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# TREE SPECIES CULTIVATION ON SUBSISTENCE AGRICULTURAL FIELDS IN NORTHWESTERN ETHIOPIA

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***Abstract:*** *The study was intended to identify species preferences, the relationship between livelihood status and tree planting, and the major tree growing patterns of smallholder subsistence farmers in rural Ethiopia. Data was collected through household interviews and the total enumeration of all tree species on respondents' landholdings. A total of 23 tree species were recorded integrated within the farming landscape as boundary plantings, scattered on crop fields, around the homestead and woodlots. There was a significant difference in the mean number of trees per household across the three wealth classes. Among the three wealth classes, the medium wealth category households have a relatively higher number of tree species than rich and poor households ($p<0.05$). Considering the ever-increasing population and the resulting demand for construction poles, fuelwood, household utensils, farm implements, and the fast-growing performance of the species, Eucalyptus camaldulensis Dehnh. was the first preferred tree species to households for planting. Tree integration in the farming landscape should be recognized since it will be invaluable in developing plans for agroforestry interventions. However, exotic tree species have dominated the status of indigenous tree species. Then, there should be a continuous and detailed extension system to upgrade the traditional management system and the tree selection to be integrated.*

***Key words:*** *tree species, Ethiopia, species preference; subsistence farming, agroforestry.*

## 1. Introduction

Low agricultural productivity, unchecked population growth, deforestation, and land degradation continue to be the major culprits causing extreme poverty, food and wood insecurity [15]. Higher dependence on woody biomass for fuel,

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construction, and furniture, the need for livestock grazing areas, and the expansion of agricultural land contribute to severe deforestation and forest degradation [19], 25]. This leads to a reduced ability of forest resources to provide goods and services [9], [17], [21], [34].

Thanks to its multifunctional properties, agroforestry[2] is part of the solution to addressing the above issues, where trees are managed together with crops and/or animal production systems in agricultural settings [27]. It offers diversification options that can reduce production risks for smallholder farmers and that can be exploited to provide increased income during difficult periods [1], thereby reducing income risks associated with climate-related shocks for smallholder farming families [7].

Managing scattered trees on farmlands is a long-aged practice in Ethiopia and other sub-Saharan African countries [3]. The rural communities maintain selected tree species on their farmland in search of social, economic, and environmental benefits [17], [26].

Nowadays, the old practice of managing scattered trees on crop fields has been suggested as one of the interventions for sustainable intensification of the smallholder agricultural system in different regions [14], [20], [22]. Rural communities preoccupied with subsistence agriculture have a long history of maintaining trees in traditional farming systems for centuries and the knowledge associated with managing these resources is their key asset [17], [29]. They manage trees on their farmlands in search of their livelihood goals of income generation, risk management, household food security, and optimal use of available land, labor and capital [8].

In Ethiopia, some available studies have indicated that smallholder farmers often conserve individual or remnant tree species on their farmlands to provide various products and services [2], [18], [30], [32]. They integrate selected tree species on their agricultural lands in a definite spatial and temporal arrangement around their home and farm crop fields [4, 5]. Farmers have accumulated long-aged experience on how to manage and take advantage of the trees on their farmlands [11], [25], [33]. However, the existing growth habits of trees on farms, species preference, and management practices are not well studied in the rural subsistence agricultural systems of Ethiopia.

Thus, since empirical evidence on species selection, management and plantation patterns through science leads to increasing the deliberate integration of trees within the cropping area, the study was aimed at understanding the local management practices and determining the rationales behind integrating trees in agricultural landscapes.

Therefore, this study was designed to investigate what is behind the selection of tree species for integrating into the subsistence agricultural system, the relationship between species selection and plantation patterns, and the linkage between the livelihood status of the farmers and the number of species integrated. This could fill the scarce scientific and quantitative evidence on the ways of expanding the values and principles in traditional agroforestry efforts for the local administration, policymakers, and other stakeholders, and

[2] Agricultural practices that involve a close ecological and economic association of trees and shrubs with crops and animals and/or pastures.

the scientific community focused on Agroforestry, forest conservation, and subsistence agriculture.

