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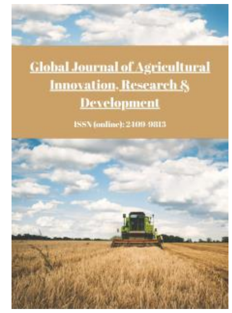

Evaluation and Promotion of Multipurpose Tree Planting in Selected Agroforestry Systems: The Case of Smallholder Farmers in Bore District, Southern Ethiopia

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ABSTRACT

The study was conducted in the Bore district of Guji zone, Southern Ethiopia. The objective of the study was to evaluate and promote multipurpose tree planting under smallholder farmers' of selected agroforestry systems. In this study, four multipurpose trees such as *Acacia saligna*, *Chamaecytisus palmensis*, *Grevilia robusta*, and *Pinus patula* were evaluated and promoted in home gardens, on farms, and boundary planting agroforestry systems. The growth performance results of the multipurpose trees in selected agroforestry systems showed that the survival rate of the trees was higher in home gardens followed by on-farm and boundary planting agroforestry systems. Moreover, the highest diameter at breast height and tree height growth performances were also recorded in home gardens, on farms, and boundary planting agroforestry systems respectively. Smallholder farmers used different management practices for multipurpose trees planted in selected agroforestry systems. Accordingly, farmers used pruning, hoeing, animal dung, weeding, and fencing management practices for better growth performance of the trees and to minimize the shade effect of the trees on understorey crops. Farmers' preferences for the evaluated and promoted multipurpose trees showed that *Pinus patula, Grevilia robusta, Chamaecytisus palmensis*, and *Acacia saligna* were ranked 1st, 2nd, 3rd, and 4th respectively. The feedback from farmers showed that they were willing to plant different multipurpose trees if they could be encouraged and supported with planting materials and technical support. Therefore, government and non-government organizations could be involved in developing agroforestry systems, by providing good planting materials and supporting smallholder farmers' through research and strong extension services.

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1. Introduction

Multipurpose tree species (MPTS) are trees grown deliberately or kept and managed for preferably more than one intended use, usually economically motivated major products and services in any multipurpose land use system, especially agroforestry systems. Thus it involves more than one purpose and multipurpose land use [1]. Agroforestry systems with multipurpose tree species offer possibilities for income generation in rural areas where few other opportunities may be available. Moreover, forestry employment, collection and sale of forest products, production and selling of seedlings, and small forests-based enterprises provide incomes that contribute to meeting household needs [2].

Agroforestry systems with multipurpose tree species (MPTS) are potentially viable options for the management of natural resources, soil and water conservation, and sustaining production of food, fuel, and fodder. Agroforestry with multipurpose trees also reduces tremendous pressure on our limited forest resources by containing serious erosion and land degradation [3]. Agroforestry practice with multipurpose trees has the potential to improve the livelihoods of rural farmers by increasing their crop yields because it consistently restores the fertility status of the soil by recycling the litter that is deposited, thus increasing soil organic matter [4].

The multipurpose tree species used in the practice of agroforestry have the ability to fix nitrogen which also helps improve soil fertility [5]. Furthermore, the system is capable of improving the water-holding capacity of the soil and other ecosystem services [6, 7]. The agroforestry practice with multipurpose tree species also has the potential to mitigate climate change by increasing carbon sequestration [8]. It is also very important for rural homesteads as it provides tree products like fodder, firewood, woodcraft, and medicinal herbs without them having to go to forests to collect them [4].

In Ethiopia, smallholder farmers practice different agroforestry systems depending on the socioeconomic and biophysical conditions [9, 10]. These include home gardens, coffee shade trees, boundary planting, silvicultures, scattered trees on farmland, and woodlots [11]. In Ethiopia, efforts have been made to develop and promote agroforestry systems with multipurpose tree species. However, agroforestry technologies developed and promoted so far are not sufficient to address the problems of soil erosion, loss of soil fertility, loss of biodiversity, income generation, shortage of fodder, and woody material scarcity for industrial and household consumption [11].

