

Research Article

Adoption of Coffee Shade Agroforestry Technology and Shade Tree Management in Gobu Seyo District, East Wollega, Oromia

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Coffee production in the form of agroforestry practices is the most important management approach to improve the livelihoods of the farming community. This study was conducted to assess factors affecting the adoption of the technology, its socioeconomic and environmental benefits, and the management practices related to the technology. Out of eight kebeles in the district, two kebeles were selected purposively based on the existing and extensive agroforestry practices. Four villages were selected randomly. Based on the preidentified criteria as coffee growers and nongrowers, coffee growers were selected purposively. Then a total of 120 households were selected by Simple Random Sampling Method. Data were collected by using structured interview and field observation. The data were analyzed by using descriptive statistics analysis. The logit model was used to identify the factors affecting the adoption of coffee shade agroforestry technology. The results of this study showed that adoption of coffee shade agroforestry technology had a positive relationship and was statistically significant at 1% level with age and area covered by coffee production, while household composition and training were at 5% level. Education level, land holding, and extension services also had positive relationship, but it was not statistically significant. The farmers in the study area mentioned other benefits of these technologies such as for animal feed, firewood and construction materials, medicinal purpose, erosion control, honey bee production, and soil fertility enhancement. Different management activities were also identified in the area (such as composting, pruning, watering, and weeding). Coffee shade agroforestry technology was important to diversify the agricultural products, to solve the problem of livelihood, and adds economic and environmental benefits.

1. Introduction

1.1. Background. Coffee is shade-tolerant plant and is mainly grown under shade trees in complex agroforestry systems. Agroforestry technologies range from traditional to recent practices such as taungya, home gardens, improved fallows, multipurpose trees, plantation-crop alley cropping, and others [1]. Specifically coffee shade agroforestry technology is a traditional and complex agroforestry system, where coffee is associated with various other species in different storeys (or “levels”). This provides ecologically and economically sustainable use of natural resources. According to Ehrenbergerová et al. [2], coffee is a shade-loving plant and the shade trees reduce the stress of coffee

(*Coffea* spp.) by ameliorating adverse climatic conditions and nutritional imbalances. Recha et al. [3] added that coffee agroforestry technology has many benefits in the economy and supports the households’ needs of medicine and timber. Soil fertility will be improved by the agroforestry practices, especially when nitrogen-fixing plants are added to the production system. The trees also contribute to the reduction of soil erosion and to the carbon sequestration.

Shade trees in coffee agroforestry system also increase and preserve surface soil humidity and reduce the direct light intensity reaching the coffee plant, which has a principal role towards amplified production of coffee. Growing coffee under shade trees is essential not only for the sustenance of coffee plantations but also for protecting the

environment in the ecologically delicate regions [4]. Lin et al. [5] reported that shade tree is essential to protect the coffee from climate extremes and water loss in the future. Higher quality of coffee beans is produced in Costa Rica, where *Arabica coffee* is grown under shade [6]. Moreover, shade trees have a role in reducing the vulnerability of households to climatic stress, pest outbreaks, falling prices/crop insurance, and food insecurity [7]. The reduction of pest abundance in shade coffee attributed to habitat complex leads to better pest control [8]. Dahlqvist [9] reported that coffee production under shade is exercised to produce coffee in a sustainable way and with least inputs of agrochemicals.

Although coffee is a shade-loving plant, it is possible to grow coffee without shade at optimal sites and with high agrochemical inputs. However, currently, such coffee shade agroforestry system got an attention by many countries because of coffee plant sensitivity to climate change and variability and also due to increasing health and environmental consciousness of people.

Adoption of different agroforestry technologies is influenced by different factors including socioeconomic, environmental, and mental processes that are governed by a set of intervening variables. Those variables include individual needs, awareness about the technology, and individual perceptions about methods used to achieve those needs [10]. Gender is also an essential variable in decision-making when adopting new agroforestry technologies [11, 12]; there is a higher likelihood of adopting high value agroforestry (HVAF) through planting tree species with timber and fruit effectiveness. Gebrelibanos [13] and Mume [14] have recognized that adoption of agricultural innovations decisions of farmers is influenced by socioeconomic, institutional, demographic, and physical characteristics.

1.2. Statement of the Problem. Most Ethiopian coffee plants grow understory of evergreen natural forest and under-managed agroforestry systems. Gobu Seyo district is in the East Wollega Zone in Ethiopia, where traditional coffee production is taking place. Coffee shade tree agroforestry practice traditionally exists at the area of coffee production system owned by many local coffee producing small-scale farmers in the study area. A lot of effort has been done since 2006 to improve its contribution to sustainable coffee production by selecting the best coffee shade tree and by introducing shade tree management techniques. In spite of its importance and the effort made by the government, there has been increasing destruction on the tree reserve due to high demand of forest products and such high deforestation rates had an impact on climate variability and detrimental effect on coffee production practice. Shade tree provides the right conditions for successful cultivation of coffee, by reducing light intensity and soil temperatures, increasing humidity, and preserving soil moisture. Prevention and rehabilitation of shade tree loss are a key issue that needs special consideration.

The success of any technology depends on its dissemination among the prospective users, which is finally measured by the level of adoption of that technology. It is to be

predictable that certain sustainable development can take place if the technology can be transferred properly. Although the strategy is launched to the area, many farmers do not adopt it fully and there are no systematic studies on coffee shade tree plantation and management practices. This study well thought of the factors that affect planting shade trees, potential benefits, and management practices of coffee shade agroforestry technology in the district.

