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Determinants of Smallholder Farmers Adoption of *Acacia decurrens* in Northwest Ethiopia

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Abstract

Planting a fast-growing multipurpose *Acacia decurrens* (AD) tree is one of the climate-smart agricultural practices that have been promoted in Ethiopia, which is widely practiced and an important livelihood strategy in Awi zone. However, the extent of its adoption varies considerably among households in the study area. This study investigated the determinants of intensity of adoption of AD among 385 randomly selected rural households in Awi Zone. Data were gathered using a cross-sectional household survey. Descriptive statistics and Two-limit Tobit model were employed for data analysis. The result of the study shows that on average the intensity of adoption of AD was 0.43 (43% of the total cropland area), though majority of the farmers (48.8%) belong to low level of adoption. The result of the analysis shows that being male, educational level, access to seedling, experience in growing the tree, extension contact has positive and significant relationship with the intensity of adoption. Age of head of household, land holding size, livestock holding size, soil fertility status, disease emergence and road distance have negative and significant influence on intensity of adoption. These suggest that expanding road infrastructure, education, access to seedling, secure land property right, disease management, and provision of extension services related to the AD can also improve smallholder farmers' intensity of AD adoption. The generated information provides a picture of the study area's situation to the attention of policy makers, development practitioners and institutional service providers to formulate a better policy intervention to sustain smallholder farmers' AD plantation.

Keywords

Adoption Intensity, *Acacia decurrens* Tree, Two-Limit Tobit, Northwest Ethiopia

1. Introduction

Agriculture is a major source of livelihoods and critical to meeting the food needs of the rapidly growing population in Ethiopia. However, land degradation already affects 40% of Ethiopia's agricultural land [1]. Climate change has a detrimental impact on agricultural productivity, because of its effect on soil moisture, faster depletion of soil organic matter, and increased heat stress [2] [3]. The current low adaptive capacity and low level of technological innovation under climate change would negatively affect the performance of smallholder production systems and the food security of millions of people [4] [5]. Ethiopia's GDP is expected to be 8% - 10% lower by 2050s compared to no-climate-change scenario but climate-related losses could be reduced by half through agricultural adaptation [6]. In Amhara region, particularly in the study area, land degradation, soil erosion, low soil fertility, and soil acidity are the key environmental issues contributing to food insecurity [7] [8].

Several land restoration and afforestation activities have been implemented by the government of Ethiopian (GoE) for nearly 50 years [9] [10]. The forestry sector was recognized as one of the pillars of a green economy [10], where goals of change adaptation and improving food security are integrated with rural livelihood strategies through on-farm trees, agro-forestry and woodlots [11]. Growing *Acacia decurrens* (AD) was promoted as climate smart agro-forestry practice in some areas in Ethiopia [12] [13]. AD is a fast-growing leguminous tree originated in Australia. It is known as black, green, and tan wattle grown commercially in many parts of the world including Africa, South America, and Europe [14] [15] [16]. Since 2009 AD, agro-forestry practice becomes an essential component of the farming systems in the study area. It provides attractive co-benefits for biodiversity conservation, ecosystem services, climate-change mitigation and adaptation through carbon sequestration, restoring degraded soils by enhancing their physical and chemical characteristics, lowering soil PH, and addressing deforestation issues [17] [18] [19] [20]. Recent empirical studies in Ethiopia identified environmental, hydrological, socio-economic, and livelihood related effect of AD tree [17] [21] [22] [23] [24].

Previous studies support positive economic and environmental contributions of incorporating AD in agro-forestry practices. Several researches have been carried out on identifying factors affecting adoption of tree planting on different tree species. The major factors are access to market, environmental and bio-physical factors, farmer preferences, resource endowments, market incentives, risk and uncertainty, secure land property rights, and socio-psychological factors

[25] [26]. The adoption and diffusion patterns are often context dependent. However, the empirical evidence on determinants of intensity of AD by households is scant. This study investigated determinants of intensity of adoption of AD among households in Awi Zone of Ethiopia. The paper presents results of the research conducted to generate evidence which is paramount to inform policy and development intervention with regard to promoting climate smart agro-forestry practices incorporating AD in other areas with similar socio-economic and ecological contexts.