The major constraints for development of the agroforestry practices vary from place to place. In Southern Ethiopia, Bahiru *et al*. [12] identified that lack of enough farmland is the major limiting factor for implementing agroforestry practices. Moreover, different scholars reported that improper selection of tree species, nonavailability of good planting material, negative attitude, acceptability, and weak extension systems were among the factors that constrained agroforestry development [11, 13].

In Ethiopia, the role of agroforestry practice in satisfying the basic needs of the rural peoples is significant, but little research has been initiated to identify suitable agroforestry technologies and appropriate tree species for specific areas of the country. Similarly, in the highland agroecology of Guji zone, the development of the agroforestry system is constrained by a lack of awareness about the agroforestry practice and the nonavailability of good quality planting materials. This calls for designing strategies to address the problem through the promotion of multipurpose tree planting in different agroforestry systems.

Moreover, awareness creation is significant for smallholder farmers to motivate the culture of local communities to plant different multipurpose tree species on their farmlands. This can be achieved by addressing the above-mentioned problems constraining agroforestry development and farmers' motives to plant trees. Therefore, the objective of this study was to evaluate and promote multipurpose tree planting under smallholder farmers of selected agroforestry systems in the Bore district of Guji zone, Southern Ethiopia.

2. Material and Methods

2.1. Description of the Study Area

2.1.1. Location

The study was conducted from 2020-2024 in Bore district at specific places of Ano wate, Ano kerensa, and Songo berecha kebeles. The study district is located 385 km to the south of Addis Ababa, the capital city of Ethiopia. The study area is located within the latitude 6°22'30''-6°25'50'' N and longitude of 44°32'30''-44°35'50'' E (Fig. **1**).

2.1.2. Climate

The study district is characterized by two agroclimatic zones, namely humid which starts in early April to November, and sub-humid which starts in late December up to the beginning of March. The mean annual rainfall of the study area ranged from 1400-1800mm with a bimodal pattern that is extended from April to November. The mean annual minimum and maximum temperature of the study district are 10°C and 20°C respectively.

2.1.3. Soil and Vegetation

The major soils of the study district are Nitosols (red basaltic soils) and Orphic Acrosols. The two soil types are found in highland areas, and they are red-brown and black-brown in color and on sloping topography and their utilization is good under natural vegetation. In terms of vegetation types, the following tree species such as *Erythrina abyssinica, Eucalyptus camaldulensis, Hagenia abbysinica, Juniperus procera, Pinus patula,* and *Schefillera abbysinica* are commonly growing in the study district. Moreover, from non-timber forest products highland bamboo species (*Arudinaria alpina*) is also growing in the study district.

