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Farmer perceptions toward the adoption of agroforestry practices: a case study of northwestern Ethiopia

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Introduction: Despite several reports emphasizing the role of agroforestry in enhancing rural livelihoods, promoting sustainable development, protecting the environment, and supporting climate change mitigation and adaptation, little is known about rural households' perceptions of the different benefits of agroforestry and the extent of adoption of its different agroforestry technologies, including contour farming with tree planting, alley cropping, woodlot and timber production, integration of fruits, nuts, medicinal trees, home gardens, fruits on farmland, boundary cropping, and live fences. Therefore, this study aimed to examine farmers' perceptions and adoption of agroforestry practices as well as the factors influencing these actions in the Banja district of Northwestern Ethiopia.

Methods: A cross-sectional research design was conducted in three kebeles of the Banja district, encompassing a sample of 340 households. The study employed a quantitative and qualitative approach, with multi-stage sampling technique results employed to select sample households using a binary logit model.

Result and discussions: The study found that 59% of respondents perceived agroforestry as advantageous, with 91.57, 75, and 60.5% recognizing its benefits for farm productivity, household income, and food security, respectively. The remaining 41% of sample households were not perceived. Approximately 56% of the respondents adopted different agroforestry practices, mainly live fences and taungya. The results of the binary logit model indicated that the adoption of agroforestry practices was influenced by factors such as sex, educational status, access to extension services, family size, soil fertility, farmland size, and slope of farmland. In contrast, age, distance to farmland, land tenure, livestock size, farm experience, and market distance were not significant. The study recommends that extension workers should strengthen rural education, improve extension services, focus on soil fertility through soil and water conservation practices, and ensure sustainability through regular monitoring, evaluation, and implementation of diverse agroforestry practices, thereby ensuring environmental sustainability and improving livelihoods at the household, community, and national levels.

KEYWORDS
adoption, perception, agroforestry practice, Banja District, Ethiopia

Background of the study

Globally, agroforestry is not a new practice because it has been used by farmers worldwide since ancient times (Jamala et al., 2013; Alemu, 2016). Agroforestry contributes to rural livelihoods and improves socioeconomic status and ecosystem function in land use (Kalaba et al., 2010; Zomer et al., 2016; Tiwari et al., 2017). Agroforestry promotes global climate change mitigation (Ghimire et al., 2024; IPCC, 2019), sustainable development (Oelbermann and Smith, 2011; Eshete et al., 2020; Barasa et al., 2021; Mungai et al., 2021), and conservation (Duffy et al., 2021; Nair et al., 2021; Sudomo et al., 2022). Agroforestry is a sustainable agricultural practice with the potential to contribute to sustainable development goals (Wanjira and Muriuki, 2020, Tebkew et al., 2024). Governmental and non-governmental organizations, academic institutions, and private enterprises are attempting to increase the advantages of agroforestry, and a better knowledge of the various hurdles to adoption is required (Bettles et al., 2021).

In developing countries, large segments of the continually growing population continue to rely on agricultural and forest products for a living (Chao, 2012). Trees growing on farmland have economic advantages and contribute to the sustainable utilization of natural resources in terms of providing an opportunity for the production of fodder, fuelwood, timber, medicine, and food, which otherwise might be taken from the forest (Lelamo, 2021). Furthermore, agroforestry practices and services could support the simultaneous achievement of agricultural sustainability and increased productivity, leading to enhanced economic, environmental, and social benefits as well as climate change resilience in sub-Saharan Africa (Getnet et al., 2023; Tega and Bojago, 2023; Awazi et al., 2022).

Large percentages of the Ethiopian population (80%) depend on agriculture for their livelihoods and contribute 42–45% of the total gross domestic product of the country (Oshora et al., 2021; Hausmann et al., 2023); however, agricultural production is currently at risk due to several factors. Among them, climate change, land degradation in the form of soil erosion, soil fertility loss, and severe soil moisture stress are partly the result of the loss of trees in their field and organic matter (Difalco et al., 2012; Mekonnen et al., 2021). Hence, tremendous efforts have been made to address these problems with the integrated conservation of natural resource management (Gebrewahid and Meressa, 2020; Getnet et al., 2023). Therefore, the adoption of agroforestry systems has the potential to address pressing issues such as rapid population growth, deforestation, and environmental degradation (Banyal et al., 2015; Amare and Darr, 2023; Hintz and Pretzsch, 2023). Despite these potential benefits, the adoption of agroforestry has not been widespread (Mbow et al., 2014).

In Ethiopia, agroforestry practices are a major source of livelihood, particularly for the rural and urban poor, as they enhance farmers' living standards by providing food and fuel and by improving the fertility of agricultural land (Shonde, 2017; Jiru et al., 2020; Cheru and Hailu, 2023). However, they have faced continued deforestation and forest degradation problems over the past three millennia (Yirdaw et al., 2017). The main causes of deforestation and forest degradation are agricultural land expansion, logging, overgrazing, fires, and illegal settlement (Tafere and Nigussie, 2018; Tesfaye et al., 2020). Various researchers have studied farmers' perceptions and adoption of agroforestry practices in different parts of Ethiopia (Mulu, 2009; Tafere and Nigussie, 2018; Arage, 2021; Tega and Bojago, 2023; Tebkew et al., 2024). However, these studies focused not only on the contributions of agroforestry practices but also on farmers' perceptions and determinants of the adoption of agroforestry practices. Likewise, previous studies have been limited in geographical coverage, and the roles of agroforestry practices are essential for every part of Ethiopia. Thus, this study was conducted in the Banja district, Amhara Region, Northwestern Ethiopia.

