natural forest results in the homogenization of the forest community [1]. For example, harvesting the best individuals of the preferred genera, for firewood, Quercus and Pinus, decreases the contrast between patches and the traditional ecosystem functions of the remaining forest which leads to forest degradation [42,43].

During the vegetation survey, some indicators of illegal activities were observed in all considered sites. These indicators include sump numbers, overgrazing or cutting trees at the base rather than the branch and leaving them for fodder purpose during drought time, not restricting the access of forest land for grazing, the expansion of agricultural land towards forest land and illegal settlement. These conditions may imply a lack of forest land tenure [7].

The variation of stem density ha^{-1}, basal area ha^{-1} and other ecological variables of different tree species are due to the environmental factor and human disturbances [40,43,44]. *Maesa lanceolata Forssk* is more ecologically dominant tree species at the Beseku and Shopha site compared to *Myrsine melanophloeos* species. This variation may be due to anthropogenic pressure on tree species. For instance, *Myrsine melanophloeos* is prioritized as the top-ranked tree species, but its frequency is highly varied between sites. Similarly, the relative frequency of the most valuable tree species, such as *Hagenia abyssinica, Juniperus procera* and *podocarpus falcatus* were lower than the relative frequencies of inferior species. In line with this finding Richard et al. [38] reported that some timber tree species in the Miombo Woodland of Bereku, Forest Reserve, such as *Pterocarpus angolensis, Dalbergia melanoxylon, Pterocarpus rontundifolius* and *Albizia verscolor* exhibit very poor relative frequencies due to overexploitation.

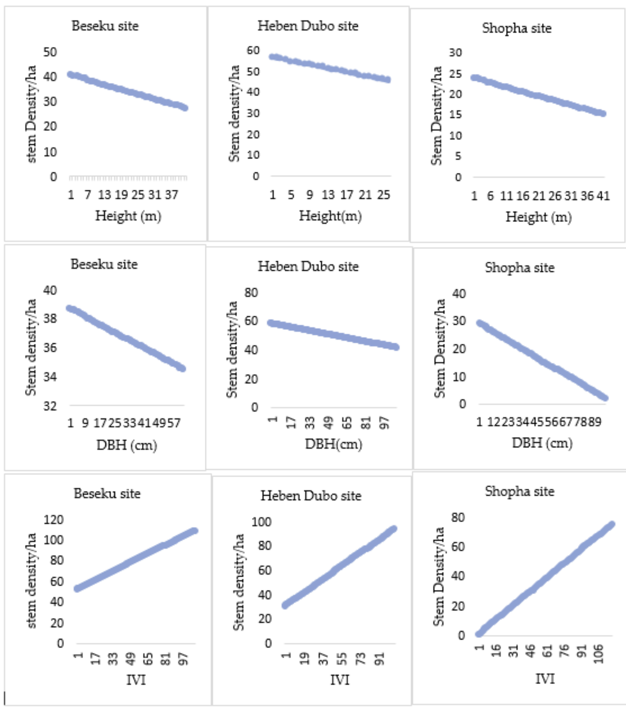

Figure 9: Simulated stem density ha^{-1} against DBH, height, and IVI for three forest sites (Beseku, Heben Dubo and Shopha).

Because all of three sites examined in this study are found in the same agro-ecological zone and are classified under the same vegetation types, these variations may be due to the accessibility of the market and roads which allow forest products to be more easily supplied to the market and accelerates forest degradation. For instance, Beseku site is characterized by good road access and is closer to the local market, which are conditions that are beneficial to the supply of forest products to the market and create high demand. People who live in the rural areas surrounding the Beseku site can more easily supply forest products to the market as compared to people who live near other sites. Additionally, key informants revealed that the presence of small-scale private wood furniture in the local market facilitates local communities to participate in illegal cutting. Of the fuelwood and other forest products supplied to Arsi-Negele town, more than 50% originates from the Beseku site. In addition to small-scale, private wood furniture, local alcohol (locally called Areke) production also creates a high demand for fuelwood more than 3,500 households in Arsi-Negele produce Areke. Each household produces on average, about 150 liters of Areke in six working days, which consumes a minimum of 450 kilograms of fuelwood [45].

The number of the stump has a positive relationship with stem density ha^{-1}. This may be because people cut the trees that are more dominant and more accessible for different purposes. However, all economically prioritized tree species are relatively more dominant species in the study area. In addition, some species were coppiced with more stem when cut down. For instance, 23 coppiced stems of *Myrsine melanophloeos* from a single stump were observed during the study. The total number of stem density ha^{-1} is decreased with disturbance and the number of stumps is one of the disturbance indicators. As the number of stumps increases, the total value of stem or tree density can be reduced [46]. But the number of stumps may have either a positive or negative effect when comparing the stem density ha^{-1} of one species to that of others [47].

The DBH class distribution pattern of *Myrsine melanophloeos* reveals distinct inverted J-shape curves at the Beseku site which indicates good regeneration. The *Myrsine melanophloeos* species at the Beseku site has high regeneration potential and the matured stand of *Myrsine melanophloeos* is overexploited. In contrast, *Myrsine melanophloeos* at the Heben Dubo and Shopha sites exhibits almost an interrupted Gauss type DBH class distribution pattern. The structural distribution of prioritized tree species varied between sites. In line with this finding, Mindaye et al. [48] found different DBH class distributions for *Boswellia papyrifera* across five studied areas. *Podocarpus falcatus* and *Juniperus procera* exhibit an interrupted Gauss type curve and *Hagenia abyssinica* is characterized by an irregularly interrupted distribution. This finding may be due to human disturbance [16,49-51]. Species with an inverted J-curve distribution exhibit a sufficient regeneration and recruitment status [16,40,48,52]. This may indicate that, in the study area the future sustainability of all economically prioritized tree species is not a promising trend. In particular, the seedlings of *Hagenia abyssinica* were not observed in the study area during vegetation data collection.

Conclusion

This paper attempts to prioritize economically important indigenous tree species and evaluates their ecological performances in the Munessa-Shashemene forest. The findings indicate that the Myrsineme lanophloeos, Haginea abysinica, Juniperus procera, Podocurpus falcatus and Maytenus arbutifolia are the top five prioritized tree species. The stem density ha^{-1}, relative density, relative frequency, relative dominance and important value index, stand density index and species diversity index of the economically prioritized tree species vary between the three considered forest sites and the structural distribution of economically prioritized species is significantly different from that of inferior tree species. In particular, the lower class distribution is very low for some economically important indigenous tree species, which could result in the loss of biodiversity and forest degradation in the future. Therefore, as an area with both general and particularly economically valuable indigenous tree species, the Munessa-Shashemene forest can be sustained by improving forest land tenure and providing economic incentives and substitutes like electricity, improved fodder and construction materials to local communities. Finally, Intensive silvicultural operations and enrichment planting should be applied to the Hagenia abyssinica, Juniperus procera and Myrsineme lanophloeos species at the Beseku forest site.

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Conflicts of Interest

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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