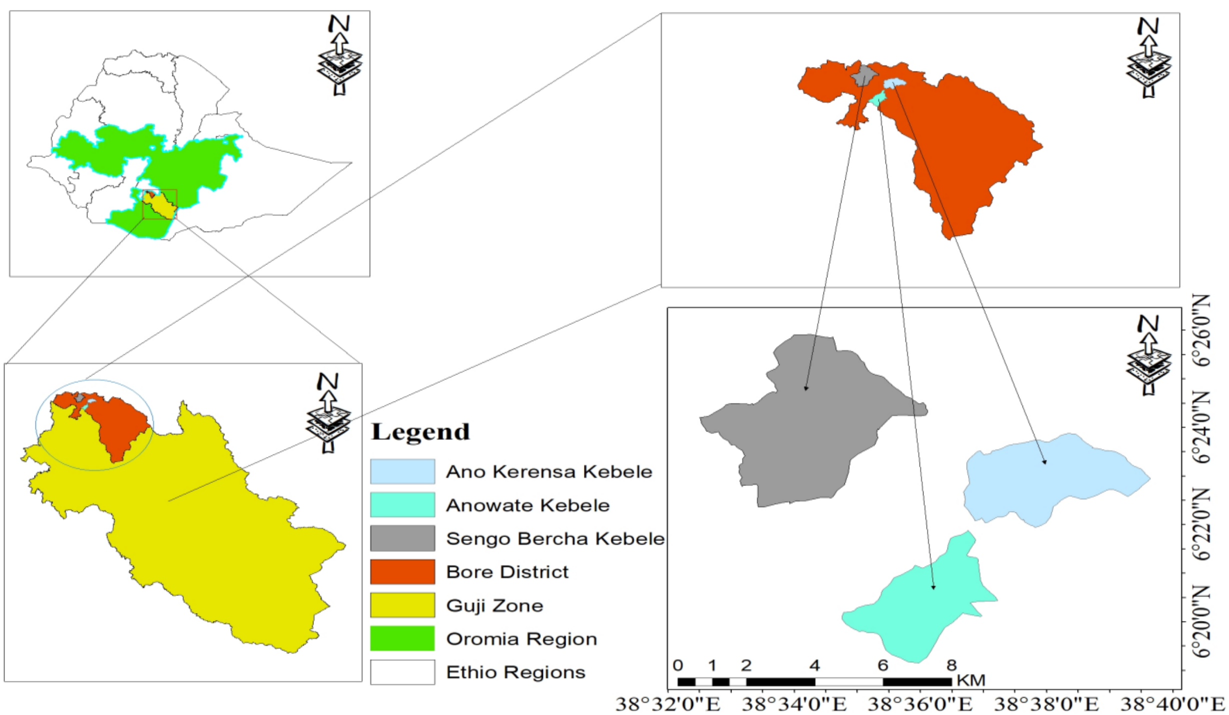

Figure 1: A map showing the study area.

2.1.4. Agricultural Activities

The farmers of Bore district produce cereal crops such as wheat, barley, and maize, and pulse crops such as faba bean and field pea. Moreover, farmers of the study district produce horticultural crops such as potatoes, head cabbage, and other vegetables.

2.2. Site and Farmer Selection

The study was conducted in the Bore district of Guji zone, in Southern Ethiopia. From Bore district three representative kebeles were selected as pilot sites and from each kebeles four farmers' research groups and a total of twelve farmers' research groups which have 60 members were established.

2.3. Selection of the Multipurpose Tree Species

The multipurpose trees selected for promotion of tree planting under smallholder farmers of selected agroforestry systems were those adapted to the area. Moreover, any multipurpose trees selected for agroforestry systems should have fulfilled the following criteria such as multipurpose uses, easily decomposable leaves, nutrient cycling and nitrogen fixation attributes, fast-growing habit, high palatability as fodder, and soil improvement attributes. Therefore, the selected multipurpose trees distributed to smallholder farmers were well adapted to the agroclimatic condition of the study area and each tree species has different multipurpose values. 11,400 seedlings of *Acacia saligna*, *Grevilia robusta*, *Pinus patula,* and Tree lucerne (*Chamaecytisus palmensis*) trees were distributed to smallholder farmers selected from the three peasant associations (Table **1**).

Table 1: Seedlings of multipurpose tree species distributed to smallholder farmers.

Multipurpose Tree Species	Amount of Seedlings Distributed in Each Kebeles		
	Ano Wate	Ano Kerensa	Songo Berecha
Acacia saligna	700	700	700
Grevilia robusta (R.Br.)	1000	1000	1000
Pinus patula	1200	1200	1200
Chamaecytisus palmensis	900	900	900
Total	**3,800**	**3,800**	**3,800**

2.4. The Raising and Care of the Seedlings

Seeds of the multipurpose tree species included in the trials were brought from Central Ethiopia Environment and Forestry Research Center, Addis Ababa. The needed seedlings of the selected multipurpose trees were raised in the Anokerensa nursery site of the Bore Agricultural Research Center. A plastic tube filled with the recommended soil mix ratio (3:2:1) was used so that seedlings have a ball of earth around their root system and be supplied with enough soil nutrients and moisture when transplanted into the field. The seeds were sown directly into the plastic tubes to reduce transplanting costs. Optimum care, such as watering, mulching, shading, and weeding was provided at the nursery site to produce healthy and vigorous seedlings for field planting. In addition, hardening and grading of the seedlings were done before field planting. It took 5-7 months, depending on the selected multipurpose tree species for the seedlings to reach the required size (25-30 cm) for field planting.

