

Assessment of Indigenous Tree Management Practices of *Hagenia Abyssinica* (Kosso): The Case of Smallholder Farmers in Gamo Highlands, Southern Ethiopia

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Abstract

Hagenia abyssinica (Bruce L.) is a multipurpose, most endangered, and threatened tree species in Ethiopia. The tree population is decreasing over time due to natural and man-made factors. The study assesses the management practices of smallholder farmers of the tree in the Gamo Highlands of southern Ethiopia. A multi-stage sampling technique was used to select three Woredas from the Gamo Highlands. Vegetation-based data were collected to estimate density, regeneration, and population structure of *Hagenia abyssinica* tree species, as well as its availability from selected agroforestry practices. Data on management practices and challenges were gathered through focus group discussions and semi-structured interviews using semi-structured questionnaires. Data were analyzed using Statistical Package for the Social Sciences (SPSS) and Excel spreadsheets. The results indicate that *Hagenia abyssinica* thrives on six different land-use types: Homegardens, mixed-woodlots, farming boundaries, grazing land, live fences, parkland, or cropland, with dominance in homegardens. The population structure of the tree was dominated by mature tree stages, with diameters ranging between 20 cm and 50 cm. The mean density was 11.13 individuals per hectare. The current status of the species is under threat, and the study recommended calls for coordinated efforts from policymakers, conservationists, local authorities, and experts, as well as serious management attention in the field.

1 INTRODUCTION

In tropical agricultural landscapes, indigenous tree species serve as vital socio-ecological anchors, providing multifaceted ecosystem services and economic benefits (Dhanya et al., 2014; Lelamo, 2021; Udawatta et al., 2019). Across Ethiopia, smallholder farmers have traditionally retained and managed these indigenous woody species across various land-use systems to support rural livelihoods and maintain ecosystem stability (Amare et al., 2019; Lelamo, 2021). They have historically integrated native wood species such as *Cordia africana*, *Croton macrostachyus*, and *Millettia ferriuginea* into farm parklands, homegardens, and boundary plantings to diversify their income and sustain soil fertility. However, rapidly accelerating land conversion for agricultural expansion, overexploitation of wood products, and a shift towards fast-growing exotic tree monoculture now threaten this natural capital (Lelamo, 2021). Also, limited access to native propagation material has severely threatened indigenous tree diversity, leaving many ecologically and economically crucial species at risk of local depletion (Amare et al., 2019).

Hagenia abyssinica (Bruce) J.F.Gmel. is a monotypic tree species belonging to the family Rosaceae (Bruce, 1790; Orwa et al., 2009). It is indigenous to the Afromontane regions of eastern Africa and is widely recognized as a multipurpose tree because of its ecological, medicinal, and socioeconomic importance (Orwa et al., 2009; Negash, 2021). The species is a characteristic component of East African Afromontane forests, where it contributes significantly to forest structure, biodiversity, and ecosystem functioning (Kassa et al., 2011; Tegene, 2018). *Hagenia abyssinica* is distributed throughout the highlands of Eritrea, Ethiopia, Sudan, Uganda, Kenya, the Democratic Republic of the Congo, Rwanda, Burundi, Tanzania, Zambia, and Malawi (EPPO, 2023). The species is characteristic of semi-humid

Afromontane forests and mountain woodlands, where it commonly occurs at high elevations (Hedberg, 1989; Feyissa et al., 2007). In Ethiopian Montane landscapes, mainly within Semian and Bale Mountains, *Hagenia abyssinica* forms dense and pure canopy stands, ecologically distinct and co-dominant in association with *Juniperus procera* (Friis, 1992; Vivero et al., 2005; Friis et al., 2010). *Hagenia abyssinica* is characterized by strict environmental adaptation and occupies narrow altitudinal gradients ranging from 2000 to 3000 meters above sea level, with an annual rainfall requirement between 1000 and 1500 mm (Ayele et al., 2017; Simion, 2018; Negash, 2021). Given its crucial ecological presence, the tree provides crucial socio-economic benefits, including traditional medicine, timber, livestock fodder, fuelwood, and bee flora that can support local livelihoods (Assefa et al., 2010; Mekuria et al., 2018; Simion, 2018; Habtemariam & Woldetsadik, 2019). Additionally, the species plays a crucial role in soil fertility, hydrological regulation, and nutrient cycling through leaf-litter decomposition (Kloos et al., 2014; Negash, 2021).

Despite its high socio-economic and ecological value, *Hagenia abyssinica* is increasingly threatened and has become one of the most endangered tree species in Ethiopia and broader African montane regions (Azene, 2007; Feyissa et al., 2007; Assefa et al., 2010). This decline is driven by a combination of natural and anthropogenic factors, including farmers neglecting its biological attributes (Habtemariam & Woldetsadik, 2019), overexploitation for timber and non-timber forest products (Assefa et al., 2010; Yineger et al., 2008), and poor natural regeneration capacity (Feyissa et al., 2007; Habtemariam & Woldetsadik, 2019). Although rural communities actively engage in planting and managing seedlings, the rate of species decline far outpaces its regeneration efforts, largely due to recalcitrant seed viability and low germination rates (Habtemariam & Woldetsadik, 2019). Sustained market demand for its timber and non-timber forest products further exacerbates the pressure on this vulnerable species (Assefa et al., 2010), emphasizing the urgent need for targeted conservation and sustainable management practices.

Empirical research on *Hagenia abyssinica* in Ethiopia is overwhelmingly focused on regeneration, distribution, ecology, and conservation in natural forest ecosystems, with comparatively limited attention given to the occurrence, the ecological role, and management practices in smallholder agroforestry (Azene, 2007; Habtemariam & Woldetsadik, 2019; Atspha et al., 2019). Consequently, substantial gaps remain regarding the status, management practices, and ecological services of *Hagenia abyssinica* within smallholder agro-ecosystems, particularly in the Gamo highlands of southern Ethiopia, where empirical studies are scarce. Critically, the specific harvesting reasons, management techniques, and conservation priorities of local farmers across agricultural land-use types remain poorly understood (Ayele et al., 2017; Feyissa et al., 2007). Since the species' natural regeneration and population variability require attention outside natural forests and protected areas, understanding the farmers' engagement is essential for designing effective landscape-level conservation strategies. To address these gaps, this study examines the population status and the management practices of *H. abyssinica* across contrasting land-use types in the Gamo highlands of southern Ethiopia, focusing on its viable, community-based management and conservation pathways.