1.3. Objectives

1.3.1. General Objective. The objective of the study was to investigate the adoption of coffee shade agroforestry technology and shade tree management practices by smallholder coffee producers in Gobu Seyo district.

1.3.2. Specific Objectives

- (i) To assess the role of socioeconomic characteristics of the household for coffee shade agroforestry technology adoption
- (ii) To examine other roles of shade trees such as environmental, economic, and social roles
- (iii) To assess shade tree management practices in the study area

1.4. Research Questions

- (i) Is the coffee shade agroforestry technology adoption affected by socioeconomic characteristics of the HHs?
- (ii) Do coffee shade trees have social, economic, and environmental values other than shading value?
- (iii) What types of shade tree management practices are applied in the area?

1.5. Significance of the Study. Coffee production dominates agriculture sector of Ethiopia in its contribution to foreign exchange and the national economy of commodity exchange [15]. Coffee also directly supports the livelihoods of more than 25% of the population in the country and is at the center of social and family life. More than 70% of global coffee is cultivated by smallholder growers in Africa, Asia, and the Americas with many of them relying on coffee as their major source of income [16]. In Ethiopia, from 1960 to 2006, mean annual temperature increased by 1.3°C [17]. Nowadays, the impact of climate variability and change is adversely affecting coffee production. The majority of Ethiopia's coffee is grown on 4 million smallholder farms. Many farmers do not have the money or resources to adapt to the changing climate. The traditional shade coffee agroforestry system is the best way to mitigate the climate impact in such resource-poor farmers, specifically the case of Ethiopia. Therefore, trying to search for the best way of doing it will contribute a lot to its better contribution and also to convincing farmers. Others also predict reduction in areas suitable for coffee production by 2050 due to climate change. To that end, such

a research on coffee shade tree agroforestry technology is a very important and urgent solution to provide realistic information to formulate policies and develop intervention mechanisms to the study area. This study also identified the factors that delay the adoption of coffee shade agroforestry technology. Therefore, the findings of this study enable the planners and extension workers in planning and implementation of programs to implement better shade coffee agroforestry technology that fits Gobu Seyo district.

2. Materials and Methods

2.1. Description of the Study Area. Gobu Seyo is one of the districts in the East Wollega Zone, which is located in the eastern part of the zone. Today, this district is subdivided into eight kebele administrations and one city center for all its administrative purposes. Anno is the capital town of the district located on the main road along with Addis at the distance of 265 km and it is located at about 65 kilometers to the east of the zonal city, Nekemte, having a total area of 383.80 km². Gobu Seyo is located at 36°53'11" to 37°03'06" east longitude and 9°01'01" to 9°20'33" north latitude. This district is adjoining with Bako Tibe district of West Shewa Zone in the east, Gudeya Bila district in the north, Boneya Boshe district in the south, and Sibru Sire district in the west. According to the Gobu Seyo agricultural office, the district is divided into two distinct geographical areas with different proportions, namely, the midland, 79.99%, having 6 rural peasant associations, and the low land, 20.01%, with 2 rural peasant associations. The general altitude range of the district is 1500 m to 1960 m above sea level; see Figure 1.

2.1.1. Climate. Most parts of the district are characterized by subhumid climatic conditions with a mean annual temperature between 13°C and 27°C and mean annual rainfall of 830 mm to 1,658 mm (Gobu Seyo agricultural office).

2.1.2. Soils. Nitisols are the most important soil in the area covering a high amount of the total cultivated land in the area. It is developed on the flat to moderately steep lower foot slope, with a slope gradient of 2 to 18%, which are marked by depth, porous solum, being well drained, and easiness to plow. Vertisols represent another of the most important soils in the area. Vertisols developed on flat to very sloping of the toe slope and found in the slope gradient of 3 to 16 percent [18, 19].

2.1.3. Population. The counted population of the district based on the population and housing census conducted in 2007 is 23,993 males, 31,433 females, with a total of 55,426. During this year, about 87.97% of the total populations are rural populations that are directly engaged in agriculture. The total HH of the district is 6309: 83.8% male-headed and 16.2% female-headed (Gobu Seyo agricultural office).

2.2. Sampling Techniques. This study relied on mixed-sampling techniques (purposive sampling and random

sampling methods). In the first stage, two peasant association (PA)/kebeles (the kebele is the smallest administrative level in the country), Sombo Kejo and Tibe Hara, were selected purposively based on their coffee production potential. In the second stage, four villages, Haro Boro and Adami Kejo from Sombo Kejo kebele and Tibe and Meti Kora from Tribe Hara kebele, were selected randomly. In the third stage, farmers having coffee farms were selected purposively from the selected villages and the sample size was determined by using formula (1). Finally, a total of 120 households (HH) were selected from those villages proportionally as indicated in Table 1 [20].

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq}, \quad (1)$$

where n is sample size, N is total number of HHs growing coffee in the selected kebeles, p is proportion in the target population ($p = 0.5$), $q = 1-p$ ($1-0.5 = 0.5$), e is marginal error considered as 5% for this study, and z is confidence level at 95% ($Z_{\alpha/2} = 1.96$).

2.3. Data Collection Methods. The study was based on a household survey and field observation conducted from December 2017 to February 2018.

