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Original Article

Farmer's Local Knowledge towards Effects of Highland Bamboo (Oldeania alpina (K. Schum.) Stapleton) in Agroforestry

Chala Mamude[1] & Elsabet Befikadu[2]*

[1] Ethiopian Forestry development, P. O. Box: 30708 Addis Ababa, Ethiopia.
[2] Haramaya University, Haramaya, P. O. Box 138, Dire Dawa Ethiopia
[*] Author for Correspondence ORCID ID: https://orcid.org/0000-0001-6612-0214; Email: chalamamude@gamil.com.

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Arundinaria Alpina, Bamboo-Based Agroforestry, Component Interaction, Informants

ABSTRACT

Highland bamboo has been playing a great role in economic, ecological, and social aspects. However, its effects while planted in Agroforestry (AF) lands have not been documented. Therefore, the aim of this study was to assess the local farmer's knowledge towards the effects of highland bamboo while planted in AF niches at Arbegona District, Sidama, Ethiopia. To this end, a reconnaissance survey was conducted to select two study kebeles from the district purposively based on the traditional bamboo-based AF potential in the area. The principal techniques such as semi-structured informant interviews, field observation, and focus group discussions were used to collect the data. A total of 50 informant farmers (25 from each kebele) were selected and interviewed through snowball method. The data were analysed using descriptive statistics by SPSS software. The findings showed that the majority of the respondents experienced positive socio-ecological effects (i.e., functioning as a windbreak (96%), fast-growing (92%), and livelihood supplement (88%) and adverse effects (i.e., high rhizome distribution (96%), shade effect and low decomposition rate of leaf litter (90%), and high competition for nutrients (86%)) of highland bamboo in AF. In addition, the major bamboo management practices by farmers were fencing (92%), thinning (88%), and terracing to rhizome control (84%). Therefore, the inclusion of local knowledge of farmers into science is vital while designing and developing agroforestry system particularly bamboo-based agroforestry. Finally, the study recommended further in-depth field experimental research should be investigated to identify the interaction effects of highland bamboo in AF practices.

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INTRODUCTION

Bamboo is a productive, sustainable, and versatile non-timber forest products providing food, raw material, and shelter that is found in a wide variety of climatic and edaphic conditions (Xu *et al*., 2019). Highland bamboo has been playing a great role in economic, ecological, and social aspects in the region (Obsa et al., 2015a and b; Yohannes et al., 2019). Nowadays, it is used for furniture (traditional processors and modern workshops), house construction, fencing, water storage/ water pipes, baskets, agricultural tools, beehives, household utensils, and various artifacts (FAO, 2020; Yohannes et al. 2019). Local communities eat highland bamboo shoot traditionally and the presence of different nutritional minerals composition is reported (Mulatu et al., 2019). Therefore, its integration into the agroforestry systems can be a source of income.

Agroforestry is a dynamic, ecologically based, natural resource management system that through the integration of trees in farm and range land, diversifies and sustains smallholder production for increased social, economic, and environmental benefits (Leakey, 2017). Bamboo-based Agroforestry (BBAF) is one of the agroforestry systems in which bamboo is deliberately grown with other agricultural and or livestock to address the mentioned above advantages of the agroforestry land-use system (Kittur *et al*., 2016). In this regard, highland bamboo functions as AF plants (Desalegn & Tadesse, 2014) through planting on private farmlands within sort of different practices such as homesteads, block planting, farm boundary (Zhao *et al*., 2018; Nigatu *et al*., 2020; Bahru *et al*., 2021), live fence (Mekuriaw *et al*., 2011), hedge row intercropping and woodlot (Obsa *et al*., 2015a) agroforestry practices.

The Unique characteristics of bamboo species such as an extensive rhizome system, a thick litter layer, highly elastic culms, and a dense canopy give bamboo ecosystems a high capacity for erosion control, soil and water conservation, landslide prevention, protection

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of riverbanks, and windbreak and shelterbelt (Song *et al*., 2011). Bamboo plays a key role in restoring soil fertility through the accumulation of organic matter and nutrients during the fallow period (Embaye *et al*., 2005). Furthermore, in bamboo-based AFS, the presence of bamboo reduced the weed density under the AFS (Dev *et al*., 2015). In general, a systematic BBAF with sufficient management practices will be more beneficial towards the extra income generation and open up more opportunities for livelihood on a sustainable basis (Kumar *et al*., 2015).