2 METHODOLOGY

2.1 Area Description

The study was conducted in the Gamo Highlands of southern Ethiopia, which encompasses three administrative woredas: Chenchazuria, Dita, and Bonke. The Gamo Highlands run northeast to southwest and are nearly 100km long (06° 02' 27" N, 37° 10' 37" E) and 30 km wide. Bonke Woreda is bordered by Geresie Woreda, Kemba, Dita, and Gacho Baba Woreda, with average annual rainfall and temperature of 1400mm and 13.05°C, respectively. The major forest trees of the area include *Acacia docurrens*, *Hagenia abyssinica*, *Croton macrostachyus*, *Erythrina brucei*, *Eucalyptus species*, *Arundinaria alpina*, *Vernonia species*, and different shrubs and herbs. *Malus domestica*, as a fruit tree, is the dominant species. Chenchazuria is bordered by Aribaminch Zuria, Mirab Abaya, Kucha, and Dita, with a mean annual rainfall of 900–1200 mm and mean annual temperatures of 12°C and 20.5°C respectively. The vegetation in the study area is mainly evergreen forest and includes species such as *Dodonaea angustifolia*, *Acokanthra schimperi*, *Ximenia americana*, *Hagenia abyssinica*, *Maytenus arbutifolia*, *Rhus natalensis* (Soromessa et al., 2004; Wana & Woldu, 2005). These species are confined to the middle and higher altitudes of the study area. However, with increasing altitude, one can find elements of Combretum-Terminalia woodland and forest vegetation, which form patches as a remnant of intensive agricultural practices in the highlands of Chenchazuria. The dominant tree species in the community woodlots are *Eucalyptus globulus*, *Juniper procera*, *Hagenia abyssinica*, *Pinus patula*, and *Cypressus lufsitanica*. Dita Woreda is bordered by Arba Minch Zuria and Bonke, Deramalo, Kucha, and Dita Woreda, with an average annual rainfall of 2200–3500 mm. In Dita Woreda, the distribution of vegetation depends on the climate, drainage pattern, and soil types as the main factors. Different tree species are available in the study area, such as *Bamboo*, *Hagenia abyssinica*, *Juniperus procera*, *Podocarpus falcatus*, *Olea europea*, and *Eucalypt*. These species were selected to represent the agroecological and land-use diversity typical of the highlands. The region is characterized by smallholder farming systems where agroforestry practices are integral to livelihoods, soil conservation, and biodiversity preservation.

2.2 Sample size determination

Six rural kebeles were selected from three woredas in which the study was conducted (Fig. 1). Systematic sampling was used to select kebeles, and a multistage procedure was used for data collection. The woredas were chosen based on their high potential for agroforestry practices. The highland sites were specifically selected because of the species' widespread distribution and popularity. A tree inventory and assessment were conducted after a reconnaissance survey and identification of households that grow *Hagenia abyssinica* on their land use types. Household heads and study sites were chosen during the reconnaissance survey. To collect data from the households, the proportional sample size determination for the families was applied to household heads of tree growers on their farmland. Thus, 180 sample households were selected using Yamane's formula for sample determination amongst the 3655 households living in the six kebeles.

2.3 Sampling Method and Data Collection

2.3.1 Vegetation and population data

The line-transect distance sampling (LTDS) method was employed to estimate the absolute density and population structure of scattered *Hagenia abyssinica* trees. Then, systematic quadrat sampling was nested within transects. Vegetation data were collected to assess the population structure and regeneration status of the species, as well as its utilization pattern and the field-level conservation status. Twelve line transects (two per site) were established across areas containing *H. abyssinica*, totaling 6 km. Each transect was 500 m long, classified into five 100 m segments, and spaced ≥ 300 m apart. A total of 100 sample quadrants were surveyed across all transects. Transect location followed a systematic random sampling approach: the starting point of the first transect was selected randomly, and succeeding parallel transects were established randomly to the left or right of the previous transect.

Data recorded within each quadrant included land-use types containing *Hagenia abyssinica*; for each tree, diameter at breast height (DBH), population counts, and indicators of tree physiological condition were recorded. Facts on management practices and challenges affecting the species were also documented. Also, the consumption of different tree parts, types of damage, and potential causes of damage on *Hagenia abyssinica* were assessed based on direct field observations.

Recorded individuals were categorized into size and age classes based on DBH and total height as follows: seedlings (total height < 1.30 m), saplings (total height ≥ 1.30 m and DBH < 4.5 cm), young trees, and mature trees.

2.3.2 Socioeconomic and management data

Socioeconomic and management-related data were collected from smallholder farmers and key informants using a mixed-methods approach within a descriptive survey design. They were collected through structured questionnaires, household surveys, key informant interviews, and FGDs to obtain facts on sampled households and the management of *Hagenia abyssinica* trees on and around croplands.

The structured questionnaire-based information comprises household demographics, tree-growing practices, on-farm management practices, major challenges and opportunities associated with *H. abyssinica*, regeneration status, and purposes of utilization, management options, and selection practices. Key informant interviews were conducted to obtain detailed information on the major uses of the species, management and conservation practices, and perceived constraints affecting its sustainability. FGDs were conducted at each site and contained up to ten participants, including elders, village leaders, and local experts. They were selected in consultation with farmers, development agents, and kebele administrators based on their age, experience, and knowledge of tree management and conservation practices. The discussions addressed issues such as agroforestry practices, growth and regeneration status of the species, utilization of on-farm tree resources, and challenges and opportunities for integrating and conserving *H. abyssinica* within agroforestry systems.

2.4 Data Analysis

The collected data were analyzed using descriptive tools. The data collected from different sources were analyzed using statistical software called Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. The presentation of the result was presented using a table, graph, and description held for each.

Regeneration

The regeneration status of *Hagenia abyssinica* was categorized into good, fair, poor, and none regenerate based on the population size of seedlings, saplings, and adult trees: Good regeneration if seedlings > saplings > old; Fair regeneration if seedlings > or ≤ saplings ≤ old; Poor regeneration if the species survives only in the sapling stage but no seedlings; No regeneration if a species is present only in adult form. New regeneration if the species has no old but only seedlings or saplings.

Density

Density for seedlings, saplings, adult trees, and old trees, tree basal area, and abundance

$$\text{Density} = \frac{\text{total number of kosso seedling or sapling or adult or old}}{\text{total area sampled}} \dots\dots\dots \text{Eq. 1}$$

$$\text{Kosso tree Species dominance} = \frac{\text{total basal area for kosso tree}}{\text{area sampled}} \dots\dots\dots \text{Eq. 2}$$

$$\text{Kosso tree Relative dominance} = \frac{\text{dominance of kosso}}{\text{total dominance for all speices}} * 100 \dots\dots\dots \text{Eq. 3}$$

$$\text{Species frequency} = \text{presence or absence of species in a sample plot} \dots\dots\dots \text{Eq. 4}$$

$$\text{Relative frequency} = \frac{\text{frequency of a kosso tree}}{\text{total frequency for all}} * 100 \dots\dots\dots \text{Eq. 5}$$

3 RESULTS AND DISCUSSION

3.1 Farmers' land-use selection for growing *Hagenia abyssinica* as an agroforestry tree

Hagenia abyssinica, an indigenous tree species, is commonly grown in the Gamo Highland, indicating that farmers utilize this species in various agroforestry practices. This result suggests that a farmer grows and retains *Hagenia* trees in one or more agroforestry practices, as indicated in Fig. 2.