The remaining parts of the paper are organized into three sections. The paper provides the data collection methods employed, the sampling techniques used in selecting the study sites and sample respondents. The second section presents the key findings of the study. The descriptive results and factors influencing the intensity of adoption of AD practices are presented in detail. The final section presents the conclusion and policy implications in relation to the key findings of the study.

2. Research Methodology

2.1. Study Area

Awi is one of the administrative zones of the Amahara regional state of Ethiopia. The Awi zone is bordered on the west by Benishangul-Gumuz Region, on the north by North Gondar Zone, and on the east by West Gojjam Zone. It has twelve districts, of which three are town administrations and nine are rural. The zonal capital (Enjibara) is situated at 445 km from Addis Ababa and at 120 km from the regional capital BahirDar. Awi Zone is located from 11˚ to 10˚85'N latitude and 36˚39'60'' to 36˚57'E longitude. The area ranges from 700 to 2900 metres above sea level in altitude **Figure 1**. The zone has the total population of 1,220,316 of which 598,880 were men and 621,436 were women. The total land area is estimated at 912,812 hectars of which 14.7%, 42.8% and 42.75% are highland, midland and lowland, respectively. The annual average temperature and rainfall in the area are 20˚C and 2150 mm [27]. Rain-fed mixed crop-livestock system are the main sources of livelihood of the rural dwellers in the study area. From the total area of 912,812 ha, 344574.3 ha was used for agriculture, 347,893 ha for forest (120,047) ha planted and 227845.6 ha natural forest), 217,139 ha for grass-land, and 449, 64.8 ha for other uses. The soil types are 15% clay, 38% red, and 47% loam soil [27].

Acacia and Eucalyptus species are the predominant exotic tree species grown in Awi zone [28]. AD tree was introduced on road side planting. By observing its fast growth and compatibility with annual crops, promotion by extension workers, farmers began planting it along plot boundaries for firewood and fencing. Since 2009 AD become an integral part of the farming systems to restore fertility of the degraded lands. Moreover, the emergence of attractive regional charcoal markets has led to its wider expansion into woodlot plantations on cultivated