Farmers' knowledge is the level of information and understanding that farmers have on their local, how to apply it and what the outcomes are in terms of products, yield, potential environmental benefits, risks, and costs (Tokede *et al*., 2020). Additionally, farmers' knowledge complements scientific knowledge by providing the long practical experience of farmers in managing and living within an ecosystem and of responding to the changes of the ecosystem (Asfaw, 2003). The inclusion of local knowledge is vital when designing interventions that aim for sustainable intensification and managing tree crop-livestock farming systems because of trade-offs and synergies (Shiferaw *et al*., 2013). In this regard, farmers in different areas commonly managed highland bamboo using traditional knowledge and experiences (Gebrekidan *et al*., 2018; Yohannes *et al*., 2019; Bahru *et al*., 2021).

Even though highland bamboo can occupy an important position in the development of AF (Nigatu *et al*., 2020), there is a limited documentation of its ecological effects while integrating into the system in the current study area. Foremost, understanding the applicability of the species in AF requires understanding the farmer's local knowledge towards ecological interaction in BBAF. However, a piece of limited information has been documented in farmers' local knowledge to inform management decisions applicable to improving the development of BBAF systems in the study area. Therefore, this study was intended to assess the local farmers knowledge towards the effects of highland bamboo grown in different AF niches.

MATERIALS AND METHODS

Description of the Study Area

Geographical Location

The field study was conducted at Arbegona District, Sidama Regional State, Ethiopia. Arbegona is situated within the coordinate of 6°35'18" to 6°56'37" N latitude and 38°35'60" to 38°53'36" E longitudes **(**Figure 1**)** with an elevation ranging from 2000 to 3336 meters above sea level. The district is demarcated by Gorche district in North West, North by Oromia region, and the East Bensa district (Girma *et al*., 2017)

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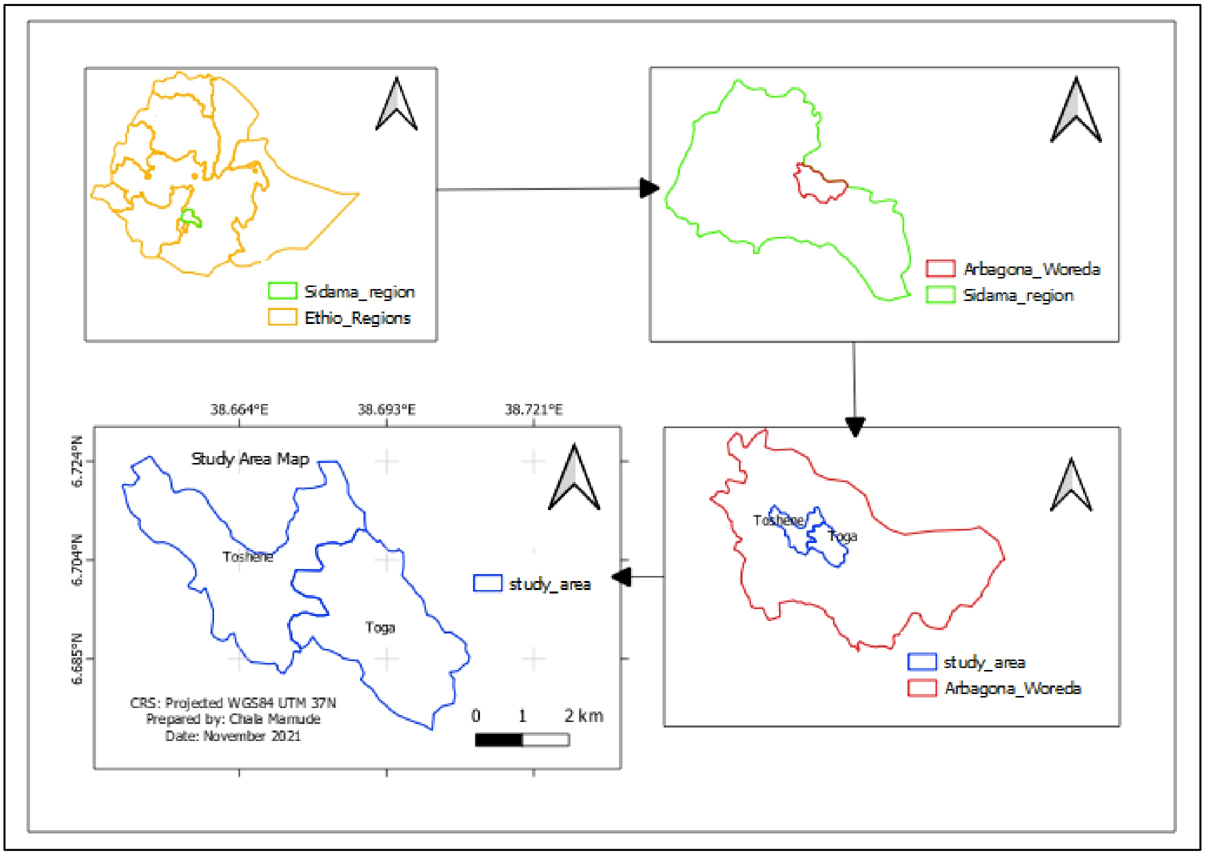
Figure 1: Map of the study area