The study conducted in the Gamo Highlands showed that *Hagenia abyssinica* is distributed across six land-use types and adjacent forest areas, demonstrating its adaptability to diverse agroecological conditions. The majority of farmers reported planting and retaining regenerated *Hagenia abyssinica* trees on cropland (63.7%), farm boundaries (62.6%), and Homegardens (61.5%). This widespread distribution indicates the species’ ecological and socio-economic importance to the local community. In contrast, Livefences and woodlots were the least land-use types, accounting for only 22% and 24.2% of the tree

population, respectively. This finding aligns with previous studies by Ayele et al. (2017), Bruijnzeel et al. (2011), and Simion (2018), which highlighted the prevalence of *Hagenia abyssinica* in agroforestry systems. The dominance of the species on cropland, farm boundaries, and Homegardens underscores its role in supporting agroecological resilience.

Farmers indicated that they preferentially grow indigenous species, particularly *Hagenia abyssinica*, due to their ability to improve soil fertility, provide a fodder source, enhance farm management, and provide protective benefits. This preference for indigenous species is consistent with Molla and Kewess (2015) and Kindu et al. (2006), who emphasized the social and ecological significance of indigenous trees in agroforestry systems. Furthermore, Habtemariam & Woldetsadik. (2019) emphasized that *Hagenia abyssinica* is highly adaptable and widely preserved in agroforestry systems, making it an ideal species for ecological restoration and domestic use.

3.2 *Hagenia abyssinica* Utilization

Communities in the Gamo Highlands recognized the multifaceted importance of *Hagenia abyssinica*, a tree deeply integrated into their livelihoods and agricultural practices. Farmers cultivate *Hagenia abyssinica* for various uses, reflecting its ecological, economic, and social value. This study shows that the stem part of the tree is used for five main purposes, with 91.7% of respondents using it for timber production and 84.4% for home construction. The bark is predominantly used as fuelwood (94.4%), while a smaller proportion of respondents reported its use for charcoal production and home heating. These findings underscore the tree's critical role in meeting household energy needs and construction.

In addition to its structural uses, *Hagenia abyssinica* holds significant medicinal value. The local traditional healers and smallholder farmers reported that various parts of the tree, including the fruit, roots, and leaves, are used to treat a wide range of ailments; for instance, the root is valued as a pain reliever and remedy for stomach pain. The leaves, however, are the most versatile part of the tree, with 96.1% of the communities using them for medicinal purposes and 84.4% for animal fodder. Similarly, research has shown that rural communities use the species to treat livestock ailments (Abebe et al., 2000; Gedif and Hahn, 2003; Asefa et al., 2010), further underscoring its role in supporting both human and animal health. Furthermore, the leaves are used to produce high-fertility compost, enhancing soil fertility and agricultural productivity (Azene, 2007). During interviews and group discussions, farmers emphasized that the diverse benefits derived from *Hagenia abyssinica* are key reasons for planting and maintaining the tree on their land. Likewise, the respondents stated that in some areas, the fruit exhibits therapeutic efficacy against specific human ailments; patients are cured of their ailments by using the fruit of the tree.

Despite its widespread use, the sustainability of *Hagenia abyssinica* is threatened by overharvesting. Medium and large-diameter trees are frequently removed for fencing, house construction, and firewood, often without consideration for their conservation. This practice raises concerns about the future availability of this valuable species and highlights the need for sustainable management practices. The significance of *Hagenia abyssinica* is well documented in the literature, with studies by Azene (2007),

Asefa et al. (2010), Feyissa et al. (2007), and Tariki (2018) highlighting its socio-economic and ecological importance.

Table 1
Repeatedly utilized/collected part of the tree

User preference rank for tree parts	tree part	Number of users	Proportion of user responses (%)
	Leaf	180	37.42
	stem	165	34.30
	seed	22	4.57
	branch	81	16.86
	Root	15	3.12
	Bark	18	3.74

According to the results of the study, the communities frequently used the tree stem and leaf parts, highlighting their importance in daily life. The stem and leaves are particularly sought after by the society and are the most widely used parts of the tree. For instance, dried leaves are often collected by women for cooking, while fresh leaves are used as animal fodder and for the production of compost (Asefa et al., 2010; Azene, 2007). One of the most intriguing findings from the discussion was that farmers plant *Hagenia abyssinica* on their farmland not only for its immediate benefits but also for use as coffins for mortuary purposes. This is possible because the tree’s wood is highly resistant to decomposition by wood-destroying pests like termites. This resistance is attributed to a toxic diethyl ether compound found in the flowers of the female *Hagenia abyssinica* tree, which deters insect pests (Desalegn 2006; Yohannes, 2006).

The stem of *Hagenia abyssinica* is widely used across the study areas due to its durability and aesthetic properties. It is the primary choice for decorative and traditional furniture, including beds, cabinet work, pillars, and sculptures. Additionally, it is used for crafting traditional house ceiling tiles, musical instruments, and domestic firewood (Getachew 1989; Desalegn, 2006; Giday et al., 2007; Habtemariam & Woldetsadik, 2019). The tree wood is also preferred for strength-based applications such as construction, fasteners, farm tools, utensils and bowls, cutting boards, fencing, vehicle bodywork, pulpwood, hardboard, particleboard, interior decoration and core stock, and fuelwood production. These diverse uses underscore the tree’s versatility and its deep integration into the cultural and economic practices of the local community.

3.3 Density and Population Structure of *Hagenia abyssinica*

Table 2
Frequency, relative frequency, and density of *Hagenia abyssinica* trees

DBH class (cm)	Frequency per class	Relative frequency	Density (stems ha ⁻¹)
< 10 cm	265	23.33	2.65
10–20 cm	329	28.96	3.29
20–30 cm	321	28.26	3.21
30–40 cm	140	12.32	1.4
40–50 cm	46	4.05	0.46
50–60 cm	19	1.67	0.19
60–70 cm	2	0.18	0.02
above 70	14	1.23	0.14
Total	1136	100	11.13

The counted mean density of the *Hagenia abyssinica* across the selected sites in the Gamo Highland was 11.13 trees ha⁻¹, encompassing all life stages of the species, including seedlings, saplings, young/juvenile trees, and old trees (over 50 cm in diameter). The highest densities were observed in the 10–20 cm and 20–30 cm diameter classes, with 3.29 trees ha⁻¹ and 3.21 trees ha⁻¹, respectively. In contrast, trees in larger diameter classes exhibited significantly lower densities: 0.02 trees ha⁻¹ for the 60–70 cm class, 0.19 trees ha⁻¹ for the 50–60 cm class, and 0.14 trees ha⁻¹ for trees above 70 cm. This inverse relationship between diameter class and tree density reflects the population structure of *Hagenia abyssinica*, where smaller and younger trees are more abundant, while larger, older trees are increasingly rare. This finding is consistent with the previous studies by Habtemariam & Woldetsadik (2019), Fikadu and Melesse (2014), and Hailemariam and Temam (2018), which identified *Hagenia abyssinica* as the dominant yet vulnerable species in various regions of Ethiopia, highlighting its ecological significance and the need for targeted conservation efforts.