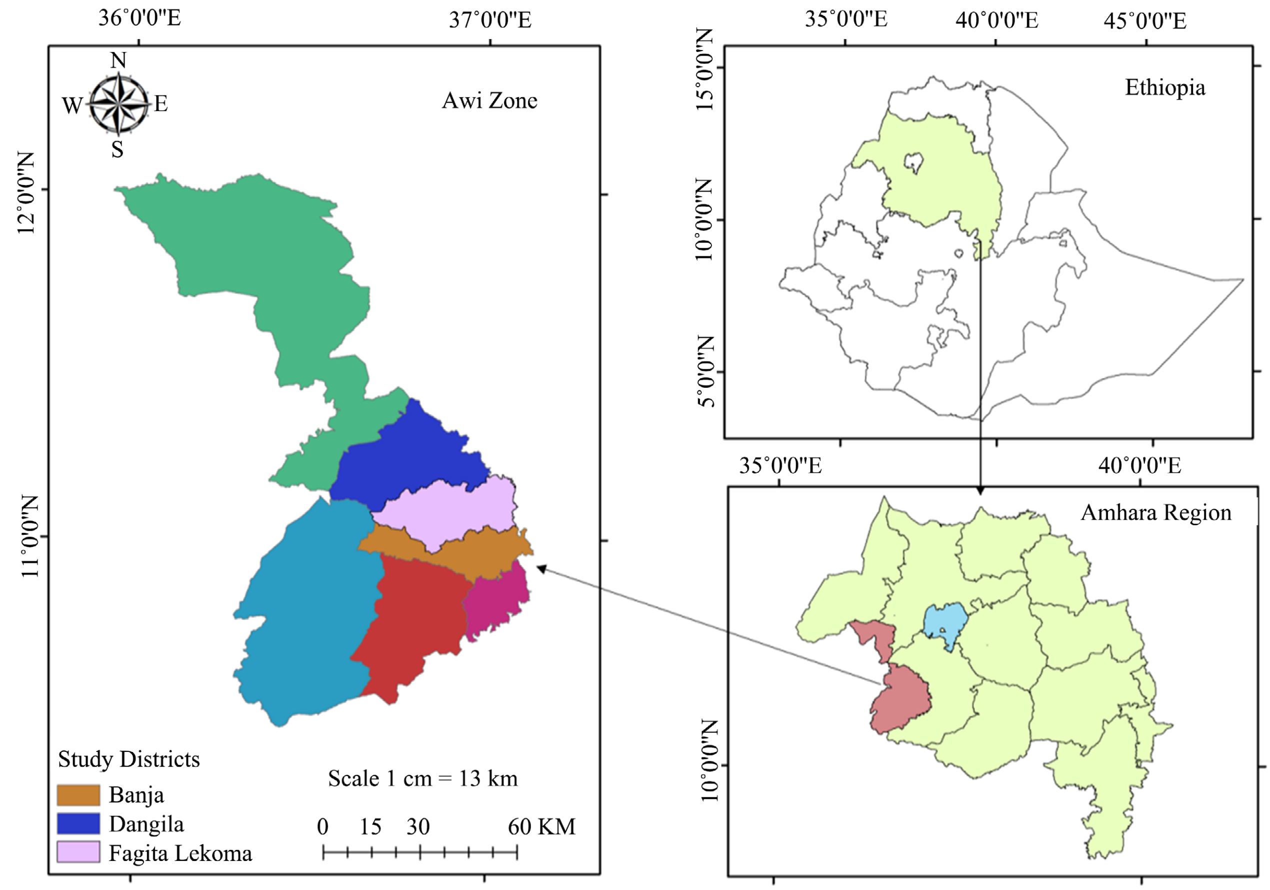

Figure 1. Map of study areas. Source: Extracted from Ethio-GIS (2021).

land because it helps to generate economic benefits, farmers have given the name "Black gold" or Black sesame due to its profitability [10] [14].

2.2. Sampling Technique and Sample Size Determination

Multistage sampling procedure was used to select representative sample respondents. Awi zone was selected purposively which was intensively involved AD production. Three districts, namely, Fagita Lekoma, Banja and Dangila were selected purposively based on the availability of farmer's Private AD woodlot expansion and commercialization in consultation with zonal experts and review of available data. This study used list of AD producing kebeles and households, a total of eight kebeles were selected randomly from three districts by following the probability proportion to size procedure, three kebeles from each Fagita lekoma, Banja and two kebeles from Dangila which has relatively low status of AD production put, [29] formula was employed to determine sample size with acceptable precision level.

$$n = \frac{Z^2 pq}{e^2} = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 385 \quad (1)$$

where: n = the calculated sample size, Z = the upper point $a/2$ standard cumulative distribution at 95% level of confidence from the statistical table which is equals to 1.96. e = the acceptable error at a given precision rate (assumed 5%). p = the estimated proportion of population engaged with AD production assumed to be 0.5 with degree of accuracy of 0.05 and q = Non-occurrence of event = 1 − p = 1 − 0.5; that is 0.5. Hence, the sample size was 385. Following this, the allocation of sample size to each district and kebeles was determined by probability proportional to size (PPS) (Table 1).

2.3. Sources and Data Collection Methods

In this study, both primary and secondary sources were used. A cross-sectional household survey was used to generate primary data from sample households. The draft questioner was pretested in a few respondents who were not sampled in the study. According to the feedback obtained from the pre-test stage, improvements were made for the final adjustment before the survey. The final pre-tested semi-structured questionnaire was employed to collect data from the sample respondents. A key informant interview was conducted with farmers, development agents and district experts through checklist. Focus group discussions were conducted in each kebeles to gain information for triangulating the data. Field observation was undertaken on some randomly selected household AD woodlots. Secondary data were generated from review of journal articles, books, conference proceedings, policy document, magazines and unpublished documents of different institutions at the district and zone level agricultural offices.

Table 1. List of selected kebeles and sample size in each study district.

Sample District	Total hhs	Sample kebeles	Total hhs	AD producers	Sample proportion (%)	Sample size
Fagita Lekoma		Ashewaafira	966	922	58	219
		Gezehara	1266	247	15	59
		Ajaseta	570	84	5	20
	21,305	**District total**	**2802**	**1253**	78	**298**
Banja		Kessa	967	38	2	9
		Surta	808	33	2	8
		Ziqgumerta	730	73	5	17
	16,217	**District total**	**2505**	**144**	9	**34**
Dangila		Gumderi	1135	97	5	23
		Gayita	814	125	8	30
	39,150	**District total**	**1949**	**222**	13	**53**
		Grand total		**1619**	**100**	**385**

Source: Own computation results based on survey data, 2021 hhs (households).