Source: The Ethiopian Geoportal, updated 2020

Climate

Arbegona district has two agro-ecological zones: Highland or 'dega' (86%) and midland or 'Woyna Dega' (14%). The district shows a bi-modal rainfall pattern, which is a minor rainy season between February to April and major rainfall between July and October with annual rainfall ranges between 1250 to 1300 mm. In addition, the temperature of the district ranges between a minimum of 14 ^{0}C and a maximum of 18^{0}C (AWAO, 2017).

Socioeconomics Characteristics

Arbegona district has one urban and 38 rural kebeles[1]. The economic activities of the district are mainly dependent on agriculture with rearing farm animals and cultivation of land. The majority of the population practice mixed subsistence agriculture (Agroforestry). The livelihood of the community in the area entirely depends on the production of stable food crop Ensete (*Ensete ventricosum* [Welw.] Cheesman) and there is a very low risk of crop loss. In addition to this, the community settled in highland agro-climatic produce crops such as; wheat, barley, and bean. The midland settlers also produce annual crops like maize

[1] Kebele is the lowest administrative unit in Ethiopia

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(*Zea mays L*.), and teff (*Eragrostis tef* (Zuccagni) Trotter) and perennial crops such as coffee (*Coffea Arabica L*) and chat (khat, *Catha edulis* Forssk. ex Endl.) for subsistence and earnings purposes and earnings purposes respectively (Quinlan *et al*., 2015).

Furthermore, the majority of the community members have planted bamboo in their farmyard in different ways mostly through farm boundaries, windbreak, home garden, woodlot, riverine, roadside, blocking, and others. They used bamboo as a supplement of tree species for different purposes such as fencing, house construction, furniture, and livelihood (field survey).

Description of Highland Bamboo (O. alpina)

Highland bamboo is one of the dominant plant species in the Arbegona district (AWAO, 2017). *O. alpina* has a synonym name of *Yushania alpina* (K.schum.) *Arundinaria alpina* (K.schum.) and other various common names; Alpine/African Alpine bamboo and locally called 'Kerkeha' in Amharic (Phillips, 1995) and 'Lemicho' in Sidama language. Highland bamboo is a very large and perennial woody type of bamboo with thick hollow culms of up to 12 cm diameter at the base and rising to 20 m from a stout branching rhizome (Mulatu et al., 2016). Highland bamboo rhizome has a spacer length (length of rhizome neck) between the mother plant and the new plant up to 30 cm. The average rhizome depth of highland bamboo ranges from 44 to 72 cm depending on the landform (Mulatu & Fetene, 2011). Finally, this species is found dominantly in almost all of the community farmlands of the current study area (own field survey, 2021).