For instance, Alelign et al. (2011) studied socioeconomic factors impacting agroforestry in the Zegie Peninsula, northwestern Ethiopia; however, the author did not consider other factors, such as biophysical, institutional, and demographic factors affecting the adoption of agroforestry practices. In addition, a study conducted by Agidie et al. (2013) on agroforestry practices and farmers' perceptions in the Koga watershed, upper Blue Nile basin, Ethiopia, showed that homestead agroforestry practices are widely practiced. However, the authors did not identify farmer adoption and the determinants of agroforestry practices, and they did not use an advanced econometric model rather than simple descriptive statistics. Anjulo and Mezgebu (2016) also indicated the determinants of agroforestry practices in the Fogera District, Ethiopia, while the authors did not address farmers' perceptions of agroforestry practices. More recently, Tega and Bojago (2023) conducted a study on farmers' perceptions of agroforestry practices, contributions to rural household farm income, and their determinants in the Sodo Zuria District, Southern Ethiopia. Similarly, Tebkew et al. (2024) showed the contribution of agroforestry practices to the income and poverty status of households in Northwestern Ethiopia. However, nowadays, agroforestry practices have not been addressed in all parts of Ethiopia, because these issues are vital for biodiversity conservation and improving rural livelihoods. As a result, this study aimed to address the gaps mentioned above by assessing farmers' perceptions, adoption, and determinants of agroforestry practices in Banja District, Northwestern Ethiopia.

Materials and methods

Description of the study area

Location

This study was conducted in the Banja District of the Amhara Regional State in Northwest Ethiopia. It is located at 10^{0} 40′0″ to 11^{0}0′0″ North latitude, and 36^{0} 40′0″ to 37^{0} 10′0″ East longitude, and an altitude of 2,541 m above sea level (ASL). It is found in the Northwest of Addis Ababa and is far away, 440 km and 120 km southeast of Bahir Dar. It is bounded by Guangua District in the West, Fagita District in the North, Guagusa Shikudad and Sekela Districts in the East, and Fagita and Guangua Districts in the South. It is one of the nine districts of the Awi Administrative Zone, established in 1985, with 27 *kebeles*[1] (Figure 1).

Topography and soil characteristics of the study area

The topography of the district is mountainous (30%), plains (52%), and depressed (18%). The Banja district is a cool highland, and the parent material is composed of volcanic rock and quaternary

1 Kebele is the lowest administrative system in Ethiopia.

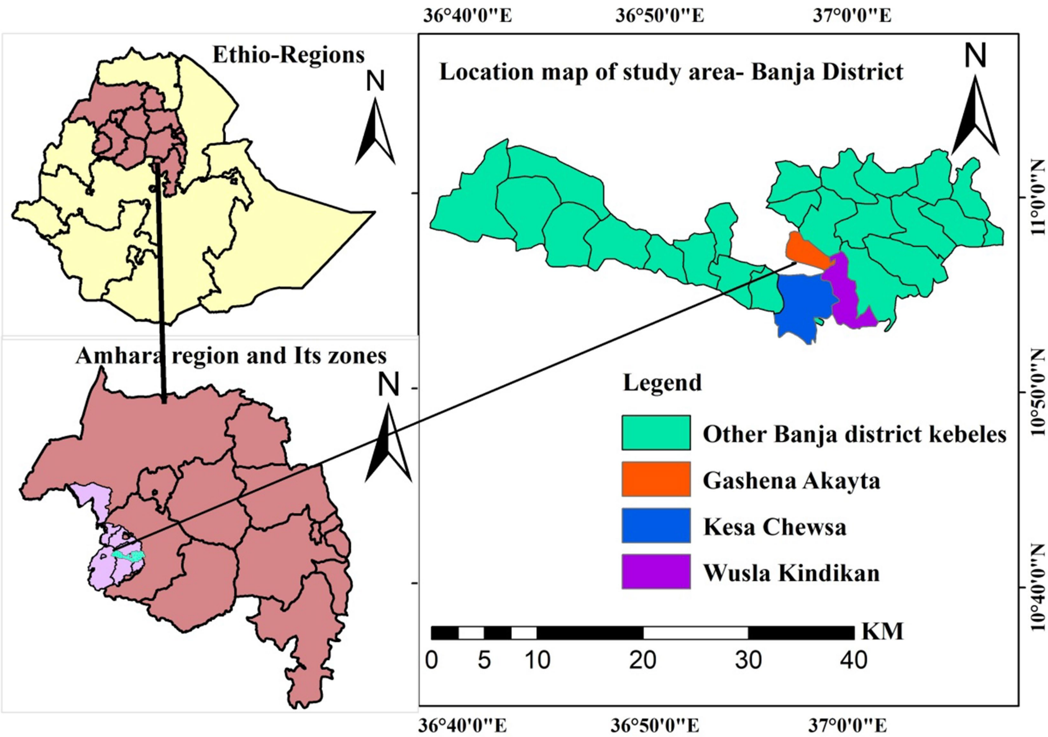

FIGURE 1
Location of the study area. Source: own extraction from Ethiopian map shape file (2018).

basalts. Three major soil types were identified: Andisols, Nitosols, and Cambisols (BDAO, 2024). Generally, the soil types in the study area are characterized by shallow, moderate to deep, and very deep depths and sandy clay to clay texture types.