## 2. Methodology

### 2.1. Study Area

The study was conducted in the Womberma District of West Gojjam Zone, Amhara Regional State, Ethiopia. Its capital Shendi is located 427 km North West of Addis Ababa. The District has a diverse topography with an altitude that ranges from 800 to 2,212 m above sea level and a geographic location which lies between 10°19'0'' N to 10°44'0''N latitude and 36°30'5''E to 37°1'0'' longitude. The annual mean temperature for most parts of the district ranges from 14°C to 26°C.

Agriculture is the main source of livelihood where the farming system is characterized by crop-livestock mixed farming which is done at subsistence scale, and crop production is the major source of income for the community. The district has both natural and plantation vegetation resources of indigenous and exotic tree species. The natural vegetation is found mainly around Ethiopian Orthodox Churches, near hillsides, and around the course of rivers. Moreover, the district has lengthy experience in managing trees on and around their farming fields.

### 2.2. Sampling Procedure

Two Kebeles[3] from the District were selected purposively based on the potential of available tree species on the farmlands discussed with the district Natural Resource Management office and on direct field observation. From each selected Kebeles, three villages were randomly selected with a total of six villages selected. After the acquisition of the lists and of the number of rural dwellers of each kebeles, the number of sample households (a total of 94 households) was determined using Yamane and Joskow's formula [35] with a 5% level of precision. Then, the random selection method was employed to obtain samples of households. Thereafter, the selected households were subjected to stratification into wealth categories based on their local criteria, with the help of key informants, and all the detailed household surveys were done.

### 2.3. Data Collection

For the socio-economic data collection, a structured and semi-structured questionnaire survey was done on household heads. Consequently, data on the socio-economic characteristics of the household, tree management practices, species preference, and major household uses of trees on the farmland was collected through household interviews. The respondents involved in the household survey were further used for the enumeration of tree species on their farms.

To collect Vegetation data, different tree inventory methods were employed based on the nature of the plantation arrangement. For woodlot[4] plantations, 10% of the land size was sampled with 5 × 10 m sample plots. For an inventory of

[3] The Bottommost Administrative unit in Ethiopia

[4] A predominant plantation of trees often very small, usually 0.1 hectare or less, aimed for poles and other tree products.

trees in boundary plantations[5], the length of boundary plantations was divided into 10-meter sections; one section was selected for every 50 m of boundary length. When the length of boundary plantations was shorter than 10 m, the actual length was considered [28]. For the inventory of trees around the homestead[6] and scattered trees on crop fields (hereafter called the parkland[7]) one quadrant sample for each agroforestry practice from a given household farm was taken [24]. Thus, for this study, a quadrate size of 10 × 5 m and 50 × 50 m was used for homestead trees and agroforestry parklands, respectively.

### 2.4. Data Analysis

The data generated from the survey was subjected to one-way Analysis of variance (ANOVA), carried out to detect the difference in the mean number of trees and species richness per household among different wealth categories and different kebele administrations. The total relative score was employed for ranking the species preference made by respondent households. The statistical mean, standard deviations, frequencies, and percentages were also calculated to summarize and present the results by employing the statistical package for social science SPSS version 20.

## 3. Results and Discussions

[5] Rows of trees planted on the side of the boundary of a field and along small rural roads and paths.

[6] Trees of a wide variety of species planted around the dwelling house.

[7] Scattered trees growing on the fields: often such trees were left when the land was cleared for agriculture, or naturally dispersed seeds may have germinated and the seedlings had been deliberately protected during farming operations.