2.4. Data Analysis Methods

This study employed a combination of descriptive statistics and an econometric model. Descriptive statistical analysis was used to summarize the demographic, socio-economic, and institutional characteristics of farm households through mean, standard deviation, percentages, and frequency. A two limit Tobit model was used to investigate factors affecting the adoption intensity of AD by farm households.

Specification of econometric model

Two limit Tobit model is the most common censored regression model appropriate for analyzing dependent variables with upper and/or lower limits [30]. Some authors call such models limited dependent variable models, because of the restriction put on the values taken by the regressed [31]. Thus, in this study, the proportion of land allocated for AD was used as a dependent variable (intensity of AD adoption), as it is an appropriate measurement of woodlot plantation and this variable is a continuous limited dependent variable. A farmer may allocate a smaller or larger share of his or her land for AD production. Two limit Tobit regression model was used for analysis of determinants of intensity of AD adoption following [32] [33].

Tobit model can be defined as:

$$Y_i^* = \beta X_i + \mu_i \sim \mathrm{N}\left(0, \delta^2\right)$$

$$Y_i = \begin{cases} Y_i^* & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \le 0 \end{cases} \tag{2}$$

where Y_i^* is the latent dependent variable which represents adoption intensity of a household i; Y_i is the observed dependent variable, X_i a vector independent variables affecting intensity of adoption for a household i, β is corresponding vector of parameters to be estimated, and the μ_i's residuals that are independently and normally distributed with mean zero and a common variance $\mu_i \sim \mathrm{N}\left(0, \delta^2\right)$.

The values of the estimated coefficients from a Tobit model do not directly give the marginal effects of the associated independent variables on the dependent variable. Instead, their signs show the direction of relationships. According to [34], the total (marginal) effect accounts for the simultaneous effects on the number of adopters and the extent of adoption. Given Y_i as the actual adoption of AD then actual adoption cannot be negative thus, the relationship between Y_i^* and Y_i is given as:

$$Y_i = \max\left(Y_i^*, 0\right) \tag{3}$$

The log likelihood function for the Tobit model is thus:

$$\log L = \sum_0 \ln\left[1 - \varphi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \tag{4}$$

where; "0" indicates summation over the zero observations in the sample while

"+" indicates summation over positive observations, $\varphi(.)$ is the standard normal cumulative distribution functions and $\phi(.)$ is probability distribution functions. According to [33] the three types marginal effects considered in the analysis of the Tobit model are shown below. These are:

1) The unconditional expected value of the dependent variable

$$\frac{\partial E(Y)}{\partial X_j} = \left[\phi(ZU) - \phi(ZL)\right] \frac{\partial E(Y^*)}{\partial X_j} + \frac{\partial\left[\phi(ZU) - \phi(ZL)\right]}{\partial X_j} + \frac{\partial\left(1 - \phi(ZU)\right)}{\partial X_j} \quad (5)$$

2) The expected value of the dependent variable conditional upon being between the limits

$$\frac{\partial E(Y^*)}{\partial x_j} = \beta_n \left[1 + \frac{\{.ZL\phi(ZL) - ZU\phi(ZU).\}}{\{\phi(ZU) - \phi(ZL)\}}\right] - \left[\frac{(\phi ZL) - \phi(ZU).\}2}{\phi(ZU) - \phi(ZL).\}2}\right] \quad (6)$$

3) The probability of being between the limits

$$\frac{\partial\left[\phi(ZU) - \phi(ZL)\right]}{\partial x_j} = \frac{\beta_n}{\sigma}\left[\phi(ZL) - \phi(ZU)\right] \quad (7)$$

where: $\varphi(.)$ the cumulative normal distribution, $\phi(.)$ the normal density function, $ZL = -\beta' X\sigma$ and $ZU = (1 - (\beta X))\sigma$ are standardized variables that came from the likelihood function given the limits of y^*, and δ standard deviation of the model. The interpretations of these marginal effects depend on the point of interest-based on the objective of the study.