Climate and agro-ecology conditions of the study area

According to the local agro-ecological classification system, which mainly relies on altitude and temperature, the study area is characterized by Woina Dega (midland) and Dega (highland). However, the tropical climate is modified by altitude. According to the Awi Administrative Zone Agriculture Office rainfall data, the district receives an average rainfall of 1,215 mm, and it has minimum and maximum temperatures of 9.4°C and 26°C, respectively (BDAO, 2024).

Land use and vegetation cover

The district has an area of 80,318 hectares; out of this area, 21,685 ha (27%) is farmland, grazing land is 25,300 ha (31.5%), and others covered 13252.47 ha (16.5%) (BDAO, 2024). The vegetation type falls under the dry Afromontane Forest. The study area was dominated by *Albizia gummifera*, *Croton macrostachyus*, *Prunus africana*, and *Apodytes dimidiata*. The lower-altitude class (1850–2,100 m), revealed strong dominance of *Albizia gummifera,* followed by *Croton macrostachyus*. In the middle altitude class (2100–2,350 m) *Prunus africana* and *Apodytes dimidiata* species were found, while *Juniperus procera* and *Ekebergia capensis* were found sparsely with undergrowth shrub species in the higher altitude. The area of the district is 4,966.54 ha, which is under state forestland and has an elevation range between 1870 and 2,570 m ASL. Most of the Banja District's land is covered with vegetation and indigenous trees, such as higher trees, riverine trees, small trees, shrubs, and ground cover grasses (Abere et al., 2017).

Population and agricultural and economic activities

The total population of the district is 188,045, of which 95,409 are males and 92,636 are females (BDAO, 2024). The district is potentially rich, particularly in farming practices. The district has different agro-climatic conditions, highland, midland, and lowland, which are suitable for the production of cereals and horticultural crops. As a result, the livelihoods of rural people depend on both cereal crops and cash. According to the District Agricultural and Rural Development Office, households are primarily dependent on small-scale rainfed agriculture for their livelihoods. The major crops grown in this area are cereals, potatoes, roots, and pulses. In addition to crops, major livestock, such as cattle and sheep, and other pack animals, such as horses and mules, are also reared (BDAO, 2024).

In Banja District, demographic and cultural profiles are shaped by the agricultural base, ethnic composition, and traditional practices, with a significant focus on community cooperation and religious observance, while also facing contemporary challenges such as climate change, land degradation, and infrastructure development. Traditional agricultural practices, including agroforestry, are important for the community's livelihood and environmental sustainability. As part of the broader Amhara region, the people of the districts celebrate major Ethiopian Orthodox Christian holidays, such as Timkat (Epiphany), Meskel (Finding of the True Cross), Genna (Ethiopian Orthodox Christmas), and the secular New Year (Enkutatash).

Research design and sampling procedure

This study employed a cross-sectional research design; that is, the data were gathered from households at one point in time only. This study employed a household survey as a research strategy and mainly used a quantitative approach complemented by a qualitative approach. A multi-stage sampling technique was employed to identify the sample households in the study areas. In the first stage, the Banja district was selected purposively from the nine districts of the Awi zone because of the existence of a larger coverage of agroforestry practices in farmlands. In the second stage, sample kebeles were selected using random sampling. Finally, simple random sampling was used to select respondents from the three kebeles from a total of 2,300 households of the three kebeles, and 340 households were selected for this study.

The total number of households in the three kebeles was 2,300 households, which was used to determine the sample size of the study. Yamane's (1967) formula was used to determine the sample size of the study. The required sample size was at a 95% confidence level (Table 1).

$$n = \frac{N}{1 + N\left(e^2\right)} : \frac{2300}{1 + 2300\left(0.05^2\right)} = 340.$$

Where N = is the population size of three kebeles.

n = is the sample size.

e = the level of precision at 5%.

Methods of data sources and collection

This study used both primary and secondary data sources. Primary data were obtained from specifically selected households in the study area. This study focuses on farmers' perception, adoption, and determinants of the adoption of agroforestry practices. Thus, this study employed a structured interview schedule method to collect data, along with key informant interviews and focus-group discussions. Nine key informant interviews and three focus group sessions were conducted for each kebele. The number of participants in focus group discussants (FGD) in one group for each kebele was 9 members.

Secondary data were collected from different organizations and institutions from kebeles to the zonal level regarding the farmers' agroforestry practices and related factors affecting the adoption of agroforestry practices. This office provides information related to the total number of households in the district and the types and benefits of agroforestry practices in the study area.

Methods of data analysis

Farmers' perceptions on agroforestry practices

This study used a combination of data analysis methods to obtain quantitative and qualitative data. Quantitative data were coded and entered into the statistical software (STATA, version 14). Data collected from key informant interviews and focus group discussions were qualitatively narrated. Farmers' perceptions of agroforestry practices were analyzed using descriptive statistics in terms of percentages, frequencies, and Likert scales. The Likert scale is the most common measure of perception (Harpe, 2015). There are different points on the Likert scale, such as three points, five points, seven points, and more. There is no specific rule on whether to use a three-point scale or a scale with more points. In practice, three-to-seven-point scales are generally used because more points on a scale provide an opportunity for greater sensitivity of measurement (Kothari, 2004). Dibaba et al. (2018) used a five-point Likert scale to know farmers perceptions toward improved chickpea and agroforestry technologies, respectively. This study used a three-point Likert scale, as follows: (1) agree, (2) disagree, and (3) neutral.