Reconnaissance Survey

Based on a reconnaissance survey conducted, multi-stage sampling was employed to select the representative Kebele's from the Arbeguna district. Arbeguna district from the Sidama regional state and the two Kebeles (Toga and Toshine) were selected purposely based on the bamboo production potential in the area especially its dominance in farmland as identified by (EFCCC and INBAR, 2020) and field observations and discussions with experts from Arbegona District Office respectively. During the reconnaissance survey, the population (household) structure data such as the maximum and minimum estimated land size, bamboo farm size, and bamboo plantation niches were collected and considered for sample size determination.

Sampling Technique and Sample Size Determination

Two focus group discussions (one in each kebele) were done with a group containing members of eight individuals (which included three model farmers, three community elders, one forestry expert, and one development agent). Informant farmers were selected from households mainly based on their local knowledge, skills, and practice of bamboo-based agroforestry on their farm land. Basically, informant farmers invited to participate in the interview were from community members who were interested to participate in the study, using the criteria of farmers who have been planting bamboo for at least 3 years in their farmland as one of the AFSs and or in other land types.

Participated bamboo farmers for informant interview were identified through a snowball

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sampling method (Goodman, 1961), which started with the model bamboo farmer in each kebele's and thereafter grew through a network of nominated acquaintances (Valencia *et al*., 2015). Accordingly, 50 bamboo farmers (25 from each kebele) were selected for interview as applied by a prior similar study (Valencia *et al*., 2015). The number of informants were limited because of the homogeneity of farmers' having BBAF in the study area.

Data Collection Methods

To assess farmers' local knowledge of BBAF, the principal technique used to elicit information was semi-structured informant interviews, field observation, and focus group discussion following the methods by Martin (1995). First, an open and closed-ended questionnaire was developed and pretested for an interview before the actual field data collection. Then, the developed questionnaire was administered to the selected informants in the local language. During interviews, which lasted between 45 and 60 minutes, informant farmers openly discussed their knowledge about bamboo integration in AF. The questions were focused generally on the ecological role, adverse impacts, and management practice of bamboo in AF. The focus group discussions using the developed open questions and field observation were conducted to get additional information to contextualize and supplement the information from interviews. The farmlands of the informants were carefully visited across the transect walk to identify the status of management and practices in BBAF.

Plate 1: Focus group discussions (left) and informant household interviews (right)

Source: photo captured by the researchers during the field survey, 2021

Data Analysis

The collected qualitative and quantitative data were analysed using descriptive statistics such as frequency distribution, percentages, and Mean ± Standard deviation that was used to describe the demographic characteristics of the respondents. The responses of informants regarding knowledge on the BBAF were analysed using frequency and percentage method with rank order. Tables and figures were used to summarize the results. The summary of the qualitative data such as Focus group discussions and field observation were also narrated through opinion interpretations. All data collected in the field survey were done by SPSS (Version 23) software.

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RESULTS AND DISCUSSIONS

Demographic and Socioeconomic Characteristics of Respondents

The demographic characteristics of the sampled 50 informant household farmers as are given in Table 2. The majority of the respondents were males (94%) and ages range between 31-40 years (40%). Regarding the education level of the respondents, 72% attended primary school and above. More than 82% of the respondents have an experience in cultivating bamboo on the different plots of their farmlands for more than ten years. The average family size was about seven persons per household.

Table 1: Demographic characteristics of respondents with their descriptive statistics.

Variables	Description	Frequency	Proportion
Sex	Male	47	94.00
	Female	3	6.00
Age (years)	20-30	4	8.00
	31-40	20	40.00
	41-50	16	32.00
	More than 50	10	20.00
Education level	Illiterate	14	28.00
	Primary school	24	48.00
	High school	4	8.00
	Higher study	8	16.00
Major income sources of the HH	Crops and rearing	47	94.00
	Crops farming	3	6.00
Duration of Bamboo cultivation (years)	3-5	5	10.00
	6-10	4	8.00
	>10	41	82.00

Source; Computations from own field survey (2021)

Bamboo-Based Agroforestry practices and area coverage

Farmers in this study area have low land allocated to highland bamboo. On average, out of the total land holding size per household were 1±0.3 ha, of which 0.3 ha is allocated to bamboo cultivation in different niches (*Figure 2*). Furthermore, a large proportion of households (90%) manage bamboo in the Farm boundary followed by homestead/home garden, wood lots, and others (i.e., riverine, gullies, and roadside) as shown in Figure 3.