2.5. Agroforestry Technologies Promoted under Smallholder Farmers

There are different agroforestry technologies appropriate for the land-use systems in the Ethiopian highlands. However, for this study, the following three agroforestry technologies were selected and promoted by smallholder farmers of Bore District.

2.5.1. Homegarden Tree Planting

The significance of multipurpose tree planting under smallholder farmers of home garden agroforestry system is to produce fuel wood and construction poles for the community. Moreover, multipurpose tree species that could be planted around home gardens can serve as windbreaks and shelter belts for humans, as well as provide feed and shelter for animals and used for income generation.

2.5.2. Boundary Tree Planting

The role of the boundary planting agroforestry system is to provide an alternative source of cash to farmers and to supply fuel wood, which is otherwise scarce. Such tree plantings can also indirectly influence the crop-livestock production system by acting as windbreaks and shelter belts. Both internal and external farm boundaries may be used for tree planting to produce poles, timber, fuel wood, and fodder. The design of this planting scheme included planting trees in lines or rows in border areas and along roadsides.

2.5.3. Tree Planting on Croplands

This agroforestry technology involves the growing of scattered individual trees and shrubs in wide spaces in croplands. Multipurpose tree species were planted on croplands in a scattered form over a crop field, between 1–20 trees per hectare to minimize impact on the companion crop. The system has much potential for supplying fodder, poles, farm equipment, fuel wood, and agricultural improvements through soil fertility enhancements of croplands.

2.6. Data Management

Tree heights were measured using either meter tape or graduated stick based on the height growth of the multipurpose tree species planted on three agroforestry systems. The diameter at the breast height of the planted multipurpose tree species was assessed at the base of the seedlings or saplings using a caliper. Survival assessment of the multipurpose tree species planted in selected agroforestry systems was carried out based on the original number of trees planted. The farmer's views on planted trees were assessed during the project phase. This helps to get farmers' feedback on multipurpose tree planting initiatives as they may reflect problems encountered along with trees planted to be addressed for wider scaling up of agroforestry technologies. Overall tree management practices offered by farmers and farmers' preferences of the promoted tree species in selected agroforestry systems were evaluated against training given.

3. Results and Discussion

3.1. Training Delivered on Capacity Building

Knowledge and capacity development on new agricultural technologies and techniques are essential for modern agricultural growth. Agricultural training is a potentially effective method to diffuse relevant new technologies to increase productivity and alleviate rural poverty [14]. Training for capacity building was given to 60 members of the farmers' research group (FRG), 9 development agents, and 5 experts (Fig. **2**). Accordingly, for successful implementation of the projects capacity building training was delivered to farmers and other stakeholders on different titles such as multipurpose tree uses and management practice, on importance, establishment, and category of various Agroforestry systems.

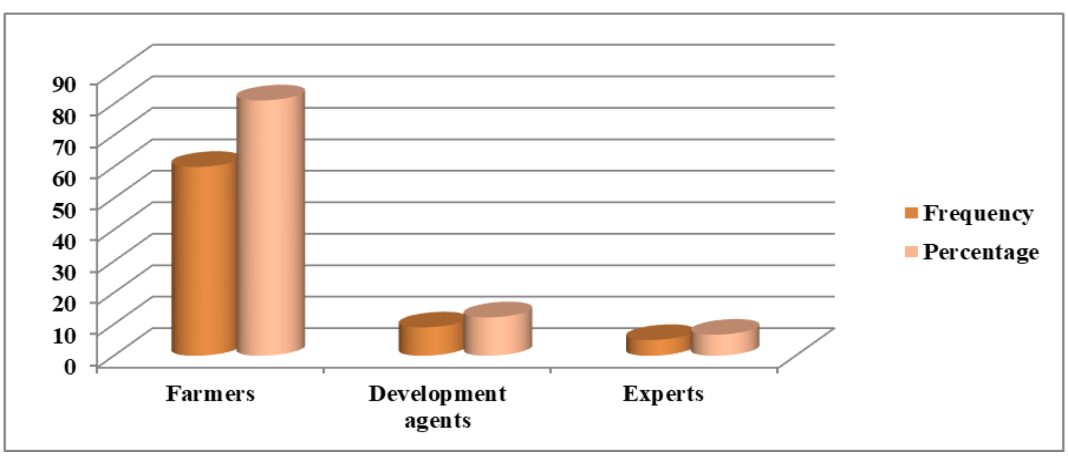

Figure 2: Training given on capacity building to different stakeholders.