Adoption of agroforestry practices

Adoptions for agroforestry practices were analyzed using descriptive statistics such as percentage, frequency, mean, and standard deviation. Inferential statistics, such as the *t*-test and the chi-square test, were also used. An independent t-test was used to verify the presence of significant mean differences between adopters and non-adopters in terms of continuous independent variables, such as age, family size, landholding, farming experience, and distance from the forest to the respondent's residence. The chi-square ($\chi 2$) test was used to test the presence of a significant percentage difference between adopters and non-adopters in terms of categorical independent variables, such as sex, education level, soil fertility, slope, and marital status. The dependent variable is dichotomous, which means adopters and non-adopters are groups in agroforestry practice.

Determinants of adoption of agroforestry practices

To assess the factors affecting the adoption of agroforestry practices, a binary logit model was employed. The adoption of agroforestry practices is the dependent variable, which has a binary outcome (adopter or non-adopter) and is expected to affect various explanatory variables. The binary logistic regression model is econometrically specified as follows: where *pi* denotes the probability

TABLE 1 Sample size selected from sample kebeles.

Kebeles	Numbers of HHs	Proportions sample
Wusla–Kindikan	720	720*340 = 107
Kesa–Chewsa	800	800*340 = 118
Gashena–Akayta	780	780*340 = 115
Total	2,300	340

TABLE 2 Results of continuous variables for adoption of agroforestry practice.

Variable	Adopters (n = 151)		Non-adopters (n = 189)		Mean difference	t-value	p-value
	Mean	Std dev	Mean	Std dev			
Age	55.074	12.133	52.76	11.92	−2.31	−1.75	0.079
Family size	5.698	1.409	4.64	1.29	−1.058	−7.14	0.000***
Farmland size	1.56	0.70	0.885	0.50	−0.675	−9.974	0.000***
Farm experience	26.30	9.83	25.28	8.23	−1.022	−1.022	0.307
Distance from home to farm	1.223	0.654	1.31	0.577	0.864	1.27	0.20
Extension services	8.76	2.93	6.79	2.79	−1.73	−5.55	0.000***
Total livestock	2.906	1.63	2.10	1.46	−0.797	−4.671	0.000***
Market distance	0.948	0.62	1.00	0.55	0.061	0.94	0.346

*, **, and *** are significant at 10, 5, and 1%, respectively.

of adopting agroforestry practices, that is, Yi = 1, and exp. (Zi) stands for the irrational number e to the power of Zi.

The model can be written as

$$Pi = E\left(Y = 1|xi\right) = \frac{1}{1+e^{-(\beta 0+\sum \beta 1X1)}} \quad (1)$$

For the case of explanation, we write (1) as

$$Pi = \frac{1}{1+e^{-Zi}} \quad (2)$$

The probability that a given household adopting agroforestry practices is expressed by (2), while the probability of households not adopting agroforestry practices is expressed by (3).

$$1 - Pi = \frac{1}{1+e^{Zi}} \quad (3)$$

Therefore, we can write

$$\frac{Pi}{1-Pi} = \frac{1+e^{Zi}}{1+e^{-Zi}} \quad (4)$$

$\frac{Pi}{1} - Pi$ Indicates the odds ratio in favor of adopting agroforestry practices. This means it is the ratio of the probability that a household adopting agroforestry practices to the probability of a household not adopting agroforestry practices.

Where:

Pi = probability of non adopting agroforestry practice ranges from 0 to 1 .

Zi = Fanction of n explanatory variables (x) .

β° = An intercept .

$\beta 1, \beta 2 \ldots, \beta n$ = Slope of the equation in the model .

Xi = vector of relevant household characteristics .

Results and discussion

Demographic and socio-economic characteristics of the respondents

Descriptive analysis of continuous variables

As presented in Table 2, the continuous variables for the adoption of agroforestry practices are discussed. The household head had a mean age of adopters and non-adopters of agroforestry practices of 55.07 and 52.76, respectively. Likewise, the average family sizes of adopters and non-adopters were 5.69 and 4.64, respectively. With regard to farmland size, the average farmland size for adopters and non-adopters was 1.56 ha and 0.885 ha, respectively, with a significant difference at the 1% level. The means of extension services among adopters and non-adopters were 8.53 and 6.79, respectively. With regard to the Total Livestock Unit,[2] adopters own more livestock (2.96 Tropical Livestock Units [TLU]) than non-adopters by a mean value of 2.96 and 2.1, with a significant difference at the 1% level. Moreover, these findings suggest that larger family size, more farmland, greater access to extension services, and higher livestock ownership are associated with the adoption of agroforestry practices.