### 3.1. Respondent characteristics

Most of the surveyed households (85%) were engaged in a crop-livestock mixed farming system and 15% of them were engaged in off-farm activities like petty trade, horse-driven cart, daily labor, and selling charcoal and wood in addition to mixed farming. In this study, large percentages of respondent household heads (82%) were males and the rest 18% were females. The surveyed respondents had an average farming experience of 20 years (ranging from 3 to 51 years). The landholding size of the households in the study sites varied from 0.25 to 3.75 ha with an average holding size of 2 ha. However, there was a significant difference in landholding size among the wealth categories ($p < 0.01$). Wealthy households had larger landholdings than the poor and medium wealth class households.

### 3.2. Amount and Type of Tree Species Recorded in Farmers' Landholdings

Trees were an integral part of the farming system and farmers have long experience of integrating trees in their farming field in the study area. A total of 23 tree species were identified and recorded in different growing niches on the respondents' landholdings (Table 1). On average, the number of tree species existing per household was 3.94 species (ranging from 1 to 9), while the mean number of tree stems per household was 111.38 tree stems per household (Table 2).

The number of tree species grown per farm household in the study area is comparable to other studies done elsewhere in the country. For instance, a study in northern Ethiopia found 25 tree

species [4]. Another study [13] in the central highlands of Ethiopia found 27 tree species, which was higher than the result of this study.

Table 1

*Tree species identified and recorded in and around respondents' landholdings in the Womberma district, Ethiopia*

| Tree species | Tree niches | Planted(P) / Retained(R) | Uses |
|---|---|---|---|
| *Acacia abyssinica* (Hochst. ex Benth.) | B, P | R | 1,2, 3, 6,11 |
| *Acacia decurrens* (Willd.) | B, H | P | 1,2,6,9,11 |
| *Acacia lahi* | P | R | 1,2,3,6,7,9,11 |
| *Acacia seyal* (Lovett.) | B, P | P,R | 1,7,6,11 |
| *Albizia gummifera* (J.F. Gmel.) C.A. Sm. | P, H | P,R | 1,2,4,6,11 |
| *Boswellia papyrifera* (Delile ex Caill.) | P | R | 7,13 |
| *Casuarina equisetifolia* (L.) | B, H | P | 1, 2,4, 8,11 |
| *Combretum molle* R.Br. ex G. Don.) | P | R | 1,2,3,4,9,11 |
| *Cordia africana* (Lam.) | B, P, H | P,R | 1,2,3,4,5,6,7,9,11 |
| *Croton macrostachyus* (Hochst. ex Delile) | B, P, H | P,R | 1,2,4,5,6,7,11 |
| *Cupressus lusitanica* (Mill.) | B, H | P | 1,3,4,5,7,9 |
| *Erythrina abyssinica* (Lam. ex DC.) | B, P | P,R | 6,7,11 |
| *Eucalyptus camaldulensis* (Dehnh.) | B, W | P | 1,2,3,4,5,7,9 |
| *Ficus sur* (Forssk.) | P | R | 6,9 11,12 |
| *Ficus thonningii* (Blume) | B, P | R | 8, 11 |
| *Ficus vasta* (Forssk.) | P | R | 6,11 |
| *Grevillea robusta* (A. Cunn. Ex R.Br.) | B, H | P | 1,2,3,7,11 |
| *Juniperus procera* (Hochst. ex Endl.) | B, H | P | 1,3,4,7 |
| *Millettia ferruginea* (Hochst.) Bak. | P | R | 1,4,6,9 |
| *Podocarpus falcatus* (Thumb.) C.N. Page | P | R | 6,11 |
| *Rosa abyssinica* (R. Br.) | P, H | R | 1,7,12 |
| *Schefflera abyssinica* (Hochst. ex A. Rich.) | B, P | P, R | 1,4,9 |
| *Terminalia laxiflora* (Engl. & Diels.) | P | R | 1,3,4,9 |