The diameter class distribution of *Hagenia abyssinica* reflects a nearly bell-shaped curve, with the highest frequencies in the middle diameter class (10–30 cm). This pattern indicates a population dominated by mature individuals, with fewer young/juvenile and old-growth trees. The low density of trees in the larger diameter class suggests past disturbance, such as selective logging or environmental stressors, which have limited the survival of older trees. Additionally, the limited regeneration observed in the lower diameter class raises concern about the species' ability to sustain its population in the future. This finding underscores the importance of conservation efforts to protect the tree species, particularly its mature individuals, and promote regeneration. Sustainable management and utilization, including reducing anthropogenic pressure and enhancing seedling establishment, are critical for ensuring the long-term survival of this species.

3.4 Regeneration Status of *Hagenia abyssinica*

The majority of individuals (83.5%) of the species were classified under the category of young-aged trees, whereas a minimum of (2.9%) were measured as old-aged trees (above 50 cm in diameter). The population of the tree species is unstable, as indicated by the reduced number of individuals in the lower classes (seedlings, saplings, and DBH below 10 cm), which showed uncertainty of new recruitment through regeneration. The primary reasons for the shortage of smaller-diameter trees were identified during the group discussion as overuse, insect infestations, replacing trees with foreign species, agricultural expansion, and poor management. The practice of *Hagenia abyssinica* tree inclusion on farmland was accomplished in two ways: retaining naturally regenerated seedlings on their farmland and undertaking seedling plantation activities. The regeneration status of *Hagenia abyssinica* was categorized into good, fair, poor, and none based on the population size of seedlings, saplings, and trees. The regeneration status of the tree was considered good if the sapling > seedling > mature (Khumbongmayum *et al.*, 2006; Dhaulkhandi *et al.*, 2008; Tiwari *et al.*, 2010).

The regeneration status of on-farm *Hagenia abyssinica* is considered poor since saplings (10.5%) are greater than seedlings (3.1%), but it is far less than young trees (83.5%), and also few older trees with a diameter above 50 cm. This was revealed in the Gamo Highlands, where the area needs more work on the regeneration of this species. Similarly, Habtemariam & Woldetsadik (2019) discovered the existence of both shrubs and trees of the species in the Homegardens at the Legambo area of South Wollo, Ethiopia. Some land uses include development phases called seedlings and saplings as well, which further reveal the level of regeneration. Also, this study was consistent with the study of Tegene *et al.* (2018) that the seedlings and saplings of *Hagenia abyssinica* rarely existed in Doshke Forest of Chencha, Gamo Gofa Zone of Ethiopia. A similar study was confirmed by Wami *et al.* (2016). This finding contradicts Hailemariam and Temam (2018) and Soromessa and Kelbessa (2014), who found that the Gole and Chilimo forests had a weak capacity for regeneration, with mature trees and seedlings stage of *Hagenia abyssinica* serving as the key regeneration indicators.

3.5 Conservation Practice and Challenges for *Hagenia abyssinica* in the Gamo Highlands

The Gamo Highlands support a diverse range of tree species, including both native and invasive species, across various land-use types. Farming communities in the region employ traditional knowledge and practices to manage these species, adapting their approaches based on the land-use differences and the ecological requirements of native versus non-native trees. Farmers utilize various tree management techniques, such as selective retention, community planting, and protection, to balance economic benefits with ecosystem sustainability. This aligns with the findings of Eyasu *et al.* (2020), who stated that farming communities in Southwest Ethiopia actively plant and retain both indigenous and exotic trees to support biodiversity conservation and ecosystem services. Indigenous tree species, such as *Hagenia abyssinica*, are more diverse in Homegardens and croplands, while exotic species are predominantly found in Homegardens, woodlots, and farm boundaries but are less common in

croplands. These variations in tree distribution and management are attributed to farmers' indigenous knowledge and experience, as supported by Kassa et al. (2011), Derero et al. (2000), and Eyasu et al. (2020).

Farmers in the highlands employ several management practices, including pollarding, pruning, thinning, fertilizing, and insect pest protection. Although these practices are not always implemented optimally, farmers actively engage in conservation efforts by planting trees in their fields and homesteads and protecting naturally regenerating trees. Farmers recognize the importance of these activities in optimizing tree-crop interaction and deriving multiple benefits such as fuelwood, fodder, and soil fertility improvement. Pruning and pollarding are commonly practiced on the trees in cropland to minimize shade effects on crops, provide fodder for livestock, and obtain materials for fencing and fuelwood. These practices can be considered forms of in-situ conservation, as they support the growth of naturally regenerating populations and enhance on-farm biodiversity. Notably, priority trees- *Juniperus procera*, *Hagenia abyssinica*, *Cordia africana*, *Croton mycrostachus*, and some *Acacia species*- have been identified for conservation due to their ecological, economic, and cultural significance.

Despite these efforts, *Hagenia abyssinica* faces significant conservation challenges. Field observations and interview results indicate that the species is threatened by insect pests, unsustainable exploitation for medicine, house construction, timber, furniture, and firewood use, as well as overgrazing of its leaves. Additionally, the substitution of indigenous tree species with exotic varieties and the lack of attention to conservation and planting programs exacerbate the challenges. This finding is consistent with the previous studies by Getachew and Biruk (2014), Wami et al. (2016), Belay (2014), and Tegegne et al. (2019). However, they contrast with the findings of Assefa et al. (2010) and Mekonnen et al. (2014), who reported that some strong farmers have an endless interest in planting and conserving the indigenous tree species in their study areas.

Hagenia abyssinica was identified as an endangered species due to overexploitation and declining interest in its traditional medicinal use. The lack of effective law enforcement and conservation policies further exacerbates the risk of extinction for this species. Urgent conservation measures are needed to address these challenges, as emphasized by Assefa et al., 2010; Belay, 2014; Feyissa et al., 2007. Another critical issue observed during fieldwork is the inadequate distribution of *Hagenia abyssinica* saplings. Despite the production of seedlings in nurseries, many remain unused and are often wasted due to a lack of recipients. Farmers attribute this to a preference for fast-growing exotic species and the susceptibility of *Hagenia abyssinica* to pest infestation, which renders the tree less desirable. This indicates the need for improved outreach, training, and support for the conservation and sustainable use of this ecologically and economically important species.