2.5. Definition of Variables, Measurement, and Hypotheses

2.5.1. Dependent Variable

The dependent variable in this study is intensity of adoption of AD by farmers, measured in terms of the proportion of land allocated for AD woodlots by farmers. This variable is a continuous limited dependent variable. It can be some value greater than zero. It is hypothesized that this will be influenced by the independent variables.

2.5.2. Independent Variables

The following independent variables were hypothesized as determinants of intensity of adoption of AD based on the theoretical and empirical literature discussed in Table 2.

3. Results and Discussion

3.1. Descriptive Results

Demographic, Socio-Economic, and Institutional Characteristics of AD Producers

Of the total respondents (n = 385), 31.69% were female-headed households while the remaining respondents were male-headed households Table 3. The average age of the sample respondents was estimated at 47.85 years, majority of farmers' ages are in the category of active labor forces. The average family size for the sample respondents was 5.29. This is higher than the national average

Table 2. The hypothesized variables of adoption intensity of AD and expected signs.

Variables	Type of variable	Measurement	Sign	Related empirical studies
Dependent	Continuous	Proportion of land allocated for AD tree planting		
Intensity of AD adoption				
Independent				
Sex	Dummy	1 if head is male, 0 female	+	[35] [36]
Age	Continuous	Years	+/−	[10] [37]
Family size	Continuous	Number	−/+	[38] [39]
Dependency ratio	Continuous	Number	−	[40]
Educational level	Continuous	Years	+	[23] [36] [41]
AD Farm experience	Continuous	Years	+	[10] [42]
Land acquisition	Dummy	1 landowned, 0 otherwise	+	[42] [51]
Training access	Dummy	1 if there is access, 0 otherwise	+	[42]
Off farm income	Continuous	Birr	+	[10] [39]
Livestock holding size	Continuous	Total livestock unit	−	[37] [39]
Land holding size	Continuous	Hectares	+/−	[37] [38]
Cooperative	Dummy	1 if member, 0 otherwise	+	[26]
Extension access	Dummy	1 if there is access, 0 otherwise	+	[39] [43] [44]
Market distance	Continuous	Kilometers	−	[45]
Road Distance	Continuous	Kilometers	−	[38] [42]
Access to credit	Dummy	1 if there is access, 0 otherwise	+	[42]
Seedling access	Dummy	1 if there is access, 0 otherwise	+	[37] [38]
Soil fertility status	Categorical	1 = low, 2 = medium, 3 = high	−	[38] [42]

Table 3. Descriptive statistics result of explanatory variables.

Variables	Unit	Mean	Std. deviation
Age	Years	47.84	10.80

Continued

Educational level	Years	1.22	1.82
Family size	Numbers	5.29	1.63
Dependency ratio	Numbers	0.69	0.64
Land holding size	Hectares	1.56	0.67
AD land allocation size	Hectares	0.40	0.16
Off/non-farm income	Birr	1242.63	564.66
AD farm experience	Years	6.37	1.60
Livestock holding size	TLU	2.40	1.33
Road distance from woodlot	Kilometers	4.13	2.56
Distance of woodlot to market	Kilometers	8.99	6.47
Sex	Dummy (1 = male)	0.683	0.465
Credit access	Dummy (1 = yes)	0.685	0.464
AD seedling access	Dummy (1 = yes)	0.576	0.494
Cooperative membership	Dummy (1 = yes)	0.825	0.379
Extension Access	Dummy (1 = yes)	0.849	0.358
Training participation	Dummy (1 = yes)	0.028	0.166
Land acquisition	Dummy (1 = owned)	0.953	0.211
Disease emergence	Dummy (1 = yes)	0.548	0.498
Soil fertility status	Categorical (1 = high)	1.976	0.765

Source: Own computation results based on survey data, 2021.1 USD - 50 ETB (Ethiopian Birr).

which was 4.6 people per household [46]. The survey result indicated that the sample households have an average educational level of 1.22 years with an average 6.37 years of AD farming experience.

On average, the sampled households owned 2.40 TLU (tropical livestock unit), gained an average off/non-farm income of 1242.63 ETB (~25 USD$). This income was obtained from non-farm and off-farm activities such as petty trading, charcoal making, fuel wood selling, local beverage preparation, weaving, and providing local transport services using horse cars and daily labor. The average distance from AD woodlot to the main road and market were 4.10 km and 8.9 km respectively.