3.2. Growth Performance of the Multipurpose Trees in Selected Agroforestry Systems

The multipurpose tree planting was evaluated and promoted under smallholder farmers in three agroforestry systems such as home garden, on-farm, and boundary planting. Seedlings of the multipurpose trees were distributed to experimental farmers and tree planting activities were conducted and evaluated on land of farmers research group. During the study time, data on survival rate, diameter at breast height, and tree height were collected.

3.2.1. Survival Rate (%)

The selected multipurpose trees showed variation in terms of their survival rate in different agroforestry systems (Fig. **3**). The maximum survival rate of *Pinus patula* was recorded in a home-garden agroforestry system (85.4%) followed by on-farm (75.4%) and boundary-planting agroforestry systems (62.2%) (Fig. **3**). The recorded survival rate of *Grevilia robusta* was (82.1%), (72.3%) and (60.1%) in home gardens, on farms and boundary planting agroforestry systems respectively (Fig. **3**). The survival rates of *Acacia saligna* and *Chamaecytisus palmensis,* multipurpose trees in home gardens and on-farm agroforestry systems were (83.5% and 80.1%) and (65.3% and 68.2%) respectively. However, in the boundary planting agroforestry system survival rate of *Chamaecytisus palmensis* was (59.2%) and the survival rate of *Acacia saligna* was (59.8%).

Therefore, the findings of the current study revealed that as compared to the other the highest survival rate of the evaluated and promoted multipurpose trees was recorded in the home garden agroforestry system. This could be due to necessary management done for planted tree species, soil type, and protection from animal damage. In support of this study, Chamagne *et al*. [15]; and Stephenson *et al*. [16] indicated that the tree growth rate in any agroforestry system may be highly variable within the same species and among different species due to variability of multiple biotic and abiotic factors.

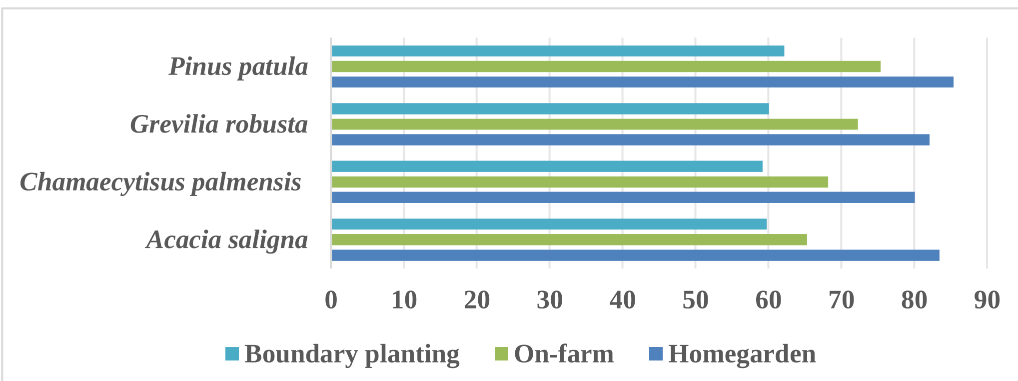

Figure 3: The survival rate of the multipurpose tree species in selected Agroforestry systems.

3.3.2. Diameter at Breast Height (DBH)

The current study showed that the evaluated and promoted multipurpose trees showed a difference in diameter at the breast height of selected agroforestry systems (Fig. **4**). In-home garden and on-farm agroforestry systems, relatively similar DBH of (5.8cm) and (5.78cm) were recorded respectively in *Pinus patula.* Whereas, in boundary planting (5.2cm) DBH was achieved in *Pinus patula.* The DBH of *Grevilia robusta* in the home garden (5.67cm) and on farms (5.64cm) was comparatively similar and in boundary planting (5.23cm) DBH was recorded. From *Chamaecytisus palmensis* DBH of (4.85cm and 4.76cm) and *Acacia saligna* (4.74cm and 4.63cm) were recorded in home-garden and on-farms agroforestry systems respectively. However, in *Chamaecytisus palmensis* (4.62cm) and *Acacia saligna* (4.45cm), DBH was recorded in boundary tree planting.