Descriptive analysis of categorical variables

The descriptive analysis of the categorical variables of the adoption of agroforestry practices is presented in Table 3. In terms of sex, male-headed households adopted agroforestry practices at a rate of 80.95%, while female-headed households adopted them at 19.05%. Regarding the educational status of the households, 43.92% of adopters and 20.53% of non-adopter households were literate, while 36.83% of the adopters and 79.47% of non-adopter households were illiterate. Among the marital status of the respondents, 25.4 and 74.6% of married and unmarried households adopted agroforestry practices,

2 TLU standardizes different types of livestock into a single unit of measurement. The conversion factor adopted is 0.7 cattle; 0.6 donkeys/horses; 0.1 sheep and goat; 0.01 poultry (Tibebu et al., 2018).

TABLE 3 Results of categorical variables for adoption of agroforestry practice.

Variable definition		Adopters (189)		Non-adopters (151)		Total		X^2-test	*p*-value
		Freq	%	Freq	%	Freq	%		
Sex	Male	153	80.95	96	63.58	249	73.24	12.92	0.000***
	Female	36	19.05	55	36.42	91	26.76		
Educational status	Literate	83	43.92	31	20.53	114	33.53	20.596	0.000***
	Illiterate	106	36.83	120	79.47	226	66.47		
Soil fertility	Fertile	176	93.12	99	65.56	275	80.88	41.22	0.000***
	Unfertile	13	6.88	52	34.44	65	19.12		
Slope of farmland	flat	140	74.07	76	50.33	216	63.53	20.422	0.000***
	gentle	49	25.93	75	49.67	124	36.47		
Marital status	Married	48	25.40	61	40.40	109	32.06	8.67	0.006***
	Unmarried	141	74.60	90	59.60	231	67.94		
Land tenure issues	Secured	88	46.56	69	45.70	157	46.18	0.02532	0.874
	Not secured	110	53.44	82	54.30	183	53.18		

*, **, and *** are significant at 10, 5, and 1%, respectively.

TABLE 4 Farmers' perception on agroforestry practices.

Statements agree disagree neutral						
	Freq	%	Freq	%	Freq	%
Increase farm productivity	183	91.57	16	8	1	0.5
Increase household income	150	75	30	15	20	10
Enhance food security	121	60.5	29	14.5	50	25
Increase cash crop production	103	51.5	94	47	3	1.5
Difficult to practice	98	49	95	47.5	7	3.5

respectively. In terms of soil fertility of the farmland, adopters of agroforestry practices (93.12%) had more fertile soil than non-adopters (65%), while fewer agroforestry adopters (6.88%) lacked fertile soil compared to non-adopters (34.44%). With regard to the slope of the farmland, the study areas were 74.07% for flat slopes and 25.93% for gentle slope adopters of agroforestry practices, whereas 50.33% were flat and 49.67% were gentle non-adopters of agroforestry practices.

Farmers' perception on agroforestry practices

Farmers' interest in adopting new agroforestry technology is influenced by their perceptions of agroforestry practices; thus, assessing their attitudes and understanding, including awareness and knowledge, is crucial. According to Cheru and Hailu (2023) and Amare et al. (2019) the perceptions of respondents were measured by their level of understanding of the importance of different types of agroforestry practices, such as home-garden agroforestry, fruit on farmland, boundary cropping, and live fence. Based on the survey results, 58.82% of the sample households perceived agroforestry practices, whereas 41.18% did not perceive agroforestry practices. More specifically, the results indicated that farmers' perceptions of agroforestry practices were specified as a means of increasing farm productive values (91.57%), household income (75%), food security (60.5%), cash crop production (51.5%), and difficulty in practice (49%). According to key informant participants in the Kesa Chewsa kebele, agroforestry boosts farm productivity by satisfying farmers' essential needs for firewood, fruits, fodder, lumber, and vegetables, while also recognizing the economic benefits of agroforestry as a crucial source of household income. In addition, farmers viewed agroforestry as playing several protective duties, such as soil and water conservation, erosion, flood control, and also the respondents perceived agroforestry as a means of food security, while other respondents perceived agroforestry as increasing the production of cash crops. It is noteworthy that the respondents opined that agroforestry is difficult to practice, which is an indication of a lack of knowledge (Table 4). This result aligns with the findings of Saha et al. (2018) and Arage (2021), who found that farmers perceive agroforestry practices as substantial to meeting their basic needs in terms of fuelwood, fruits, fodder, timber, and vegetables.

During the FGD discussion from the three sample *kebeles* on the issues of agroforestry practices, participants elaborated that agroforestry is important for shading purposes, improving soil fertility, and reducing erosion. Similarly, one key informant from kessa chewsa kebele said that agroforestry is important for soil fertility improvements and filling the gap in forest product demand. A majority of the farmers were aware of agroforestry practices and technologies, but they did not practice agroforestry. This is due to different factors such as bio-physical, demographic, institutional, and socioeconomic factors. A study by Mekoya et al. (2008) and Alelign et al. (2011) showed that agroforestry practices are affected by biophysical and socioeconomic factors other than awareness and perception values.

Adoption on agroforestry practices

Of the 340 total respondents, 189 (55.6%) and 151 (44.4%) adopter and non-adopter households, respectively, adopted agroforestry practices. This implies that majority of the respondents were adopters of agroforestry practices in the study area (Figure 2).

Types of agroforestry practices

The results of the study revealed that, of the 340 respondents, 189 respondents adopted agroforestry, the majority of respondents adopted live fence agroforestry practices (95.2%), followed by scattered trees (68.8%), home gardens (60.8%), boundary planting (55.03%), and Taungya (50.8%), as shown in Figure 3.