The result of the study shown in **Table 4**, indicated that an average land holding size of sample households was 1.56 hectare. Out of the total land area allocated for other crops by sample households about 43% of the land was allocated for AD. The remaining proportion of land was covered by annual crops (cereals. pulses, oilseeds, and vegetables), eucalyptus tree, perennials (coffee, gesho and fruits) and grazing as 31.5%, 2.3%, and 0.93% respectively.

Table 4. Land use by the sample respondents.

Category	Mean	Standard deviation
Total land size (ha)	1.56	0.67
Land covered by AD tree(ha)	0.438	0.256
Land covered by annuals crops (ha)	0.315	0.104
Land covered by perennials (ha)	0.0004	0.002
Land covered by Eucalyptus tree	0.0093	0.025
Grazing land (ha)	0.023	0.044

Source: Own computation results based on survey data, 2021.

Table 5 presents the level of adoption of sample respondents across the study areas. Based on the range of adoption index the sample respondents were classified in to three categories: low, medium and high. That is, households with adoption index score of 0.01 - 0.33 were categorized as low adopters, while those with adoption index of 0.33 - 0.66 and 0.67 - 1 were counted in the medium and high adoption categories. Of the total respondents, nearly half (48.83%) fall into the low adoption category while about one-third (33.77%) of the total respondents fall into the medium adoption category. Only 17.40% of the respondents fall into the high adoption category. This shows that there was a considerable variation across the sample respondents in terms of their intensity of adoption of AD practices.

3.2. Econometric Model Results

Determinants of Intensity of AD Adoption

Two limit Tobit model was employed. Before running the regression analysis, the existence of multicollinearity and heteroscedasticity problems were checked. Since the mean Variance Inflation Factor (VIF) score was 1.60. There is no evidence of multicollinearity problem in the model. In addition, a test for normality of Adoption intensity was made using Kernel density plot residuals. The Kernel density plot provides smooth curve that closely resembles a normally distributed curve, indicating that the normality assumption was not violated Figure 2.

The regression model includes a total of 19 explanatory variables. Of these, a total of 12 variables (sex of the household head, age of the household head, educational level of the household head, landholding size, livestock holding size, AD farming experience, road distance from AD woodlot, seedling access, extension contact, land acquisition, disease emergence, and soil fertility status) were significantly associated with intensity of AD of adoption. The details of the results are indicated in Table 6.

The age of the household head had a negative association with the intensity of AD adoption at less than 5% significant level. Other factors remaining constant, a one-year increase in age results in a decrease by 0.2% in the intensity of adoption. Young people are more flexible in adopting of new technology while aged people are reluctant. The other reason is that all activity during AD planting and harvesting time are done by manpower; and older farmers might prefer activities that require less labor and generate return in a short term. Similar finding was reported by [10].

Table 5. Distribution of respondents by their level of AD adoption (385).

Adoption index range	Adoption category	Frequency	Percentage
0.01 - 0.33	Low	188	48.83
0.34 - 0.66	Medium	130	33.77
0.67 - 1	High	67	17.40
Total		385	100

Source: Own computation results based on survey data, 2021.

Table 6. Tobit model estimation results of intensity of AD adoption.

Variables	Marginal effect	Std. Err	Z value
Sex	0.032***	0.010	3.12
Age	−0.002**	0.001	−2.50
Educational level	0.009**	0.004	2.16
Family size	−0.001	0.003	−0.42
Dependency ratio	−0.001	0.008	−0.17
Cooperative membership	−0.002	0.014	−0.13
Seedling access	0.028***	0.009	2.80
Credit Access	0.013	0.013	0.99
Landholding size	−0.349***	0.070	−4.95
Off/non farm income (log)	0.000	0.002	0.19
AD farming experience	0.012***	0.003	3.42
Livestock holding size	−0.010**	0.004	−2.40
Extension access	0.068***	0.019	3.53
Training access	0.002	0.030	0.09
Land acquisition	0.061*	0.032	0.90
Road distance	−0.010***	0.003	−3.34
Market distance	0.001	0.001	1.19
Disease emergence	−0.033***	0.012	−2.62
Soil fertility status	−0.035***	0.008	−4.41
Constant	0.619***		

Sigma = 0.255, No of observation = 385, Log likelihood = −58.5662, Prob > F = 0.000, F(19) = 299.48, Pseudo R^2 = 0.885.