2.3.1. Field Observation. The inspection was carried out in the selected villages to assess the existing situation of agroforestry systems and technologies adopted and to observe various tree species and their management techniques integrated by farmers in their farmland and coffee farming system and around their homes. Observations were to validate the collected information during the household questionnaire.

2.3.2. HH Interview. To generate both qualitative and quantitative data, sampled HHs were interviewed individually using a structured questionnaire. The questionnaire for the survey of households includes the information on household characteristics (age, sex, education level, family size, and landholding size), types of shade trees adopted, time of adoption, socioeconomic and environmental benefits of shade trees, extension activities, and others as indicated in. The data was collected by the researcher himself and enumerators (three diploma holders) after they have been given an explanation and orientation. The questionnaire was translated into the local language, Afan Oromo, for easy understanding and pretested on about 5 farmers who were not considered as respondents in the main survey.

2.4. Methods of Data Analysis. The collected data was coded and filled into Statistical Package for the Social Sciences (SPSS) version 20. Logit regression was used to identify the effects of socioeconomic characteristics of the sampled HHs on the adoption of coffee shade agroforestry technology. X^2 was used to figure out the difference between adopters and nonadopters and the differences in management activities.

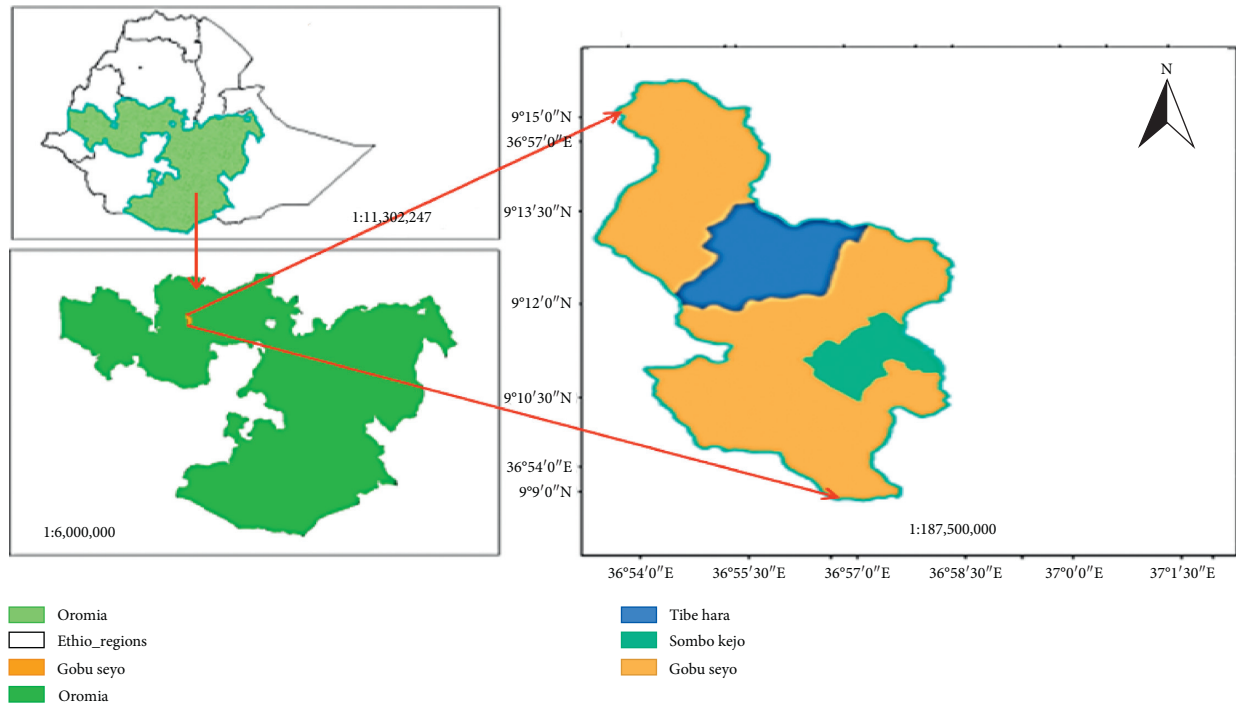


FIGURE 1: Map of study area.

TABLE 1: Proportional sample sizes and total HHs of coffee growers in the villages.

Name of villages	Total HHs	No. of coffee grower HHs	Sample size	%
Haro Boro	139	87	23	26.4
Meki Bafano	179	99	26	26.3
Tibe	233	151	37	24.5
Meti Kora	246	139	34	24.5
Total	797	476	120	25.2

Descriptive statistics, such as mean, frequency, cross-tabulation, and percentage, were also used.

2.5. Model Specification and Description of Variables. Several adoption studies in the past have widely used dichotomous choice data models such as logit and probit in trying to determine the probability of adoption and its determinants such as socioeconomic and household characteristics [21–23]. This is because they allow for a more detailed analysis of farmers’ adoption decisions on a single technology [24, 25]. Currently, there is a need for the adoption of coffee shade agroforestry technologies as a package, hence the need for analysis using the count data model. Given the assertion that over time there are more than just two identified groups (adopters and nonadopters), it is possible to have a more refined distinction of adopters. Both the logit and probit analyses specify a functional relationship between the probability of adoption and various explanatory variables [26]. To generate talented bordered probabilities within zero to one interval, a logistic cumulative distribution function was realized to apply a logit model. Like log linear regression, logistic regression is based on probabilities and odds ratios. In the case of the logit

model, the odds ratio is defined as the ratio of the odds of being classified in one category of the dependent variable for the two different values of the dependent variable. The ordered logit model recognizes unequal differences between ordinal categories in the dependent variables. That is, given a unit change in a descriptive variable, the model captures the qualitative differences between adopters and nonadopters of coffee shade agroforestry technology used, hence accounting for the categorical nature of dependent variables as well as their ordinal nature.