As the findings of this study showed that, the diameter at breast height growth performance of the multipurpose trees showed variation in selected agroforestry systems of this study. This might be due to variations in management activities, topography, soil properties, and multipurpose tree properties. The results of this study were in line with the findings of Cavelier *et al*. [17]; Kbler *et al*. [18]. Their study results reported that micro-topography variation, soil nutrient distribution, and biological processes may influence variations in individual tree growth rates.

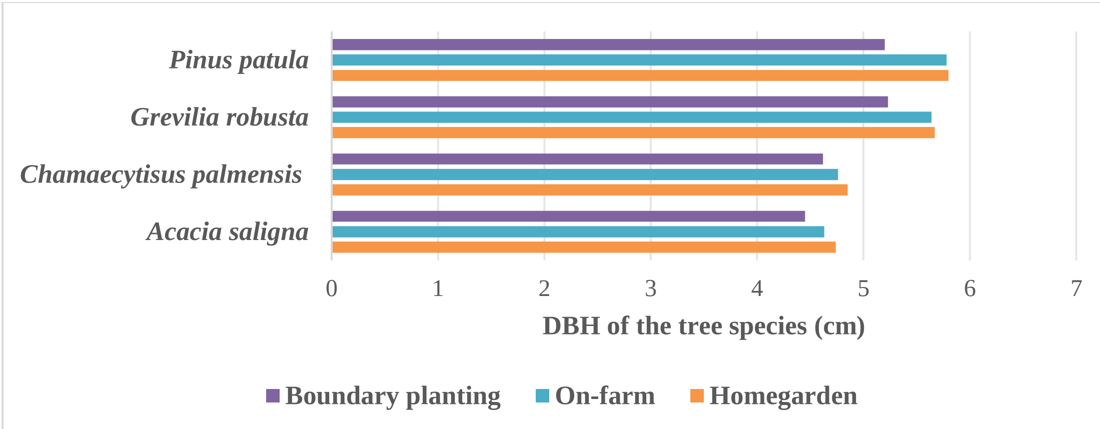

Figure 4: DBH of the multipurpose tree species in selected Agroforestry systems.

3.3.3. Tree height

In terms of tree height growth performance, the evaluated and promoted multipurpose tree species showed variation in different agroforestry systems (Fig. **5**). In *Grevilia robusta* the maximum tree height growth (5.33m) was recorded in the home garden followed by on-farms (5.25m) and boundary planting (4.42m). The tree height growth of *Pinus patula* in the home garden, on-farms, and boundary planting were (5.55m), (5.44m) and (4.52m) respectively. Similarly, from *Acacia saligna* and *Chamaecytisus palmensis,* the highest tree height of (5.42m) and (5.33m) was registered in the home-garden agroforestry system (Fig. **5**). Whereas, tree height growth performance of *Acacia saligna* and *Chamaecytisus palmensis* in on-farms and boundary planting were (5.22m, 4.65m) and (5.11m, 4.45m) respectively.

The result of this study revealed that the height growth performance of the multipurpose trees showed variation among the agroforestry systems. This could be due to variations in management practice, properties of multipurpose tree species, and other factors. In agreement with this study, Setrida Mlamba [19] reported that dry spells before or immediately after planting seedlings, livestock, and human damage, and poor sitting of woodlots were mentioned as causes of low growth performance of agroforestry trees.

Figure 5: Height growth of the multipurpose tree species in selected Agroforestry systems.