In addition to increasing current agricultural productivity, agroforestry can provide sustainable agriculture by promoting and practicing integrated and bio-diverse processes (Wilson and Lovell, 2016). This is because agroforestry can combat various environmental problems to assist farmers in maintaining soil fertility; ensuring diversification of crop, wood, and timber species per unit area; and stabilizing, improving, and conserving farmers' environments (Arage, 2021). Therefore, the level of agroforestry adoption by farmers, is very important because it determines their livelihoods. The main reason for the high level of adoption was the multiple benefits the farmers gained from the crop-tree combination, and agroforestry has been an age-long practice among local farmers not only in the study area but all over the country (Tafere and Nigussie, 2018). However, the success of agroforestry practices is determined by farmers' level of adoption of agroforestry (Saha et al., 2018).

Furthermore, this finding from the focus group discussants (FGD) in all three kebeles showed that agroforestry practices play many roles in sustaining better life by providing shading, controlling erosion, fuelwood, and improving soil fertility. Moreover, based on the key informants in all three sample kebeles, agroforestry adopters mentioned that they have been obtaining diverse types of benefits from their agroforestry practices such as poles, timber, and fuel wood, acting as windbreaks to reduce the effects of strong winds on plowed fields, animal shedding, crops from being flattened, cultural and esthetic, value, beatification, and reduced farmland boundary conflict in the study area. This result is similar to that of Tega and Bojago (2023). Similarly, Edo et al. (2024) stated that agroforestry practices contain diverse species of annual and perennial crops that have ecological, social, and economic benefits.

On the other hand, the main problems of adoption of agroforestry practices were discussed and presented in Table 5. Thus, lack of cultivated land (78.24%), pests and diseases (72.35%), lack of seed supply (57.06%), market access (44.71%), inadequate infrastructure (41.47%), and competition of crops for light and water (41.37%) were the most prominent challenges of adoption of agroforestry practices in the study area. This result is in line with Pathania et al. (2020), who reported that a small landholding size was the most important problem perceived by farmers. Moreover, during key informants and focus group discussions, farmers identified and listed different adoption problems currently limiting agroforestry development in all

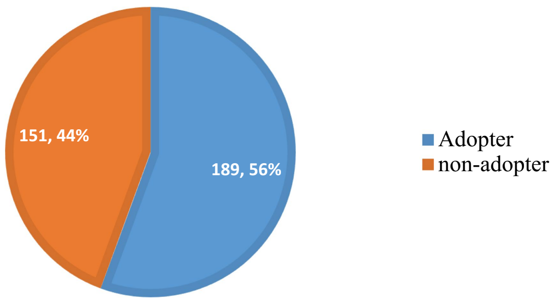

FIGURE 2
Agroforestry adoption level in the study area.

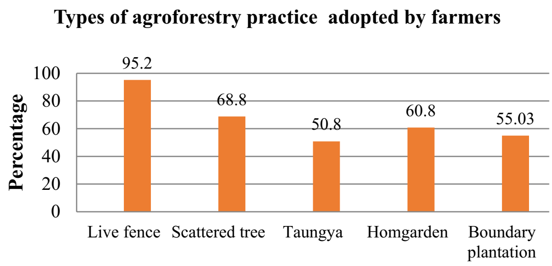

FIGURE 3
Types of agroforestry practices adopted by farmers in the study area.

TABLE 5 Major problems of adopting agroforestry practices.

No	Reason	Frequency	Percent (%)
1	Lack of supply seed	194	57.06
2	Pest and disease	246	72.35
3	Inadequate infrastructure	255	41.47
4	Competition of crops for light and water	141	41.37
5	MARKET access	152	44.71
6	Lack of cultivated land	266	78.24

three kebeles, highlighting that they were a shortage of land for cultivation, and pests and diseases were also big threats to adopting agroforestry practices next to lack of land.

Determinants of adoption of agroforestry practices

The determinants of agroforestry practice adoption were identified using a binary logit model. Before running the model, the presence or absence of multicollinearity issues was checked. The variance inflation factor (VIF) was applied to test for the presence of a strong multicollinearity problem among the continuous explanatory variables, whereas the contingent coefficient was used to test for categorical variables. As a rule of thumb, the VIF value should be less than 10 in the absence of multicollinearity. Accordingly, the mean VIF value was 1.44 (See Appendix A), which is less than 10, and the contingent coefficient (CC) evaluation also confirmed that there were no multicollinearity problems among categorical variables. As a rule of thumb, the CC value should be less than 0.75 in the absence of a multicollinearity problem. The values of the contingency coefficient range between 0 and 1, with 0 indicating no association between the variables and values close to 1 indicating a high degree of association. An association was considered high when the value was greater than 0.75. Hence, all discrete variables were entered into the logit analysis. Finally, no explanatory variable dropped from the estimation model because there was no multicollinearity problem (See Appendix 1 A,B).

A model goodness-of-fit test is essential to conduct confidentially in the future study. Pearson and Hosmer-Lemeshow tests were used to observe the fitness of the model. Thus, the model fits well, as shown in (See Appendix 2). The Hosmer–Lemeshow test was 0.0907, which shows a failure to reject Ho. The binary regression model PROB > chi2 was 0.0000, implying that the model is a good fit at less than 1% or the adoption of agroforestry practices in the study area is expressed by the explanatory variables included in the model.