The dependent variable in the observed estimation is the choice of planting a coffee shade tree. While farmers adopt a coffee shade agroforestry technology, several factors can influence their decision to aspire in a technology. This section has identified the variables which determine the adoption of various technologies using binary logistic regression (Table 2). The choice of the descriptive variables is based on accessible data. The descriptive variables included household characteristics such as gender, age, education level, household size, total farm size, and area covered by coffee; institutional factors such as training and extension services were hypothesized to influence the adoption of coffee shade agroforestry technology. Of these eight variables, three were dummy and five categorical were included

TABLE 2: Relationship of training given and decided to plant shade trees ($n = 120$).

Types of training	Have you ever participated in any type of coffee production training program?		
	No	Yes	Percent
Coffee nursery management	0	10	8.3
Coffee production and management	0	65	54.2
Coffee seed preparation	0	12	10
Coffee processing and marketing	0	18	15
No training	15	0	12.5

in the model. Table 3 gives the descriptions and nature of the variables used for the judgment. Likewise, the hypothesis of how the variables influence the adoption of planting coffee shade agroforestry technology is presented in the next chapter.

2.6. Interpretation of Results of the Logistic Regression Analysis. Interpretation of the logistic regression results follows those of [27, 28], Hair Jr. et al. [29], and Pallant [30–33]. It focuses on the Wald test, coefficients, and odds ratios. The Wald test is one of the simplest ways of evaluating the contribution of individual coefficients/predictors to a model [34]. The Wald statistics are used to test the significance of individual coefficients in the model (Bewick et al., 2005; [29, 34]) if a good enough model is found [34]. The Wald statistic provides the statistical significance for each estimated coefficient for hypothesis testing to occur [35]. The Wald statistic tells us whether the β coefficient for the predictor is significantly different from zero [36]. Each Wald statistic is compared with a distribution with 1 degree of freedom (Bewick et al., 2005). Coefficients that are significantly different from zero indicate that the predictor is making a significant contribution to the prediction of the outcome (Y) [36].

Logistic regression tests the hypothesis that a coefficient is different from zero [35]. The coefficients (B) for the predictors are the natural logs of the odds ratio $\exp(B)$ [34]. The sign of the coefficient indicates whether it is increasing or decreasing as x increases [33]. Although the coefficients are similar to the odds ratio, the odds ratio is favored, because it does not require a logarithmic transformation and is easier to understand [36].

3. Results and Discussion

3.1. Basic Household Sociodemographic Characteristics. In this study, the age of the respondents lies in the range of 30–50. The majority (80%) of the HHs in the area were male-headed. In general, 75.8% of the sampled HHs were educated and only 24.2% were not educated. The average family size of the respondents in the area is 4.87 and almost all of the respondents (96.7%) were married (Table 4). The average landholdings of the farmers in the study area were 2.43 ha.

Concerning coffee area coverage, the maximum area covered by coffee was 1 hectare and the minimum is 0.015 hectares. The average area coverage is 0.28 hectares. This area coverage has a direct relationship with the total landholding of the farmers. Relatively respondents having a large hectare of total farming land have large coffee areas (Table 4).

3.2. Factors Affecting Adoption Decision of the Farmers.

Sex of the household head was found to be negatively influencing the decision of HH to adopt coffee shade agroforestry technology. The result indicated that if the household head is male, the chances of adoption of coffee shade tree decrease by the factor of 0.48 as compared to female-headed, but the result was not statistically significant (Table 5).

The effect of the age of household head on the adoption of coffee shade agroforestry technology was statistically significant at the 1% level (Table 5). The result revealed that as the age of the HH head increases the chance of adoption of the technology increases by a factor of 29.75; other factors remained constant. This implies that the older generation is more likely adopters of coffee shade agroforestry technology package as compared to younger farmers (Table 5). The reason could be the opportunity of getting information and knowledge through experience about technology. This result agrees well with other studies such as those by Kebede et al. [37], Ketema and Kebede [38], Abera [39], and Asfaw et al. [40]. Similarly, Hagos [41] found a positive influence of age on agricultural technology adoption. Conversely, Hailu et al. [42, 43] found a negative influence of age on the adoption of technology confirming that the younger age groups are adopters compared to their counterparts, the elders. The age of the head of the household can be used to capture the farming experience. Studies in Ethiopia by Kebede et al. [44] have also shown a positive relationship between the number of years of experience in agriculture and the adoption of improved agricultural technologies, while a study in [45] indicates a negative relationship between age and adoption of improved soil conservation practices. Older age is believed to be associated with access to information on improved technologies and higher productivity through experience. Therefore, farmers with older ages are more likely better to adopt coffee shade agroforestry technology.

Education was found to have positive relationships with planting coffee shade trees. This result showed that higher educational status increases the awareness of farmers about the values and benefits of the shade tree (Table 5). In the same way, the result agreed with the findings of [46] on the adoption of other technologies such as fertilizer application and [47] also observed that education of the household head positively influenced the chances of adopting improved varieties of barley and wheat. The odds ratio result shows that the education level increases the decision of the farmers to adopt coffee shade agroforestry technology by 5.01 factors (Table 5).