Key*: Tree niches: B = Boundary, P = Parkland, W = Woodlot, and H = Homestead;*
Uses: *1 = Fuelwood, 2 = Charcoal, 3 = Construction, 4 = Timber, 5 = Cash income, 6 = Shade, 7 = Fence, 8 = Fodder, 9 = Utensil, 10 = Medicine, 11 = Soil conservation, 12 = fruit, 13 = incense (resin).*

Moreover, the average number of tree stems recorded per household in the study area was higher than the tree stems recorded (99 trees) in [10] and lower than (150 trees) those recorded in a study by Gebreegziabher and Mekonnen [16] in northwestern Ethiopia. This may be due to the likeness of the local knowledge by which a farmer manages the component mix of the traditional agroforestry system. Similarly, the mean number of tree species (about 4 tree species) per household was comparable, but lower than the number of species counted (4.88 species) [16] and (6 tree species) recorded in a study in northwestern Ethiopia [10].

Trees on farmlands are described by the respondents as important assets since they are vital for farmers' day-to-day life. To integrate trees on farmlands, farmers apply certain criteria, including fast growth, utility and compatibility to other

crops, multipurpose value, drought resistance, and access to seedlings. The respondent households mentioned one to several uses for why they integrated trees on their farmlands. The major use-values that were mentioned by farmers include fuelwood (16%), cash generation (26%), for construction (33%), household tools and utensils (13%), soil fertility (3%), land demarcation (6%), shade for humans and animals (2%), and need for fruit (1%). This indicated that the major reason that respondents integrate tree species on farmlands was mainly for construction, followed by cash income generation and for household fuelwood consumption. From among the species planted in the area, *Eucalyptus camaldulensis* (Dehnh.) was the major species used for house construction mainly planted on boundaries and woodlots. Similar results were reported by earlier researchers [23]. Furthermore, trees are planted by smallholder farmers in Ethiopia either for tree biomass as an energy source or as a major source of income generation in crop-livestock mixed farming [6].

The mean number of tree stems and the number of tree species at household level indicated the difference between the two study kebeles. The mean number of tree stems *(129 trees)* per household at Dafni-Shambla kebele was higher than the values (93 trees) in Kentefin *kebele* (Table 2). This could be due to the effect of agro-ecology (i.e., Dafni-Shambla is found in the midland and Kentefin is in the lowland). Previously, the lowland part of the district was known for its tree products such as gum and resin from species such as *Terminalia laxiflora* (Engl. & Diels) and *Boswellia papyferia* (Delile ex. Caill.) Hochst. But nowadays those tree species are being harvested due to the high expansion of agricultural investment. Similarly, the overall mean number of tree species (4.72 species) on farms of respondent households at Dafni-Shambla kebele was slightly higher than the values (3.1 species) at Kentefin kebele.

Table 2

*Number of tree stems per hectare and number of stems per household (mean ± standard deviation) in the two study kebeles*

| Kebele | Village | Mean number of tree species per household | Mean number of tree stems per household |
|---|---|---|---|
| Dafni-shambla | Huayta | 5.39±1.97[b] | 128.50±117.35[a] |
| | Warba | 4.69±2.36[b] | 123.88±141.84[a] |
| | Shambla | 3.85±1.14[a] | 136.77±156.32[a] |
| | **Total Mean** | 4.72±1.99 | 129.21±134.35 |
| Kentefin | Mehal Bitir | 3.30±1.34[a] | 111.00±119.91 |
| | Mehal Damot | 3.07±0.77[a] | 86.68±74.82 |
| | Bitir | 3.22±1.20[a] | 95.56±58.37 |
| | **Total Mean** | 3.15±0.98 | 93.55±82.38 |
| **Overall mean** | | 3.94±1.75 | 111.38±112.281 |

Key: *Different letters following the row on mean values indicate a significant difference (P<0.01) among village categories*

The result of the ANOVA test indicates that from the three villages in Dafni-Shambla *kebele*, Huayta village has a significantly higher number of tree species

per household, but it has no significant difference with Warba village. However, Shambla village has a higher number of tree stems per household which is greater than the mean of the two villages (Table 2). This is due to the accessibility of the village to the roads and local markets; farmers grow trees on their landholding mainly for cash income. In Kentefin *kebele* there was an almost equal mean number of tree species per farm across three villages (ranges from 3.07 to 3.3), but within the kebele, the mean number of tree stems per household was higher in Mehal bitir than in other villages.