Source: Own computation results, 2021. ***, **, and * indicate significance levels at 1%, 5% and 10%, respectively.

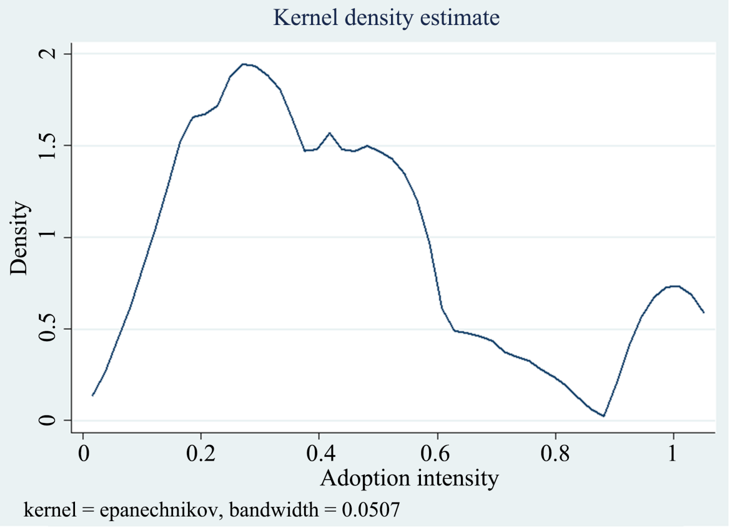

Figure 2. Kernel density estimate for intensity of AD adoption. Source: Computed from survey data (2021).

Sex of the household head positively influenced the intensity of adoption of AD at 1% significance level. The result shows that being male headed household would have the intensity of adoption of AD higher by 3.2% than female headed households, keeping other factors unchanged. Male-headed households have better labor force which is needed in planting and harvesting time than female-headed households. The finding is consistent with [10] [36] [38] [45].

Educational level of household had a positive influence on the intensity of adoption of AD at less than 5% significance level. Education increases people's capacity to acquire, interpret, and apply information from different sources. [41]. The survey result in **Table 6**, indicated in that an additional year of schooling increases adoption intensity of AD increases by 0.9%. This implies that educated farmers are better to understand climate change impacts on their agricultural production, which leads their adoption of AD as climate-smart agricultural practice. The other reason may educated households have better chances for employment opportunities and can afford the costs of AD farming. For instance, AD production needed a cost of 12,427 ETB (~583.5 USD) and 71,273 ETB (~3346 USD) per hectare during planting and harvesting time [47]. Previous studies [23] [41] [48] [49] reported similar findings.

Land size was found to have a negative and significance association with intensity of AD adoption at less than 1% significance level. An increase in the size of land by one ha would decrease the intensity of adoption of AD by 34.9%. Famers used small size of lands as a trial of new technologies. Households with small land size are practiced (adopted AD) at a faster rate than large sized lands. [10] reported that when landholding size increases, the proportion of land allocated to AD first rises, but as landholding size continues to expand, it begins to decline because AD requires high cost of production than other crops. Previous studies by [10] [35] found similar results.

The size of livestock possessed by the households (TLU) was found to influence the intensity of adoption of AD negatively at less than 5% level of significance. A unit increase in TLU decreases the intensity of AD adoption by 1%, keeping other things remaining constant. Livestock production offers a better source of income that may discourage expansion of AD since the later competes for land with livestock feed. This result is consistent with previous studies [10] [42].

AD farming experience was positively associated with the intensity of adoption at 1% significance level. Households with knowledge gained over time from AD production are expected to have full information, able to recognize the advantage, and allocate more land for AD than inexperienced farmers. All other things remain unchanged, as households' experience increases by one year, the intensity of adoption would increase by 1.2%. The current result is in line with the findings of other studies [10] [42].

Seedling access was found to have a positive and significant effect on the intensity of adoption at less than 1% significance level. Seedling is one of the most important inputs for AD production. For households who get seedlings the intensity of adoption be higher by 6.6% than households who don't have seedling access. Seedling access encourages expansion of the tree planting as supported by the previous studies [21] [37] [38].