3.4. Farmers' Management Practice for the Promoted Multipurpose Tree Species

For better growth performance of the evaluated and promoted multipurpose trees planted in three selected agroforestry systems, smallholder farmers employed different management practices (Fig. **6**). Particularly, for multipurpose tree species planted in home gardens and on-farm agroforestry systems farmers use weeding and hoeing management practices. This result is consistent with that of Kunhamu [20], who indicated that in tropical home garden agroforestry, hand weeding plays a crucial role in removing unimportant vegetation that competes for light, water, and nutrients. Moreover, in line with this study Talemos *et al*. [21], also reported that weeding management practice in home garden agroforestry systems contributes much to delaying the competent species for water and other nutrients and a significant role in the growth performances of the tree species. Furthermore, similar to this study Mehari [22], also showed that in the highland of Oromia, the major tree management operations conducted by farmers in traditional Agroforestry practices are weeding, hoeing, manuring, fencing, and watering.

Another management practice conducted by farmers was fencing. Through fencing the multipurpose tree species planted in selected agroforestry systems are protected from human, animal, and other wild animals attack which can damage the species growing stage. Similar to this study, in their former study results Getahun *et al*. [23] Madalcho and Tefera [24] and Kumar and Nair [25] showed the significance of fencing in protecting the tree species from different damage. Moreover, in order to improve the growth performances of the multipurpose tree species farmers used organic manure or cow dung. In agreement with this study, in their earlier study results Paul and Hossain [26] and FAO [27], reported the significance of organic manure for improving the growth of leguminous agroforestry tree species.

Especially, to minimize the shade effect of multipurpose tree species on understorey crops planted in home gardens and on farms agroforestry systems, farmers used pruning management practices. In support of this study, Workineh [28] reported that pruning by farmers of trees on croplands intended to reduce competition with crops for nutrients and water and to obtain fuel wood, and construction material. Similarly, Mustapha and Jimoh [29] and Adedire [30] also indicated that trees integrated into arable farmlands are pruned periodically to provide green manure and to prevent shading of the growing crops.

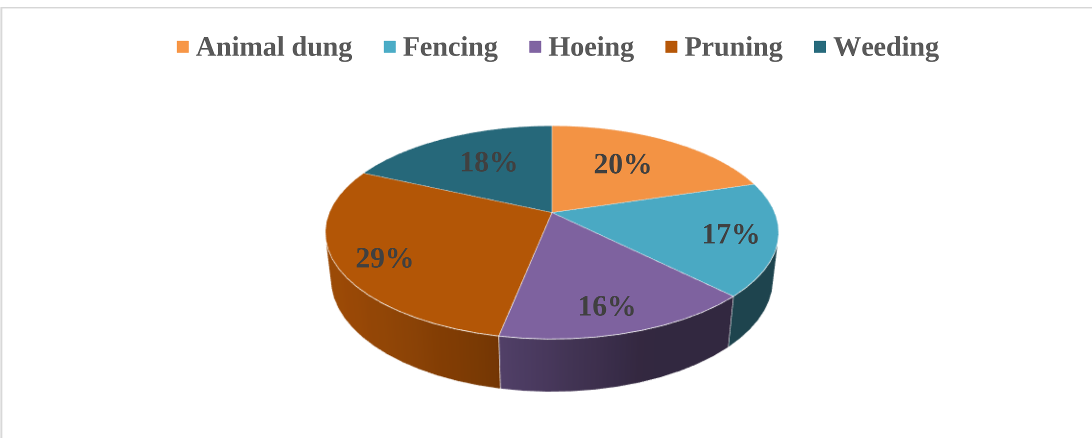

Figure 6: Farmers’ management practice for multipurpose tree species.

3.5. Farmers’ Preferences for the Promoted Multipurpose Tree Species

In order to find out smallholder farmers' preferences for the evaluated and promoted multipurpose tree species, a farmers' research group carried out preferences of the tree species. Different attributes have made the evaluated and promoted multipurpose tree species easily preferred by smallholder farmers. Accordingly, the main selection criteria set by the farmers' research group included: fast rate of growth, survival rate, timber value, soil fertility attributes, firewood/construction value, and significance of the tree for animal feed. In agreement with this study Mehari [22], revealed that farmers' preference criteria for different tree species in traditional Agroforestry practices in the highlands of Oromia, were based on the beneficial effect on soil fertility, favorable effect on adjacent crops, and contribution to wood production.