The determinants of the adoption of agroforestry practices by rural households are provided in Table 6. Among the 14 variables included in the model, 7 significantly affected the adoption of agroforestry practices by smallholder farmers. These are sex of household head, educational status, frequency of extension services, soil fertility, farmland size, family size, and slope of farmland, which showed a significant and positive effect on the adoption of agroforestry practices. Of these variables, except for the gender of households, all significant variables positively affect the adoption of agroforestry. The gender of the variable was coded as 1 if female and 0 if male. The negative sign in the model implies that being female reduces the probability of adopting agroforestry practices, because male (0) is used as the base variable.

Sex of household head (sehh)

The sex of the household head negatively and significantly influenced the adoption of agroforestry practices at a 1% significance level. The estimated coefficients and odds ratios were − 1.668 and 0.189, respectively. This means that compared to male-headed households, female-headed households are less likely to adopt agroforestry practices by an odds ratio of 0.189. A possible explanation for is that male-headed households have better access to farmland, labor, agricultural technologies, and improved practices, all of which foster the adoption of agroforestry practices. Due to a lack of these resources, female-headed households are forced to provide their lands (if they have them) for sharecropping rather than adopting agroforestry practices, which confirms the prior expectation that male-headed households are more involved in agroforestry practices because males have more access to technology, information, and extension services than female-headed households.

In addition, information gained from key informants and focus group discussion (FGD) revealed that the major problem for women to participate actively in agroforestry practices was their multiple responsibilities in their household, such as childcare, fetching water, cooking food, and traveling long-distance to markets to purchase food non-food items necessary for the family. This result is in line with Duguma et al. (2019), who reported that women are commonly busy with household activities, and their prime responsibility is usually child-rearing.

Family size of household head (famszhh)

The model revealed that family size was significant at the 1% level and was positively related to the adoption of agroforestry practices; the coefficients and odds ratios of the variables were 0.418 and 1.519, respectively (Table 6). This implies that when other factors remain constant, as the family size of the households increases by one person, the probability of adopting agroforestry practices increases by a factor of odds ratio 1.519. The possible justification for this would be that more family members in the households are important labor sources, and agroforestry practices also need more labor for their implementation. As a result, it is not surprising that households with larger families adopt agroforestry and vice versa. A large family size means a high availability of labor (Beyene et al., 2019).

Educational status of household head (edlhh)

The model revealed that the education level of the household head was significant at the 1% significance level and positively related to the adoption of agroforestry practices. The coefficients and odds ratios of the variables were 1.244 and 3.467, respectively. The odds ratio is an indicator of the probability that farmers with better education would be more likely to adopt agroforestry, which would increase by a factor of 3.467

TABLE 6 Binary logistic regression estimates for the adoption of agroforestry practice.

Variable	Coef.	Std. Err.	*Z*-value	*p*-value	Odds ratio	dy/dx
Sex	−1.668042	0.5029729	−3.32	0.001***	0.1886161	−0.3437914
Age	0.0199618	0.01821332	1.10	0.273	1.0201662	0.0047717
Family size	0.4181134	0.1388209	3.01	0.003***	1.519093	0.0999467
Education	1.243571	0.3920467	3.17	0.002***	3.467974	0.2755684
Farm size	1.733549	0.2771226	6.26	0.000***	5.66071	0.4143913
Experience	−0.0128106	0.0246464	−0.52	0.0603	0.9872712	−0.0030623
Distance to farm	0.4027935	0.2921019	1.38	0.168	1.495998	0.962846
Extension	0.12266947	0.0514777	2.38	0.017**	1.130539	0.0293292
Soil fertility	1.613557	0.4296739	3.76	0.000***	5.020638	0.3824066
Land tenure	0.2919525	0.3249063	0.90	0.0369	1.339039	0.0695176
Slope of farm	0.9249294	0.340119	2.72	0.007***	2.52169	0.224199
Livestock	0.1326774	0.1152138	1.15	0.249	1.141882	0.0317155
Marital	0.600875	0.3176253	0.19	0.850	1.061929	0.0143297
Market dist.	−0.1269731	0.2942659	−0.43	0.666	0.8807574	−0.0303519
Cons	−7.612753	1.193724	−6.38	0.000	0.0004941	
Log likelihood	= − 150.08478					
Number of obs	=340					
LR chi^2 (14)	=166.91					
Prob > chi^2	=0.0000					
Pseudo R^2	=0.3574					

** and *** are significant at 5 and 1%, respectively.

(Table 6). This finding indicates that educated farmers had more awareness and were more keen to adopt agroforestry practices than illiterate farmers. When farmers are educated, they have better access to information and innovations, which will help them quickly adopt new technology. This is because educated household heads play a significant role in shaping household members' participation in various income-generating activities. This finding is in line with Mekoya et al. (2008), who found that agroforestry technologies are knowledge-intensive and therefore require sufficient education in the adoption process to support this finding. In addition, the authors reported that literate farming household heads are more willing to implement agricultural extension advice, accept and use modern agroforestry technologies, and diversify their sources of income than illiterate ones.