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Figure 2: Average land size per Households and its allocation to different land-use types

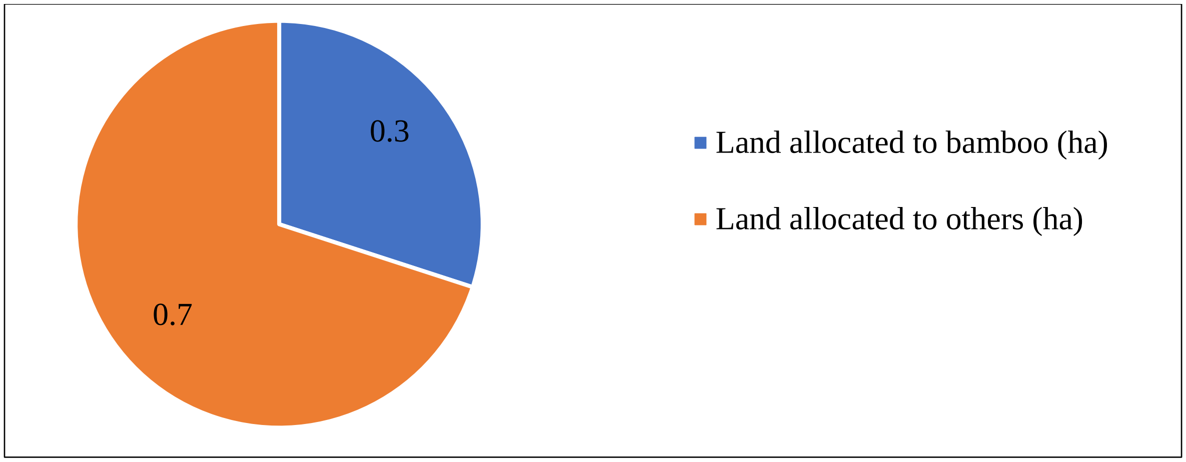
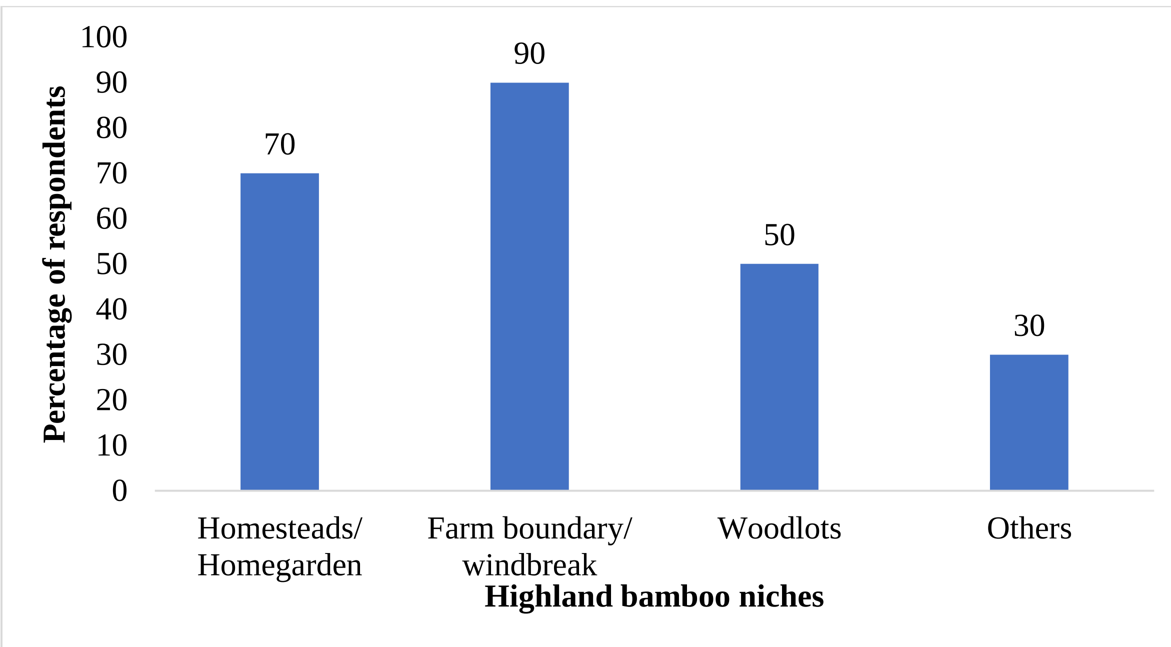