4 CONCLUSION

Agroforestry, a traditional land-use practice, integrates trees into farming systems, including *Hagenia abyssinica*. Farmers in the Gamo Highlands manage native and exotic tree species on their farmland,

balancing economic benefits and sustainable ecosystem services. Among the native species, *Hagenia abyssinica* is a significant feed source for cattle, fuelwood demand fulfillment, disease treatment, and lumber production. The mean density of *H. abyssinica* is 11.13 trees per hectare, with the largest populations falling within the 10–20 cm and 20–30 cm diameters. Threats to *Hagenia abyssinica* include insect infestations, agricultural expansion, poor management, unsustainable exploitation, and exotic tree substitution. Proper distribution and seedling distribution are crucial for survival. The study highlights the overexploitation of *Hagenia abyssinica*, a medicinal plant, in a forest reserve. It calls for coordinated efforts from policymakers, conservationists, local authorities, and other stakeholders to protect the species. The report emphasizes the importance of awareness and managing species disturbance at seedling and sapling stages, prioritizing plantation programs to conserve native species, and training local experts on collaborative action for red-list plants.

Declarations

Conflict of Interest

The authors declare that they have no conflict of interest

Author Contribution

Both Esubalew Girma and Aman Abeje jointly conducted a preliminary survey and identified the problem. They subsequently collaborated on community consultation, methodology development, data collection, and identification of appropriate software for data analysis. Esubalew Girma entered the data into the software, verified and analyzed the data, and together they prepared the initial manuscript. Finally, both authors reviewed and approved the manuscript.

Data Availability

All the data were obtained from a field survey and questionnaire. The data presented for this study are available upon request from the corresponding authors.

References

1. Abebe, D., Debella, A., & Urga, K. (2003). Medicinal plants and other useful plants of Ethiopia.
2. Amare, D., Wondie, M., Mekuria, W., & Darr, D. (2019). Agroforestry of Smallholder Farmers in Ethiopia: Practices and Benefits: D. Amare et al. *Small-scale Forestry*, 18(1), 39–56.
3. Assefa, B., Oba, G., Weladji, R. B., & Colman, J. E. (2010). An assessment of the roles of *Hagenia abyssinica* in the livelihoods of local communities in the Bale Mountains, Ethiopia. *Mountain Research and Development*, 30(3), 253–260. <https://doi.org/10.1659/MRD-JOURNAL-D-10-00012.1>

4. Atsbha, T., Desta, A. B., & Zewdu, T. (2019). Woody species diversity, population structure, and regeneration status in the Gra-Kahsu natural vegetation, southern Tigray of Ethiopia. *Heliyon*, 5(1), e01120. <https://doi.org/10.1016/j.heliyon.2019.e01120>
5. Ayele, T. B., Gailing, O., & Finkeldey, R. (2017). Spatial distribution of genetic diversity in populations of *Hagenia abyssinica* (Bruce) J.F. Gmel from Ethiopia. *Annals of Forest Research*, 60(1), 47–62. <https://doi.org/10.15287/afr.2016.740>
6. Azene B., T. (2007). Useful trees and shrubs for Ethiopia. Identification, propagation and management for 17 agroclimatic zones.
7. Belay, T. T. (2014). Perception of farmers on soil erosion and conservation practices in Dejen District, Ethiopia. *International Journal of Environmental Protection and Policy*, 2(6), 224–229.
8. Bruce, J. (1790). *Travels To Discover The Source Of The Nile, In the Years 1768, 1769, 1770, 1771, 1772, and 1773* [... Vol. 2.
9. Bruijnzeel, L. A., Scatena, F. N., & Hamilton, L. S. (Eds.). (2011). *Tropical montane cloud forests: science for conservation and management*. Cambridge University Press.
10. Desalegn, G. (2006). Some Basic Physical and Mechanical Properties Of The Valuable *Hagenia abyssinica* Timber and Their Interactions: Implications for Its Rational Utilization. *Ethiopian Journal of Biological Sciences*, 5(2), 117–135.
11. Dhanya, B., Sathish, B. N., Viswanath, S., & Purushothaman, S. (2014). Ecosystem services of native trees: Experiences from two traditional agroforestry systems in Karnataka, Southern India. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 10(2), 101–111. <https://doi.org/10.1080/21513732.2014.918057>
12. EPPO. (2023). *Hagenia abyssinica* (HAGAB). EPPO Global Database. <https://gd.eppo.int>
13. Eyasu, G., Tolera, M., & Negash, M. (2020). Woody species composition, structure, and diversity of homegarden agroforestry systems in southern Tigray, Northern Ethiopia. *Heliyon*, 6(12).
14. Feyissa, T., Zhu, L. H., Negash, L., & Welander, M. (2007). Regeneration and genetic transformation of *Hagenia abyssinica* (Bruce) JF Gmel.(Rosaceae) with the rolB gene. *Plant cell, tissue and organ culture*, 88(3), 277–288.
15. Fikadu Erenso, F. E., & Melesse Maryo, M. M. (2014). Endemic plant species composition and their status in Boda Dry Evergreen Montane Forest, West Showa, Ethiopia.
16. Friis, I. B. (1992). *Forests and forest trees of Northeast tropical Africa*.
17. Friis, I. B. (2011). *Atlas of the potential vegetation of Ethiopia*. *Annals of Botany*.
18. Gedif, T., & Hahn, H. J. (2003). The use of medicinal plants in self-care in rural central Ethiopia. *Journal of Ethnopharmacology*, 87(2–3), 155–161.
19. Giday, M., Teklehaymanot, T., Animut, A., & Mekonnen, Y. (2007). Medicinal plants of the Shinasha, Agew-awi and Amhara peoples in northwest Ethiopia. *Journal of Ethnopharmacology*, 110(3), 516–525.