### 3.3. Dominant Tree Growing Patterns on Farmers' Landholdings

One of the features of on-farm tree management is that the biological characteristics of a tree are often taken into account to determine where it should be grown [8], [36]. A pattern or a combination of patterns of trees may exist in a given land-use system [5]. The growing niches (hereafter called agroforestry practices) that were distinguished in the study area were trees in the homestead area, parkland, trees on farm boundaries, and trees on woodlots. Farmers select tree species suitable to each tree growing niche[8] and the density of planting to minimize the effect of the trees on the crops and on other components, and to reduce competition between tree species. For instance, trees that contribute positively to crops are grown dispersed in crop fields, while trees that compete with crops are planted separately. For this study, the tree growing niche refers to the location and arrangement of trees on the farm with other components (such as crops and animals) or to their growing pattern in the farming landscape.

The highest frequency of respondent households was practicing parkland agroforestry followed by boundary planting in both kebeles (Figure 2). This is because Parkland trees are predominantly integrated through the protection of previous forest remnants, naturally regenerated seedlings. Respondents plant trees on the boundaries of the farm and on the roadside for boundary demarcation, to use as a shelterbelt from wind, to use as a live fence for protection of their crops from livestock damage, and for the production of household utensils. The least common growing niche (7%) recorded was the farm woodlot (Farmer-managed tree plantations on farming lands) which was mainly practiced only with *Eucalyptus camaldulensis* (Dehnh.). The reason that the woodlot has not been preferred could be the long fallowing period of the species (E*ucalyptus camaldulensis* Dehnh.) and land shortage for staying tree plantation for a long time.

Similar trends were also reported in other studies elsewhere in Ethiopia [13]. The highest abundance of trees in boundary planting and woodlots was mainly due to narrow planting density by farmers. Most farmers (93.6%) prefer to plant *Eucalyptus* trees on their farm boundaries for demarcating their farm fields commonly from the roadside. Respondents frequently argue that *Eucalyptus* retards the growth of crops in the proximity. Therefore, usually they do not choose to plant this species in association with crop fields unlike *Croton macrostachyus* (Hochst ex. Delile) and *Albizia gummifera* (J.F. Gmel.) C.A. Sm.

[8] The specific area or arrangement where trees are planted

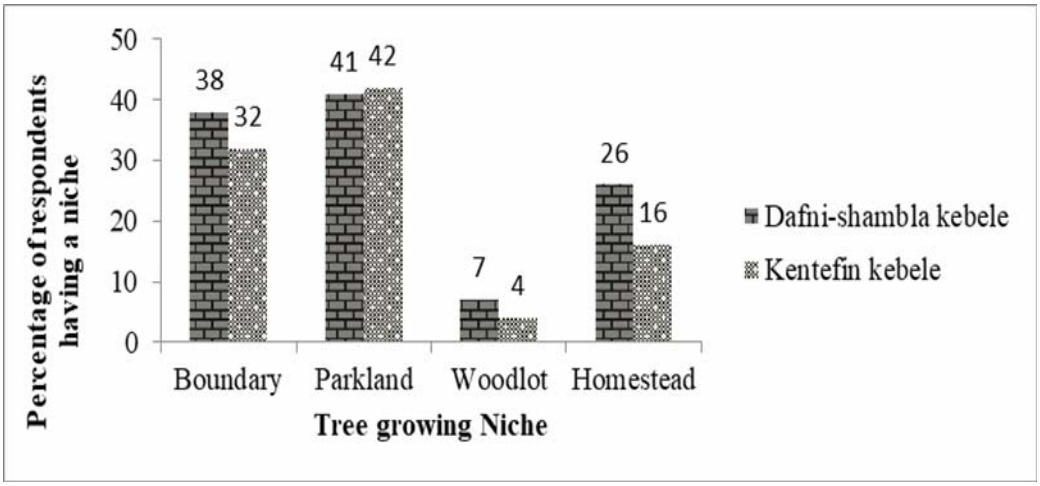


Fig. 2. *The major tree growing positions with the number of respondents (%) in the study Kebeles*