Figure 3: Number of respondents and types of bamboo-based agroforestry niches.



The land size figure in the current study is almost the same as the result found by Gebrekidan et al. (2018), on average 0.32 ha of land per household in the neighbour Kokosa District. However, little higher than the result found by Teshale et al. (2017) and Bahru et al. (2021) reported from Hula (0.20 ha) and Masha districts (0.14 ha) respectively. Besides, the current study result was lower than the results found by Bahru et al. (2021) which was 0.59 ha per household in Hula districts. Finally, despite the land shortage, this study confirmed farmer's high willingness to expand their bamboo plantation.

Regarding this, farmers have been trying to overcome their land scarcity through the practice of bamboo-based agroforestry (Table 3). The field observation in this study area

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confirmed highland bamboo planted in different traditional agroforestry systems such as farm boundary, homesteads and or home gardens, windbreak, woodlot, riverine, and others. Overall, these findings are in accordance with findings reported by Nigatu et al. (2020) and Partey et al. (2017). Different annual crops such as barley, wheat, bean, maize, and perennial like Enset are grown adjacent to bamboo farmland in the study area. In general, the finding of this study indicated as the application of agroforestry is one of the major strategies of the farmers to overcome the land scarcity in the study area.

Farmer's Local Knowledge towards Bamboo based agroforestry

Role of Highland Bamboo in Agroforestry

This study was the first attempt that examined farmer's local knowledge towards bamboo integration in AF of the Arbegona district. According to the respondents, the integration of bamboo in different agroforestry practices has a great ecological and socioeconomics role. The majority of the respondents reported bamboo integration into agroforestry to function as a windbreak and suppress weed growth (96%), fast-growing (92%), and supplement for livelihood (88%), and others as shown in *Table 2*.

Table 2: Farmer's knowledge towards the role of bamboo integration in agroforestry

A positive effect of bamboo in AFS	Frequency (proportion), n=50		
	Yes (%)	No (%)	Rank[2]
Fast-growing and high biomass Production.	46 (92)	4 (8)	2
Suppresses weed growth	48 (96)	2 (4)	1
Helps for livelihood Supplement	44 (88)	6 (12)	3
Serves as windbreak	48 (96)	2 (4)	1
Improve soil fertility	30 (60)	20 (40)	4
Improve soil moisture	30 (60)	20 (40)	4

Note: 'n' represents number of respondent informants in this study

This basic finding is consistent with research that showed highland bamboo can increase soil fertility through an accumulation of organic matter (Embaye et al., 2005; Obsa et al. 2015b). It is also agreed with the findings of prior studies by Obsa et al. (2015a) and Yohannes et al. (2019) which reported that highland bamboo helps the community through the supplement of livelihood and replacing the other tree service such as house construction, fence, and furniture. In the end, it is notable that the current study results revealed that local bamboo farmers have a good experience of the ecological role of bamboo cultivation in agroforestry practice. However, the socioeconomic role of the species was not fully assessed in the current study.

[2] Rank order is given based on the respondents' proportions answered 'yes' to a given positive effects.

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Adverse Effects of Bamboo Integration in Agroforestry

In this study, the effects (both positive and negative) of highland bamboo parts in adjacent crops in agroforestry were identified. Figure 4 shows the effects of bamboo parts namely; culms, roots, branches, and leaves on adjacent crops. A large proportion of respondents reported better positive effects on crop performance due to bamboo branches (88%), culm (86%), and leaves (70%). On the other hand, 54% and 30% of respondents reported negative effects of roots and leaves on crops respectively.