20. Habtemariam, A. A., & Woldetsadik, A. M. (2019). Current distribution, regeneration and management practice of *Hagenia abyssinica* in different agroforestry systems of Ethiopia: A review. *International Journal of Biodiversity and Conservation*, 11(9), 266–271.
21. Hailemariam, M., & Temam, T. (2018). The vegetation composition, structure, and regeneration status of Gole natural forest, West Arsi Zone, Oromia regional state. *Ethiopian Journal of Agricultural Sciences*, 2.
22. Hedberg, O. (1989). Afroalpine flora and vegetation. In O. Hedberg & I. Hedberg (Eds.), *Tropical Alpine Environments: Plant Form and Function* (pp. 1–22). Cambridge University Press.
23. Kassa, H., Bekele, M., & Campbell, B. (2011). Reading the landscape past: Explaining the lack of on-farm tree planting in Ethiopia. *Environment and History*, 17(3), 461–479.
24. Kindu, M., Glatzel, G., Tadesse, Y., & Yosef, A. (2006). Tree species screened on nitosols of central Ethiopia: biomass production, nutrient contents, and effect on soil nitrogen. *Journal of Tropical Forest Science*, 173–180.
25. Kloos, H., Menberu, T., Tadele, A., Chanie, T., Debebe, Y., Abebe, A., ... Debella, A. (2014). Traditional medicines sold by vendors in Merkato, Addis Ababa: aspects of their utilization, trade, and changes between 1973 and 2014. *The Ethiopian Journal of Health Development*, 28(2).
26. Legesse, N. (2010). *A Selection of Ethiopia's Indigenous Trees: Biology, Uses and Propagation Techniques*. Addis Ababa University Press, Addis Ababa, Ethiopia. ISBN 978-99944-52-27-9.
27. Lelamo, L. L. (2021). A review on the indigenous multipurpose agroforestry tree species in Ethiopia: Management, their productive and service roles and constraints. *Heliyon*, 7(8), e07874. <https://doi.org/10.1016/j.heliyon.2021.e07874>
28. Mekuria, A. B., Belachew, S. A., Tegegn, H. G., Ali, D. S., Netere, A. K., Lemlemu, E., & Erku, D. A. (2018). Prevalence and correlates of herbal medicine use among type 2 diabetic patients in a teaching hospital in Ethiopia: a cross-sectional study. *BMC complementary and alternative medicine*, 18(1), 85.
29. Molla, A., & Kewessa, G. (2015). Woody species diversity in traditional agroforestry practices of Dellomenna District, Southeastern Ethiopia: implications for maintaining native woody species. *International Journal of Biodiversity*, 2015(1), 643031.
30. Negash, L. (2021). *The Indigenous Trees of Ethiopia: Biology, Uses and Propagation Techniques* (2nd ed.). Addis Ababa University Press.
31. Orwa, C. (2009). *Agroforestree Database: a tree reference and selection guide, version 4.0*. <http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp>.
32. Simion, T. (2018). *Kossoff (Hagenia abyssinica (Bruce) JF Gmel.) Genetic Resource*. *Agricultural Research & Technology: Open Access Journal*, 16(3), 10–9080.
33. Soromessa, T., & Kelbessa, E. (2014). Interplay of regeneration, structure and uses of some woody species in Chilimo Forest, Central Ethiopia. *Science, Technology and Arts Research Journal*, 3(1), 90–100.

34. Soromessa, T., Teketay, D., & Demissew, S. (2004). Ecological study of the vegetation in Gamo Gofa zone, southern Ethiopia. *Tropical Ecology*, 45(2), 209–222.
35. Tegene, A. S. (2018). An ethnobotanical study of traditionally used medicinal plants for treatment of human diseases in Goba district of Bale Zone, Southeast Ethiopia. *Advances in Life Science and Technology*, 68, 1–7.
36. Udawatta, R. P., Rankoth, L. M., & Jose, S. (2019). Agroforestry and biodiversity. *Sustainability*, 11(10), 2879.
37. Vivero, J. L., Kelbessa, E., & Demissew, S. (2005). The red list of endemic trees and shrubs of Ethiopia and Eritrea.
38. Wana, D., & Woldu, Z. (2006). Vegetation of Chenchas Highlands in Southern Ethiopia. *SINET: Ethiopian Journal of Science*, 28(2), 109–118. <https://doi.org/10.4314/sinet.v28i2.18247>
39. Yineger, H., Yewhalaw, D., & Teketay, D. (2008). Ethnomedicinal plant knowledge and practice of the Oromo ethnic group in southwestern Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, 4(1), 11.
40. Yohannes, G. (2006). Evaluation of termite-resistant plant attributes for their bioactivities against *Macrotermes* termite. M. Sc. thesis, Addis Ababa University.

Figures

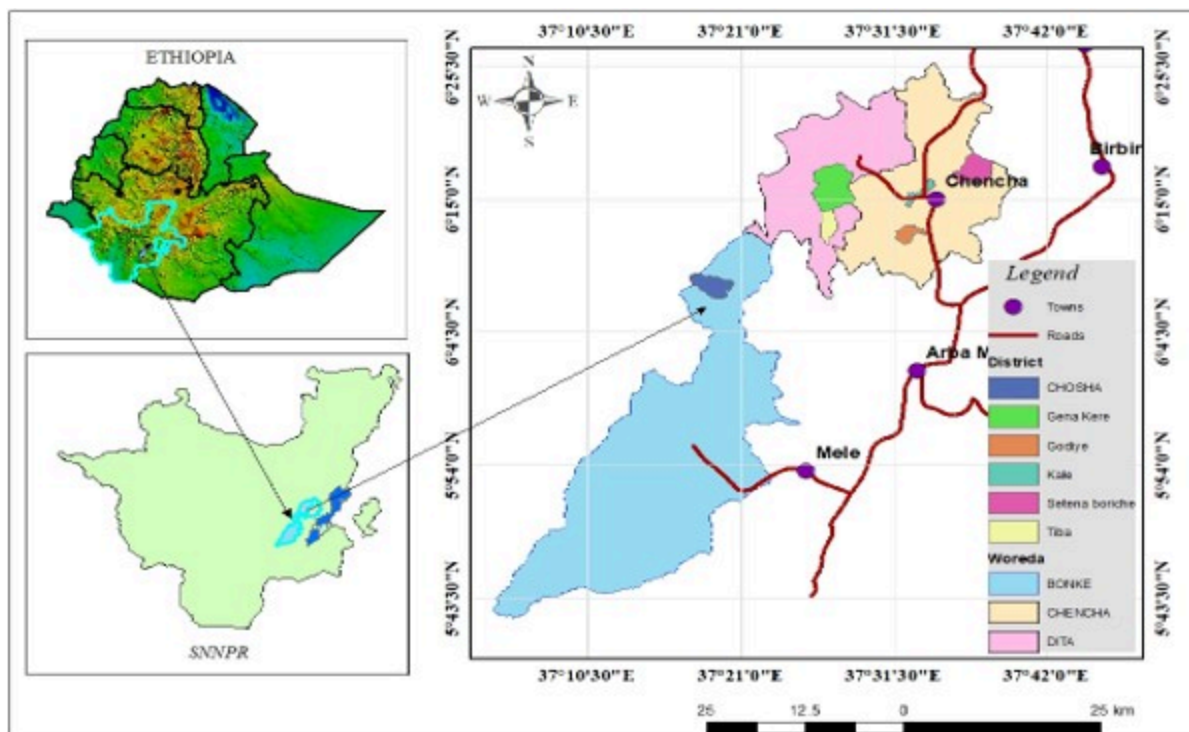


Figure 1

Map of the study area showing sampling woredas and sites (kebeles).