A higher level of education is believed to be associated with access to information on improved technologies and higher productivity [48]. Therefore, farmers with higher

TABLE 3: Description of the variables affecting the adoption of the technology.

Variables in the model	Types of variables	Description of the variable	Expected sign
Sex	Dummy	1 if male, 0 otherwise	+/-
Age	Categorical	Category 1 = age in 20–30 yrs, category 2 = age in 30–40 yrs, category 3 = age in 40–50 yrs, and category 4 = age above 50 yrs	+
Education level = Educ	Categorical	1 = none, 2 = primary, 3 = secondary, and 4 = above	+
HHcomp = HH composition	Categorical	Category 1 = member <4, category 2 = member 5–8, category 3 = member 9–12, and category 4 = member above 12	+/-
Farmsiz/total farm size (ha)	Categorical	Farmsz 1, <2; farmsz 2, 2–3.5; farmsz 3, 3.5–5; and farmsz 4, less than 5	+
Areacoff = total area of coffee (ha)	Categorical	Areacoff 1 = 0–0.11, areacoff 2 = 0.11–0.125, areacoff 3 = 0.125–0.25, and areacoff 4 = 0.25–1	+/-
Training	Dummy	1 if get training, 0 otherwise	+
Extension	Dummy	1 if access to service, 0 otherwise	+

TABLE 4: Basic HH characteristics in the study area.

	Category	Frequency	Percent
Age	20–30	21	17.5
	30–40	40	33.3
	40–50	41	34.2
	Above 50	18	15
	Total	120	100
Sex	Male	96	80
	Female	24	20
	Total	120	100
Marital status	Married	116	96.7
	Single	3	2.5
	Divorced	1	0.8
	Total	120	100
HH composition	Less than 4	47	39.2
	5–8	69	57.5
	9–12	4	3.3
	Total	120	100
Education level	None	29	24.2
	Primary	75	62.5
	Secondary	13	10.8
	Above	3	2.5
	Total	120	100
Total farm size (ha)	<2	44	36.7
	2–3.5	57	47.5
	3.5–5	16	13.3
	>5	3	2.5
	Total	120	100
The total area covered by coffee (ha)	0–0.11	20	16.7
	0.11–0.125	27	22.5
	0.125–0.25	37	30.8
	0.25–1	36	30
	Total	120	100

levels of education are more likely better to adopt coffee shade agroforestry technology.

The output of the model for farm size shows that farm size is among the major positive determinants of coffee shade agroforestry technology adoption and it is statistically not significant (Table 5). As a result, the addition of one more hectare of the land to coffee production increases the chance of planting a shade tree by a factor of 14.06; other factors remained constant. The regression result showed that

as the size of land owned by an individual increases, the probability of an individual plant shade tree would increase (Table 5). Kebede et al. [37], Ahmed [46], Shiferaw et al. [49], and Liechty et al. [50] have observed similar positive influence of farm size on the adoption of new technologies. In a different line to this finding, Amponsah et al. [38, 51] observed the negative influence of farm size with the adoption of crop technologies. Farm size is also considered as a factor that influences the adoption decisions of farmers.

TABLE 5: Logistic regression results of variables affecting coffee shade tree planting.

Adoption	β	Std. err.	Z	$P > z $	Exp (β)
Sex	-0.74	1.35	-0.55	0.58	0.48 ^{ns}
Age	3.39	1.19	2.86	0.00	29.75 ^{***}
Educ	1.61	0.91	1.77	0.08	5.01 ^{ns}
HHcomp	2.78	1.32	2.11	0.04	16.06 ^{**}
Farmsiz	2.64	1.44	1.84	0.07	14.06 ^{ns}
Areacoff	2.15	0.84	2.57	0.01	8.58 ^{***}
Training	4.27	2.07	2.06	0.04	71.33 ^{**}
Extension	2.08	1.24	1.68	0.09	7.98 ^{ns}
Constant	-22.47	7.13	-3.15	0.00	0.00 ^{***}

Number of obs = 120, LR χ^2 (8) = 121.71, $\text{prob} > \chi^2 = 0.0000$, pseudo- $R^2 = 0.8042$, and log likelihood = -14.814462. *** represents that adoption of the technology is significantly affected by $\leq 1\%$, ** is significantly affected by 5%, and ns means not significant; β is a vector of parameters to be estimated.

The relationship between farm size and technology adoption varies from country to country [52].

HH composition, the member of the family, positively and significantly influenced the adoption of coffee shade agroforestry technology at a 5% level of significance (Table 5). So this result shows that as a member of the HH increases, the adoption probability of this technology increases by the factor of 16.06; other factors remain constant. This result is in line with the findings of Kebede et al., [37] where as the family members increased, the adoption of new technology increased. Nevertheless, Ketema and Kebede [38] observed that negative relationship as family size increases the level of adoption of technology decline in the case of fertilizer application. The influence of HH composition on coffee shade agroforestry technology can be seen from two angles. The first assumption is that HH with large families may be forced to divert part of the labor force to off-farm activities in an attempt to earn income to ease the consumption pressure imposed by a large family [53]. The other assumption is that large family size is normally associated with a higher labor endowment, which would enable an HH to accomplish various agricultural tasks. Croppenstedt et al. [54] argue that households with a larger team of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages at peak times.