Furthermore, *Table 3* illustrated the different major adverse effects of highland bamboo integration on adjacent crops in agroforestry. A large proportion of the respondents reported adverse effects of bamboo integration in AF such as; high rhizome distribution (96%), shade effect and low decomposition rate of leaves (90%), and high competition for nutrients and water (86%). In addition, 34% of the respondents reported the toxicity of bamboo leaves on adjacent crops.

Figure 4: HH Response on the effect of bamboo parts on adjacent crops

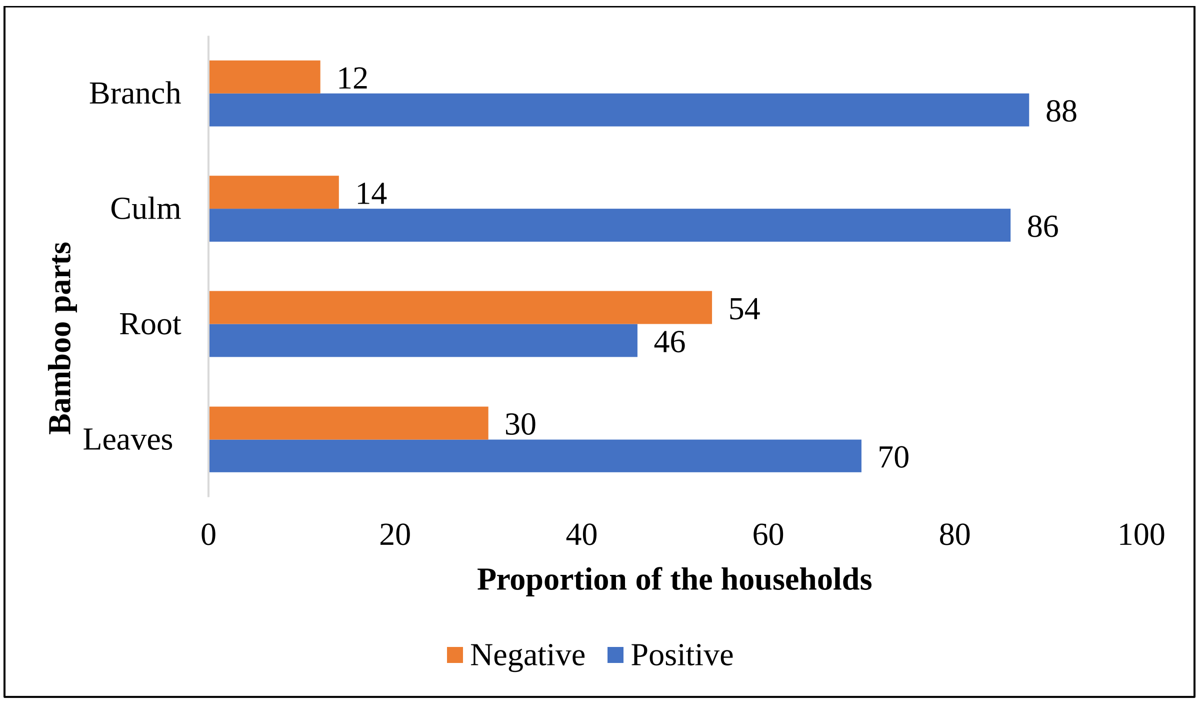

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Table 3: Farmer's knowledge towards the adverse effects of bamboo in agroforestry

An adverse effect of bamboo in agroforestry	Frequency (Proportion), n=50		
	Yes (%)	**No (%)**	**Rank**
Rhizome distribution affects crops	48 (96)	2 (4)	1
Shade effects on understory crops	45 (90)	5 (10)	2
Extremely competes for nutrients and water	43 (86)	7 (14)	3
Leaves have low decomposition rate	45 (90)	5 (10)	2
Causes toxicity on adjacent crops	13 (26)	37 (74)	4

Source: Retrieved from analysis of field study (2021)