Farmland size of house heads (flmhh)

Land is the main asset of farmers in the study area. The logit model results showed that the farmland size of household heads negatively and significantly influenced the adoption of agroforestry practices at the 1% significance level, and the coefficients and odds ratios of the variables were 1.733 and 5.66, respectively (Table 6). This finding was similar to that of Nigussie et al. (2019), who reported that large areas are more likely to adopt agroforestry practices. This implies that an increase in the landholding size of the respondent increases the adoption of agroforestry practices in households. Conversely, farmers with small land sizes had difficulty in adopting and increasing their level of use of agroforestry practices. In agrarian communities, arable land is a fundamental economic base for households. Therefore, those with relatively larger and better-quality farms are considered economically better off. This suggests the need to support farmers with less land area to enhance the adoption process.

The soil fertility of the farmland (silfhh)

This variable positively and significantly influenced the adoption of agroforestry practices at a 1% level of significance, and the coefficients and odds ratios of the variable were 1.613 and 5.020, respectively (Table 6). This implies that those who have fertile soil are more likely to adopt agroforestry practices by approximately 5.02 factors than those whose land is infertile. A possible justification for this might be that agroforestry can improve soil fertility. Therefore, households with less fertile soil might adopt other soil-enhancing mechanisms, and soil quality is one of the most important factors affecting the adoption of agroforestry practices.

Slope of farmland (fhhh)

According to the survey results, the slope of the household heads positively and significantly influenced the adoption of agroforestry practices at a 1% probability level. The coefficients and odds ratios of the variable were 0.924 and 2.521, respectively (Table 6). The odds ratio indicates that keeping other factors constant, as the slope on farmland increases, the likelihood of adopting agroforestry technologies would increase by a factor of 2.52. Farmers with steep farmlands are more vulnerable to soil erosion than those with gentle slopes. Therefore, it is easy to distinguish that steeper land soil loss is more severe than gentle steep land due to steep land being more easily erodible than flat. Slope is less productive and requires different types of conservation, including agroforestry practices. Alelign et al. (2011)

reported that slope is a potential variable and that high erosion creates a positive incentive to adopt technologies that will alleviate these conditions. If plots of land are located in sloping areas, they are less productive and need different types of conservation measures, including agroforestry practices.

Extension services

The influence of this variable was consistent with previous expectations, and it was positive and statistically significant in influencing the adoption of agroforestry practices at a significance level of 5%. The positive sign and magnitude of the odds ratio imply that as the frequency of farmers' contact with extension service providers increases by one time, the probability of adopting agroforestry practices would increase by a factor of 1.130, as presented in Table 6. This is not surprising because extension services can equip farmers with a better understanding of the usage and implementation of agroforestry practices. The findings of this study agree with those of Asfaw et al. (2011) and Gebremariam et al. (2021), who reported that farmers who had frequent contact with development agents adopted agricultural technologies more frequently than those who had less contact.

Conclusion and recommendations

Conclusion

The study was conducted in the Banja District of Northwestern Ethiopia, focusing on farmer perceptions toward the adoption of agroforestry practices. This study employed descriptive statistics, inferential statistics, and a binary logit model to assess the farmers' perceptions toward the adoption of agroforestry practices. The results from descriptive statistics showed that 59% of the respondents perceived agroforestry as an advantageous practice, with 91.57, 75, and 60.5% recognizing its benefits for farm productivity, household income, and food security, respectively. Whereas the remaining 41% of sample households were not perceived. About 56% of the respondents adopted different agroforestry practices, mainly live fences and taungya. The results of the binary logit model revealed that the adoption of agroforestry practices is determined by sex, educational status, extension services, family size, soil fertility, farmland size, and farmland slope. *The study endorses that extension workers should strengthen rural education, improve extension services, focus on soil fertility through soil and water conservation practices, and ensure sustainability through regular monitoring, evaluation, and implementation of diverse agroforestry practices, thereby ensuring environmental sustainability and improving livelihoods at the household, community, and national levels.*

Recommendations

Based on the results of this study, the following recommendations have been made:

- The study showed a positive relationship between the educational level of household heads and the adoption of agroforestry practices. Hence, rural education should be strengthened at all levels to increase awareness and promote the adoption of agroforestry practices among household heads.
- Farmers' positive perceptions of agroforestry significantly contributed to its adoption. To enhance this, extension workers should raise awareness among larger farmers. Additionally, attention should be paid to those who perceive agroforestry positively but have not adopted it, warranting further investigation into their reasons for non-adoption.
- Extension services positively contributed to the adoption of agroforestry practices in the study area. Therefore, the quality and extent of extension services should be strengthened to foster the expansion and adoption of agroforestry practices.
- Female-headed households in the study area did not adopt the agroforestry practices. Therefore, the concerned, including the extension agents, should pay due attention to female-headed farmers and work closely to enhance their adoption of agroforestry practices, thereby improving their livelihood.
- Finally, the agricultural sector should raise awareness about soil fertility through soil and water conservation practices and apply regular monitoring and evaluation to legalize its sustainability. Hence, the slope of the land should be covered by different agroforestry practices.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

The studies involving humans were approved by Mekdela Amba University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not obtained from the participants or the participants' legal guardians/next of kin because most of the households or the sample respondents could not read the document. The researchers obtained verbal consent from the respondents. Following this, semi-structured interviews were conducted with the sample respondents or households.

Author contributions

MG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. DM: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. TD: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1512761/full#supplementary-material

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