The area of land allocated to coffee production influenced the decision to plant shade trees on their coffee farm. Coffee production in the study area was a garden coffee production system and the farmers did not allocate a large area. The coefficient of the result implies that the area allocated for coffee production increases the decision of planting coffee shade by 8.58 factors, with other factors remaining constant. That means the area allocated for coffee has a positive relation with shade tree planting at a 1% level of significance (Table 5). This finding is in line with the findings in Ethiopia by Tura et al. [55], reported that as the portion of land allocated for maize production increases, the use of improving maize variety also increases.

Extension contact of the farmer influenced the adoption of the coffee shade tree positively but the result is not

significant (Table 5). The result of the odds ratio shows that contact of extension can raise the chance of planting coffee shade trees by the factor of 7.98, with other factors remaining constant. Access to the extension has been extensively taken into account to positively influence the adoption and continued use of agricultural technologies [56]. Yirga et al. [47] reported that extension contacts do not have significant effects on the adoption of the improved varieties of crops, suggesting that mere provision of information would add little to changing the mindset of farmers.

Access to training significantly influenced planting coffee shade trees at a 5% level. The chances of planting coffee shade tree agroforestry technology increases as the farmer gets training. The odds ratio value of the model shows that training can increase the chance of adopting technology by 71.33 factors; other factors remained constant (Table 5). This finding agreed with [47]: access to training on improved varieties of crops significantly and positively influenced the chances of adopting improved varieties of barley, potatoes, and fava beans. But Liechty et al. [50] observed that training does not significantly influence the adoption of agroforestry-based land management practice; rather, it facilitates the process.

3.2.1. Training and Extension Services. The majority of the respondents (87.5%) in the area had attended some training on coffee-based agroforestry practices, while the rest (12.5%) had not (Table 2). This means that many respondents were able to make informed choices on what they do on their farms. Those who had attended training reported having had already gained some knowledge and acquired some skills which had helped them to the made decision of adoption. This implies that regular extension contact and training for farmers are necessary because they motivate, expose, and cultivate interest and create a positive attitude towards the adoption of technology. They also had helped them to gain knowledge and information on the benefits and uses of new technology.

Extension services and different pieces of training on coffee production correspond to access to the information required to decide whether to adopt coffee shade agroforestry technology. Various studies in developing countries including Ethiopia report a strong positive relationship between access to information and the adoption behavior of farmers [53]. Frequently, the uptake of new technology is said to be subjective to the farmer's contact with extension services. Reasonable access to extension services would significantly increase adoption technology [57]. However, fine or poorly performed extension education can also be a major factor in influencing the toughness and adoption of new technology [58].

3.2.2. Total Landholding and the Total Area Covered by Coffee. The result shows that the total area covered by coffee is affected by the total landholding of the HHs (Table 6). In Ethiopia, holding size is among the most crucial assets that determine the adoption status of farmers. For example, a study by [59], on the adoption of improved wheat varieties in

TABLE 6: The relationship of total landholding of the HHs and the area covered by coffee (%).

Total farm size (ha)	The area covered by coffee (ha)				
	0–0.11	0.11–0.125	0.125–0.25	0.25–1	Total
<2	15	11.7	5.8	4.2	36.7
2–3.5	0	10	20	17.5	52.5
3.5–5	1.7	0.8	5	5.8	13.3
>5	0	0	0	2.5	2.5
Total	16.7	22.5	30.8	30	100

Northwestern Ethiopia, indicates that landholding size can affect the rate of adoption.

3.3. *Why Farmers Did Not Plant Shade Trees?* The respondents who were not planting shade trees mentioned their reasons. The reasons were lack of awareness on the values and benefits of shade tree planting, the negative response of coffee production under irrigation, and lack of large farm size (Table 7).

3.4. *Preference of Farmers on Coffee Shade Trees.* From the total respondents, 67.5% were adopters of shade trees and 32.5% were not adopters of shade trees (Figure 2). Planted shade trees in the area were mentioned as *Sesbania sesban*, *Cordia africana*, *Albizia gummifera*, and *Acacia abyssinica* and the least were *Leucaena leucocephala* preferred in consequence (Figure 2).

Shade tree selection is a difficult experience, especially for diverse, multistratum, and low-input plantations where farmers' understanding and the forces of secondary succession interact [60]. Another study confirmed that the coffee shade tree species selection is based on farmers' knowledge of the morphological, physiological (the nature of its canopy cover), and ecological features of indigenous tree species [60]. Considering these parameters, the trees identified as suitable for coffee plantations are *Albizia* sp., *Ficus* sp., *Acacia albida*, *Cordia africana*, *Leucaena leucocephala*, *Citrus sinensis*, *Sesbania sesban*, *Grevilia robusta*, *Pterocarpus marsupium*, *Cedrella toona*, *Artocarpus integrifolia*, *Artocarpus hirsute*, *Bischofia javanica*, *Erythrina lithosperma*, *Terminalia bellirica*, and so forth. It is desirable to have a mixture of all these trees in a given plantation for providing top canopy shade [61].

The preference of coffee shade trees showed that farmers' decision on tree management in their plantation based on tree characteristics such as height, crown width, leaf size, and deciduousness and litter decomposition rate [62], leaf and crown characteristics, tree height, and their impact on coffee yield [63]. The study of [64] shows that management could strongly influence the main drivers of coffee growth and yield: photosynthesis, shade temperature, or light use efficiency. Increasing the efficiency of shade management buffering with increasing temperatures could encourage stakeholders to grow coffee plantations under high coverage shade trees without pruning because; even low densities can reduce maximum daily canopy temperature without the

TABLE 7: Nonadopters' reasons not to plant shade trees ($n = 39$).