### 3.4. Number of Tree Species within Different livelihood Statuses of Households

The mean number of tree species maintained and/or planted per household across the three-wealth categories has varied. Medium wealth class households have a relatively higher number of tree species than rich and poor households. This is because rich households have higher landholding sizes than poor farmers, as well as more access to capital to purchase seedlings, labor force for management, and other costs regarding tree integration.

Other studies also reported that lack of capital influences tree density, tree species-preference, and other management activities on farmlands [32]. Farmers with less access to resources, particularly land, may focus on the cultivation of a few staple food crops for their subsistence production, depending on their relative benefits. There can also be more fundamental economic pressures that prevent or discourage farmers from managing trees on their agricultural lands.

Studies [3] indicated that wealthy households plant a higher number of trees and have more diverse tree species than their counterparts. Still, the mean number of tree stems (total abundance) on the farms of the respondent households increased with the wealth category of the respondents (poor, medium, rich) and there was a significant difference ($p<0.05$) in the number of stems per household across the three-wealth classes. Thus, the number of trees on the farms of households has increased across wealth categories (Table 3). Rich households have a significantly higher number of trees than both poor and medium wealth category households.

Table 3

*Tree species and stems per household (Mean ± standard deviation) of respondents with wealth category in the two study Kebeles*

| Kebele | Parameter | Wealth category | | |
|---|---|---|---|---|
| | | Poor | Medium | Rich |
| Dafni-Shambla | Number of species | 4.00±1.65[a] | 5.35±1.96[a] | 5.10±2.38[a] |
| | Number of tree stems | 31.75±20.19[a] | 129.82±110.32[b] | 323.10±82.94[c] |
| Kentefin | Number of species | 3.25±1.00[a] | 3.00±1.14[a] | 3.23±0.73[a] |
| | Number of tree stem | 27.31±28.94[a] | 101.78±80.50[b] | 163.69±67.16[c] |

Note: *Different subscript letters within row indicate a significant difference between wealth category at P<0.05.*

### 3.5. Tree Species Preference and Management

In this study, tree species preference ranking was done with a relative score in the two kebeles independently. Thus, respondents were asked to rank the three most important tree species among the species they plant and/or retain. The top seven preferred tree species for respondents and the reasons for their preference are presented in Table 4.

Considering farmers' tree species preference is important to develop research ideas and relate their indigenous knowledge with scientific work. The importance of trees in addressing the production and service function issues has been well understood by farmers through the centuries and has been demonstrated in traditional tree-based agricultural farming and land-use systems. In this study, criteria commonly used by the respondents regarding tree species selection include growth, soil fertility, demarcation, cash income, fuelwood, construction, and benefits. Similar results were reported in other studies [12], [23], [31].

*Eucalyptus camaldulensis* (Dehnh.) was the first tree species in terms of the percentage of households' preference and planting (Table 4). This is because of an ever-increasing population and the resulting demand for construction poles, fuelwood, household utensils, farm implements, and the fast-growing performance of the species. This result was in line with the previous results reported in [10], [17], [30], [36] which also pointed out that *Eucalyptus camaldulensis* (Dehnh.) is the most important tree species preferred by households in northern Ethiopia.