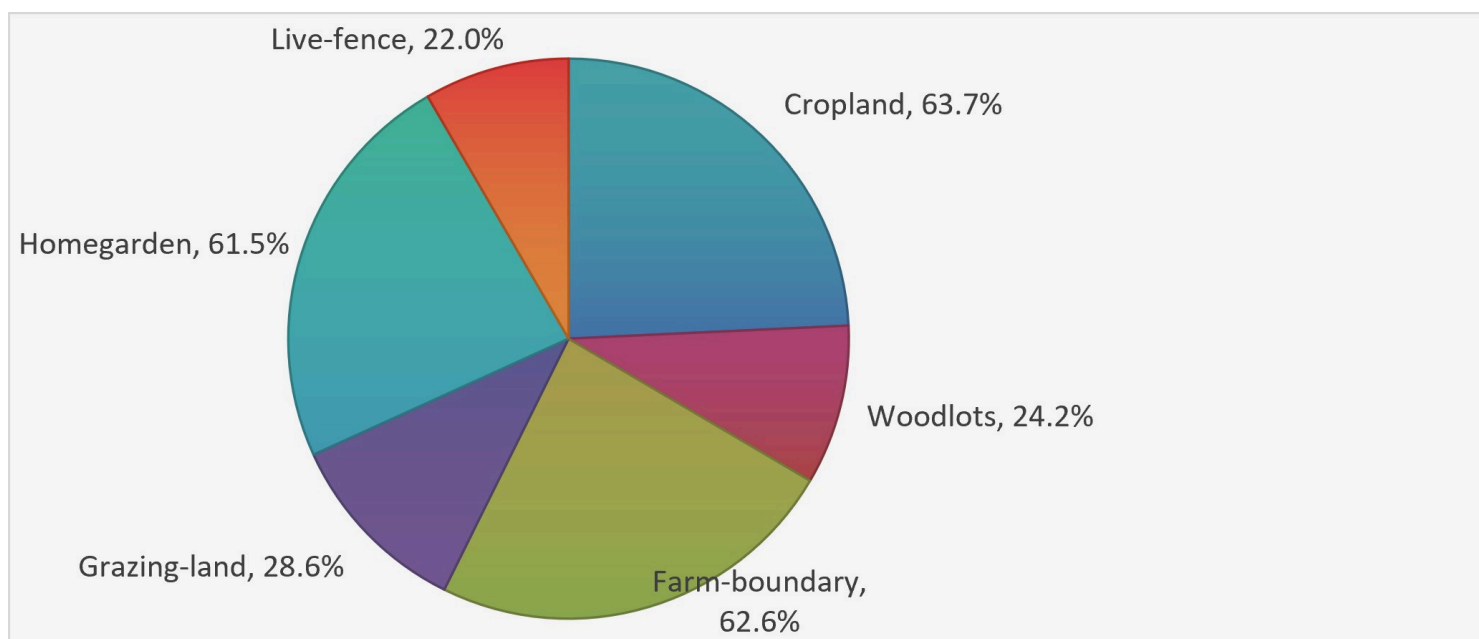


Figure 2

A farmer's land-use preference to grow the tree in existing agroforestry practices