Why do you not plant coffee shade?	Percent
No awareness	10.8
It is not suitable for irrigation	5
I do not have free spaces	15
I have enough shade trees	1.7
Total	32.5

expense of high tree densities or intensive pruning of shade trees such as *Cordia alliodora* [64].

3.5. *Other Benefits of Coffee Shade Trees.* The majority of the interviewed farmers perceived other desirable benefits derived from shade trees. Some of the mentioned benefits of shade trees are fodder, firewood, timber value, construction materials, erosion control, improved soil fertility, honey bee production, and medicinal value. All shade trees are grown in coffee plantation because of the additional economic benefits that they provide to the farmers. As the respondents of the study area replied, these benefits of shade trees are ranked as in Table 8.

According to the respondents, *Sesbania sesban* was typically superior by fodder and firewood contribution: 30.8% and 26.7% of the respondents, respectively, report it. *Albizia gummifera* was superior by soil erosion control that 17.5% of the respondents were responding it and it was the only shade tree mentioned for the medicinal purpose (6.7%) in the area. *Cordia africana* was considered superior for construction materials (35%) and it was the only shade tree mentioned for timber production (15.8%) by the respondents in the area (Table 8).

Franzel and Shurr [65] assumed that planting tree species that produce high-value fruits, fodder, and timber is driven commercially, as they are deliberately planted and more intensively managed as an investment. Biggelaar and Gold [66] believed that native tree species naturally regenerated in agroforestry practices are managed less intensively but still serve multiple utilities, not only for direct consumption such as fuel and construction materials but also for ecosystem services such as shade and as windbreaks, soil fertility enhancement, and soil erosion control.

Farmers sustain trees in their coffee farms for additional functions such as fruit trees, firewood, or honey production [60, 63]. Under careful management systems, shade trees provide substantial revenue to the coffee growers in the form of timber, firewood, edible fruits, and so forth [61].

Protector makes a diverse layer of shade trees, combining natural shade trees for enhanced functional biodiversity, erosion control, carbon sequestration, soil fertility, drought resistance, and serve as a shade, with particularly useful multipurpose species such as legume trees for nitrogen fixation and wood production [67]. Shade trees provided environmental values by their forest-like structure [68]. They also have social and economic value in reducing the vulnerability of households to climatic stress, pest outbreaks, falling prices, and food insecurity. Growing coffee under shade trees allows other sources of income. These are

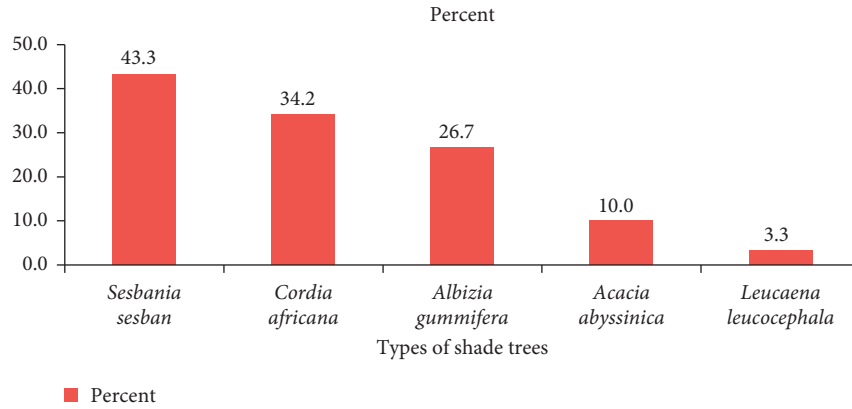


FIGURE 2: Types of shade trees planted by adopters in the area.

TABLE 8: Uses of shade trees planted by adopters in addition to shading value in Gobu Seyo district.

Uses of shade trees	No. of HHs and types of shade trees planted by adopters					%
	<i>Sesbania sesban</i>	<i>Leucaena leucocephala</i>	<i>Albizia gummifera</i>	<i>Cordia africana</i>	<i>Acacia abyssinica</i>	
Fodder	37	3	—	—	2	35
Firewood	32	1	8	—	12	44.2
Improve soil fertility	15	—	—	—	—	12.7
Fence	10	1	5	—	4	16.7
For erosion control	—	—	21	—	—	17.5
Medicinal purpose	—	—	8	—	—	6.7
Construction materials	—	—	9	42	—	42.5
Honey bee production	—	—	—	25	8	27.5
Timber production	—	—	—	19	—	15.8
Total	94	5	51	88	26	—

fruits, fuelwood, and timber; it could be also socially more acceptable, economically more viable, and environmentally more sustainable [69].

The shade trees in coffee production systems provide numerous economic and ecological benefits. Several studies have demonstrated the multiple uses of coffee shade trees and their role in soil fertility management [70, 71]. Shade trees are used for biodiversity conservation [72, 73]. For carbon sequestration [74], microclimate regulation and prevention of coffee plants from damage by frost or other extreme conditions [75] and cash income generation from the sale of timber and nontimber products [76] have been well documented.