Most importantly, the respondents in this study area frequently highlighted the challenges of highland bamboo leaves that are very dense and do not decompose quickly like other broad-leaved AF trees. It also covers the upper soil part rapidly while matured and falls. The work of Embaye et al. (2005) confirmed that the Highland bamboo litter fall resists decaying rapidly due to the presence of high silica content on it. Besides, farmers added that Highland bamboo leaves could also affect cultivated crops inside the BBAF system since the leaves have a toxicity character that makes the other plants including weeds not grow in the understory of the bamboo culm area. It is one of the basic interaction effects that should need special consideration during agroforestry practice. Because, such effect is hidden from farmers and occurred in the soil system. Nair (2021) highlighted the possible presence of such adverse effects of AF trees/plants on the other crops due to interactions between the components while competing for resources, microclimate, and allelopathy.

This result is consistent with the finding from the study by Yohannes et al. (2019) that reported a major negative effect of Highland bamboo expansion is its leaves acidity on the soil system and damage the growth of adjacent crops in northern Ethiopia. The findings also reveal that the other major negative consequences of highland bamboo integration to AF are high competition for nutrients and shade effect on adjacent crops. These characters of Highland bamboo deprived the farmers to practice different intercropping traditional AF in their farmlands. This finding is similar to a study by Bahru et al. (2021) which reported the good experience of local farmer's towards highland bamboo management and conservation surveyed in the neighbouring districts of southern Ethiopia.

Major Bamboo Management Practice

The following *Table 4* shows the traditional bamboo management practice used by the respondents to increase production and reduce the adverse effects of highland bamboo in the agroforestry practices of the study area. According to respondents, the dominant traditional bamboo management practice used in the study area are fencing (protecting from any damaging agents like livestock, and echidna), regular culm thinning, trenching to manage rhizome distribution, and compost application to increase the quality and production yield of highland bamboo in agroforestry (*Table 4*). The focus group discussion conducted in the study area were

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also confirmed a similar practice used to manage bamboo plants in BBAF.

Table 4: No of respondents mentioning bamboo management practice at the study area.

Major management practices	Frequency (proportion), n=50		
	Yes (%)	No (%)	Rank[3]
Household use pruning management practice	19 (38)	31 (62)	6
Household use thinning bamboo culms	44 (88)	6 (12)	2
Remove leave to minimize its negative effects	26 (52)	24 (48)	5
Households manage rhizome distribution	42 (84)	8 (16)	3
Households use mulching and composting	40 (80)	10 (20)	4
Households use Fencing for protection	46 (92)	4 (8)	1

Source: Retrieved from analysis of field study (2021)

Even though most of the respondents in the current study area have low experience of traditional leaves management practice and pruning, they have demonstrated that integrating annual crops into the bamboo farm is advisable only up to the first 2-3 bamboo growth years. Otherwise, the high biomass of culm, leaves, and root distributions of bamboo could be an obstacle to ploughing and cultivating annual crops. In general, the management practices experienced help farmers to overcome the above adverse effects and maximize the productivity of the BBAF systems. This result was in line with the study reported by Girma et al. (2017) from the neighbouring Kokosa districts that the major management practice used by farmers are fencing and compost application. Finally, the assessment of local knowledge above was an important, precondition to understanding the challenges and opportunities in BBAF.

CONCLUSION AND RECOMMENDATIONS

The current study assessed the local farmers knowledge towards the effects of highland bamboo in agroforestry in Arbegona district. Farmers in this district plant highland bamboo dominantly in different agroforestry niches and manage with their local knowledge. The study concluded that farmers in the district demonstrated better understanding and has a profound knowledge on the positive and negative effects and management practices of highland bamboo plants while growing in different agroforestry niches. Therefore, the inclusion of local knowledge of farmers into science is vital while designing and developing agroforestry system particularly bamboo-based agroforestry. Promotion of such good experiences of bamboo farmers in this study area to the other localities plays a vital role in enhancing productivity and secure sustainability of highland bamboo resource in different niches. Finally, the study has

[3] Rank order is given by considering the proportion of respondents answered ‘yes’ for each question (Similarly for Table 2 and 3 above

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suggested that further in-depth field experimental research that will clearly identify the interaction effects of highland bamboo in different agroforestry practices should be investigated.

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