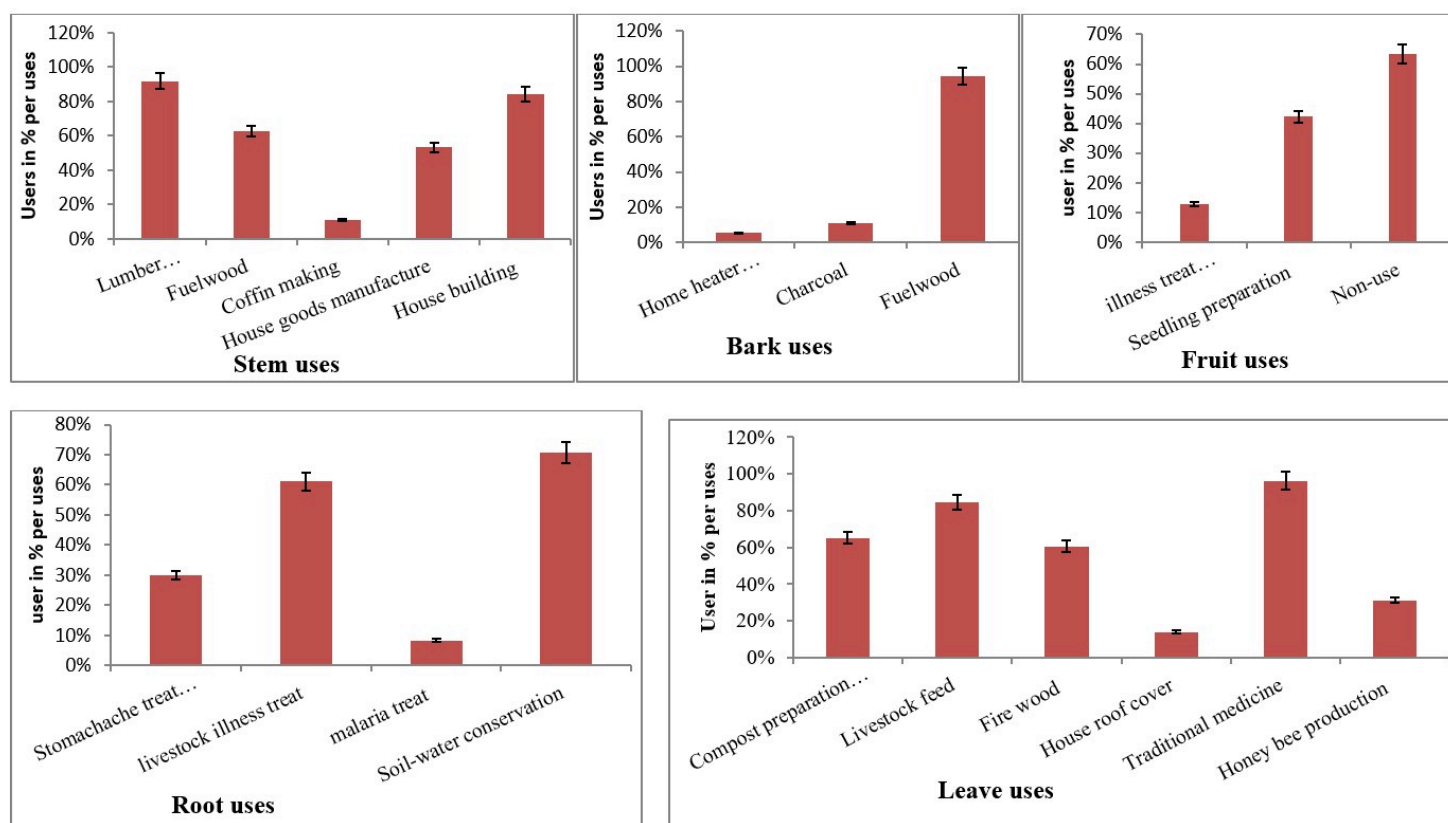


Figure 3

Hagenia abyssinica tree utilization by respondents at Gamo highland areas

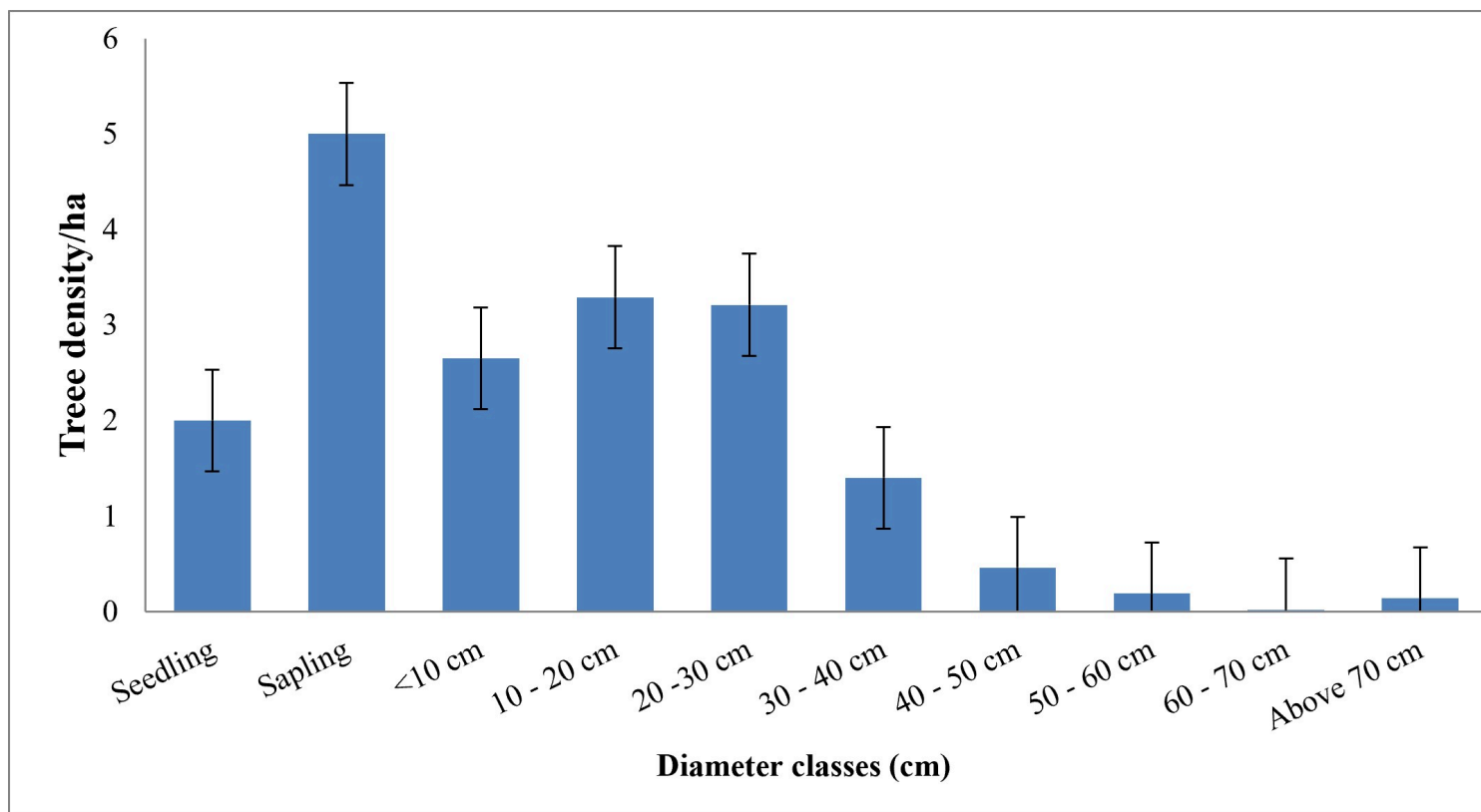


Figure 4

Population distribution of *Hagenia abyssinica* on identified agroforestry practices

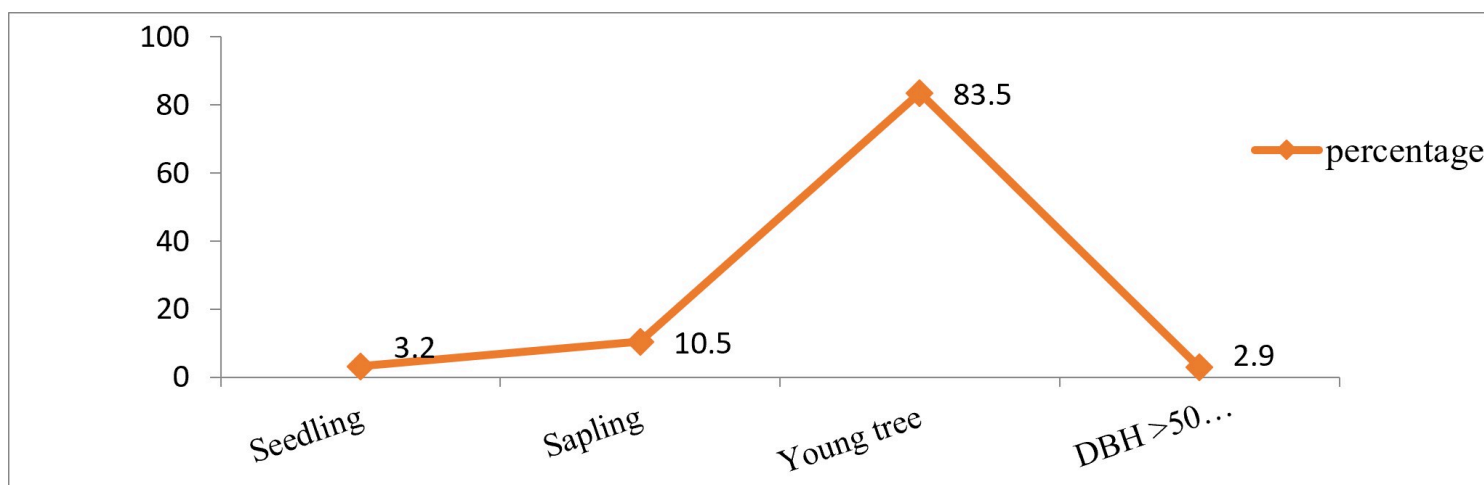


Figure 5

The regeneration status of *Hagenia abyssinica* on farmland agroforestry practices