3.6. Shade Management Practices. Farmers manage the shade tree canopy to optimize coffee production while maximizing the use of the different tree species. Concerning management practice, the responses of the farmers in the study area were identified (Table 9). Shade management options are available to improve the attractiveness of coffee systems, while simultaneously maintaining coffee output at regular and productive levels. Dead or dry weeds and the residues of pruning can be used as mulch. Mulching will reduce the number of weeds, as well as water losses by evaporation, and add soil microorganism by the decomposition process.

TABLE 9: Shade tree management practices experienced by adopters in Gobu Seyo Woreda ($n = 81$).

Managements	Frequency
Pruning	22
Mulching	10
Pruning and mulching	26
Pruning, watering, and composting	8
Mulching, watering, and composting	15

The traditional coffee management practice includes thinning of the tree canopy by purposively maintaining certain tree species in the semiforest and semiplantation coffee systems [77–79].

3.7. Socioeconomic and Environmental Benefits of Shade Trees. This section deals with the socioeconomic and environmental benefits of adopting coffee shade tree agroforestry. Most of the information on this adoption was obtained through interviews. Table 10 reveals that 67.5% of the respondents reported socioeconomic and environmental benefits of shade trees by practicing coffee shade tree agroforestry technology planting.

Among other ecological benefits, shade trees are believed to provide substantial economic benefit to coffee growers in the form of wood, firewood, edible fruits, and so forth. This

TABLE 10: Socioeconomic and environmental importance of shade trees mentioned by farmers in Gobu Seyo Woreda.

Socioeconomic benefit	No. of HHs	
	Frequency	%
House tools	28	23.3
Honey bee production	38	31.7
Source of feed for animal and human	19	15.8
Construction materials	9	7.5
Source of energy/charcoal and firewood	36	30.0
Source of medicine	8	6.7
Environmental benefit		
Improve soil fertility	68	56.7
Erosion control	79	65.8
Serve as windbreak	31	25.8
Minimize environmental pollution	70	58.3

is, therefore, a worthy compromise among an acceptable decline in coffee plant productivity and diversification of revenues from sales of timber products and fruit [4].

Shade trees reduce evaporative demand and, hence, drought stress of understory plants. Improved growing conditions and reduced drought stress in shaded conditions are observed in the coffee shade agroforestry system [68].

Leguminous shade trees have been shown to improve soil quality by the fixation of nitrogen. Pruning of leguminous species shade trees and using the cuttings as mulch improve the soil nitrogen content and minimize the crop-tree competition for light and water. The shade tree canopy can control the temperatures and the humidity levels and keep the soil water from evaporating by a cover of leaf litter [80]. A tree with a pruned crown will transpire less and thereby use less water [81].

The system is also an ideal way for the leaf and other falls of the tree shade will add to the organic matter content of the soil by contributing organic biomass to the litter [4]. Various researches discovered that trees contribute biomass (leaf litter, small twigs), which is among the essential elements of maintaining the organic matter content in the soil [4]. Various nutrients in the deep strata of soil will also be absorbed by the deep root system of shade trees and will be available to the upper layers of the soil in the form of biomass [4].

The inclusion of legume trees can improve the nutrient status of the soil [82]. This is because of symbiosis with the *Rhizobium* bacteria that provide the plant with nitrogen taken from the atmosphere [83, 84]. Trees have been shown to improve soil fertility through better nutrient cycling, since their roots go deep down in the soil and reach nutrients that may not be accessible to the coffee plants [85].

Shade trees help to minimize the erosive power of rainfall by acting as a physical barrier in reducing the intensity of the rain reaching the ground. They also help in the deep infiltration of rainwater because of their deep rooting system; this in turn will contribute to the recharging of groundwater [4]. Shaded plantations are also well protected against drought effects. The cool temperature above the coffee bushes, due to shade, ensures that the loss of soil moisture through evaporation and transpiration is minimized. Moreover, the shaded plantations being rich in soil

organic matter retain moisture for longer periods during dry months when compared to open conditions [4].

4. Conclusion and Recommendation

4.1. Conclusion. The adoption of coffee shade agroforestry technology has to pay a considerable awareness of researchers and policymakers. While farmers adopt new technology, several factors can influence their decision to choose technology. This study has been dedicated to analyzing the factors influencing the adoption of agroforestry technologies. An agroforestry technology may considerably increase yields or agricultural productivity when it has been adopted. It also solves the problem of livelihood and adds economic and environmental benefits. It also supplies many benefits to the farmers including the source of income, for different house tools, source of foods, source of fuel/firewood and charcoal, for construction materials, source of fodder, for medicinal purpose, for erosion control, and soil fertility enhancement. However, the introductions of the technology have met with only partial success, as measured in observed rates of adoption.

Coffee shade agroforestry technology was important to diversify the agricultural products and to solve the problems related to deforestation by increasing the land cover system. Particularly, it is the land use system that was recommended in the area, to minimize high temperature that negatively affects the coffee production system.

4.2. Recommendation. Based on the findings of this study, the following statements were recommended:

- (i) Since this agroforestry technology has the potential to provide economic, social, and environmental benefits that are capable of solving the problem of household income, livelihoods and food insecurity, and environment-related challenges, different pieces of training should be prepared and given to the farmers to develop their awareness on the technology.
- (ii) To guarantee endorsement of the extension of coffee shade agroforestry technology, the rural households must participate in pieces of training to improve their productivity and maximize the benefits of coffee shade agroforestry technology.
- (iii) Further research is needed for detailed assessments of shade tree management activities basically on coffee productions under irrigation systems.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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