Table 4

*Ranking of preference for tree species integrated into farmlands by the respondents in the Womberma District*

| Kebele | Species name | Total relative score | Rank |
|---|---|---|---|
| Dafni-Shambla | *Eucalyptus camaldulensis* (Dehnh.) | 30.93 | 1 |
| | *Cordia africana* (Lam.) | 9.47 | 2 |
| | *Croton macrostachyus* (Hochst. ex Delile) | 3.18 | 3 |
| | *Acacia decurrens* (Willd.) | 2.11 | 4 |
| | *Albizia gummifera* (J.F. Gmel.) C.A. Sm. | 1.24 | 5 |
| | *Acacia abyssinica* (Hochst. ex Benth.) | 0.12 | 6 |
| | *Grevillea robusta* (A. Cunn. ex R.Br.) | 0.05 | 7 |
| Kentefin | *Eucalyptus camaldulensis* (Dehnh.) | 29.37 | 1 |
| | *Terminalia laxiflora* (Engl. & Diels.) | 8.80 | 2 |
| | *Croton macrostachyus* (Hochst. ex Delile) | 4.99 | 3 |
| | *Cordia africana* (Lam.) | 2.05 | 4 |
| | *Millettia ferruginea* (Hochst.) Bak. | 1.28 | 5 |
| | *Acacia seyal* (Lovett.) | 0.31 | 6 |
| | *Acacia decurrens* (Willd.) | 0.12 | 7 |

Farmers employ various management practices which assist them to attain sustainable use of on-farm tree products. The purposes of these management practices were to increase the growth of active growing trees, to minimize competition, reduce shade effect, and to use the intermediate products for fuelwood and fencing demands, as claimed by the respondents (Table 5).

Farmers not only know different tree/shrub management practices but also differentiate which woody species require a different set of management practices and appropriate time. For instance, prescribed burning is applied for *Eucalyptus camaldulensis* (Dehnh.) in woodlots and sometimes on boundary plantings. Respondents reported that burning of stumps after coppicing is done in the dry season to facilitate the dormancy breaking after coppicing for *Eucalyptus camaldulensis* (Dehnh.). Similarly, mulching[9] was carried out mostly in the dry season to increase the moisture level of the soil around the trees. Thinning and coppicing were also applied at the base of the trees depending on the age class at their mature stage. Furthermore, protection of tree planting in the early stage was the main management practice to protect the trees from animal and human interference through fencing with wood and tree branches. The study in Northwestern Ethiopia [31] noted that coppicing, pollarding, pruning, and thinning are among the most important tree management practices identified in the area.

[9] Addition of crop, animal residue, or grass around the rooting zone of a given plant

## 4. Conclusion

Integrating trees in the agricultural landscape can be used as a means of enhancing rural livelihoods and sustaining the provision of goods and services. Trees on farmlands can result from different regeneration processes such as retention of trees that were present before farms were established, tolerance (and protection) of natural tree regeneration after farms were established, or active planting by farmers of selected trees in preferred locations. This study determined that *Eucalyptus camaldulensis* (Dehnh.) was the dominant tree species preferred for planting by a majority of households for reasons related to income generation, construction, source of energy, and other household uses.

This study also confirms that farmers in the study area possess their own knowledge and wisdom on the activities of tree integration in their farming area. They do apply different tree management practices to reduce competition, to protect from animal damage, to maximize the quality of the product they aimed to earn from the tree. Tree management started by selecting the species which should be integrated and grown up through the harvesting stage.

However, exotic tree species such as *Eucalyptus camaldulensis* (Dehnh.), *Acacia decurrens* (Willd.), and *Grevillea robusta* (A. Cunn. Ex R.Br.) were planted by farmers at an increasing rate and the status of indigenous tree species has decreased from time to time. Therefore, there should be a continuous and detailed extension system to upgrade the traditional management system and tree selection to be integrated. Stakeholders in the area of agroforestry and forest management should work in association with farmers on incorporating multipurpose tree and shrub species that are economically important and compatible with the other components of the agroforestry system.

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