Therefore, based on the selection criteria of the farmers' research group, *Pinus patula,* and *Grevilia robusta* were ranked 1st and 2nd respectively. Whereas, *Chamaecytisus palmensis* and *Acacia saligna* multipurpose tree species were ranked 3rd and 4th respectively. Based on the findings of this study, *Pinus patula* and *Grevilia robusta* received the best scoring for firewood, construction purposes, and timber value (Table **2**). In terms of soil fertility attributes and animal feed value *Acacia saligna* and *Chamaecytisus palmensis* received the highest scoring. However, regarding the fast growth rate all of them were recorded with similar grading by the farmers' research group (Table **2**).

Table 2: Preference ranking of multipurpose tree species based on their attributes to smallholder farmers.

Multipurpose Tree Species	Farmers' Preference Criteria						Total Score	Ranks
	Fast Rate of Growth	Survival Rate	Timber Value	Soil Fertility Attributes	Firewood/ Construction Value	Feed Value		
Acacia saligna	5	3	0	5	2	5	20	4th
Chamaecytisus palmensis	5	4	0	5	2	5	21	3rd
Grevilia robusta	5	4	5	3	5	0	22	2nd
Pinus patula	5	5	5	4	5	0	24	1st

3.6. Farmers' Feedback on Promoted Multipurpose Tree species

Group discussion were held with smallholder farmers' participated on evaluation and promotion of multipurpose tree planting in selected Agroforestry systems of the current study. Smallholder farmers' stated that they were willing to plant various multipurpose tree species which have different values. They also indicated that, in addition to exotic multipurpose tree species a plan is to cover their farmlands with indigenous multipurpose tree species which are more adapted to the area. In conformity with the farmers' idea of this study, Getahun *et al*. [23] and Negash *et al*. [31], reported that smallholder farmers in Southwestern and Southeastern Ethiopia prefer Indigenous multipurpose tree species due to they are adapted to the environment and are already an integral part of the ecosystem.

Moreover, smallholder farmers of the study area indicated that based on the experience obtained from this study they need to plant different tree species in various agroforestry systems which could play vital roles in terms of soil fertility improvement, fruit production, timber and construction values, fodder attributes, and firewood production. Therefore, they want support from the government and non-government organizations in terms of multipurpose seedling planting material and technical assistance.

4. Conclusion and Recommendation

Agroforestry practice with multipurpose trees has the potential to improve the livelihoods of rural farmers by increasing their crop yields. In this study, four multipurpose tree species such as *Acacia saligna, Chamaecytisus palmensis, Grevilia robusta,* and *Pinus patula* were promoted under smallholder farmers in three agroforestry systems such as home gardens, on farms, and boundary tree planting. The growth performance of the multipurpose tree species showed a significant variation in selected agroforestry systems. Accordingly, as compared to boundary planting agroforestry system the highest survival rate, diameter at breast height, and tree height were recorded in home gardens and on farms agroforestry systems respectively. Smallholder farmers who participated in this study used different management practices for planting multipurpose tree species in selected agroforestry systems. The major management practices commonly used by smallholder farmers were pruning, animal dung, weeding, hoeing, and fencing respectively.

In the final phase of this study, preference ranking was conducted to identify the best multipurpose tree species that are more selected and preferred by smallholder farmers. Based on their multipurpose uses such as fast rate of growth, survival rate, timber value, soil fertility attributes, firewood/construction value, and animal feed contribution of the tree species. Accordingly, *Pinus patula, Grevilia robusta, Chamaecytisus palmensis,* and *Acacia saligna* were preferred by smallholder farmers in the 1st, 2nd, 3rd, and 4th ranks respectively. The feedback of smallholder farmers' on evaluated and promoted multipurpose tree species showed that they are willing to plant more different tree species that have multipurpose values in their farmlands. Therefore, the findings of this study concluded that, if smallholder farmers could be encouraged and supported with planting materials and technical supports it would be easy to diversify both indigenous and exotic multipurpose tree planting in current studied agroforestry systems and others which didn't included in this study. Therefore, for wider scaling up of agroforestry technologies government and non-government organizations could be involved in the development of agroforestry systems, through providing good planting materials and supporting smallholder farmers through research and strong extension services.

Conflict of Interest

The authors declared that they have no conflict of interest.

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