Contact of households with extension agents, influenced the intensity of adoption of AD positively at less than 1% significance level. The marginal effect estimation shows that, holding other factors constant, households who had contact with extension agents, would have higher intensity of adoption by 6.8% as compared to those households who did not have contact. This is because contact between the extension agent and farmer facilitates the flow of new ideas and encourages profitable innovations. This result is consistent with some studies [38] [43] [44] [50].

Distance between AD woodlot and the main road has a negative influence on the intensity of adoption at 1% significant level. Keeping all other factors constant, a one-kilometer increase in woodlot distance from main roads would decrease the intensity of adoption of AD by 1%. Farmers who are located far from the main road trouble in access to transportation of both input and outputs. Farmers pay ETB 4 - 8 (0.08 - 0.15 USD) per sack to transport AD charcoal to main road which serves as a stand-in for market accessibility to transportation. This result is in line with the findings of some studies [10] [35] [42].

Having own land (long-term use right) has a positive significant effect on the intensity of adoption at less than 1% significant level. The result shows that the intensity of adoption of AD for land owner households is higher by 6.1% as compared to land-less households, keeping other factors unchanged. Farmers seek to plant and invest in their own lands rather than on rented land. In fact, AD tree growing takes a 5-year investment period, which has long pay-off periods as compared to other annual crops. Thus, the right of farmers who rent land from others depend on obtaining permission to plant trees from the land owners. The survey result indicated that majority of AD adopters are young and educated though youth owned small size of lands in the study area. Thus, secure land property right is a key factor for adoption of tree planting. This result is in line with the findings of [42] [51].

Disease emergence has a significant and negative influence with the intensity of adoption of the AD at 1% significant level. Keeping other factors unchanged, households whose AD woodlots were infected by disease had lower intensity of adopting AD by 3.3% than households' woodlots were free from disease. This implies the productivity of a highly profitable and environmentally beneficial tree is now under threat. The survey result revealed that new disease is emerging on AD tree woodlot and seedlings at nursery sites. Australian and Ethiopian researchers were collaborated to tackle the emerging disease, although, the distribution, damage impact, long-term and sustainable pest management solutions still unidentified.

The result in **Table 6** indicates that soil fertility status is negative and significant at less than 1% level implying that soil fertility is an important factor in determining intensity of adoption. The most important motivations to engage in AD plantations are to improve the soil fertility of degraded lands and to control soil erosion. Farm households who perceived their lands to have moderate and high soil fertility would have lower intensity of adoption by 3.5% as compared to households who perceived their farms to have low fertility [28] reported that AD plantations have significantly higher soil organic matter and nitrogen contents as compared to adjacent crop lands. [35] [42] were found similar results.

4. Conclusions and Recommendations

AD tree would have significant impacts on farmers' incomes and food security, but only if it is adopted by most of farmers in the study area. Therefore, this study investigated the determinants of intensity of adoption of AD among rural households in Awi Zone. The results of simple descriptive analysis showed that out of the total land area allocated for other crops by sample households about 43% of the land was allocated for AD, though majority of the farmers (48.8%) belong to low intensity of adoption. Moreover, the two limit Tobit model results confirm that being male, educational level, access to seedling, experience in growing the tree, and extension contact has positive and significant relationship with the intensity of adoption, while age of head of household, land holding size, livestock holding size, soil fertility status, disease emergence and road distance have negative and significant influence on intensity of adoption. Based on the findings, the following recommendations are forwarded.

Extension services and seedling access should be provided; capacity building through providing education will improve the intensity of adoption. Improving road that connects kebeles far from the main road will reduce transportation cost and improve access to market. We found a very strong relationship between adoption of AD and land ownership (long-term use right) though tenure insecurity demotivates AD adoption. Hence, distributing marginal and degraded areas to poorer and landless youth farmers through private ownership is pre-requisites for improving farmers' intensity of AD adoption. Disease emergence on AD plot discouraged farmers' intensity adoption. Therefore, there is an urgent need of interventions by government and concerned stakeholders in identifying the distribution of disease, damage impact and sustainable management solutions. There is no doubt that growing AD as climate smart agro-forestry practice has attractive benefits for smallholders' farming systems and livelihood in the study area, proper attention should be given to formulating a better policy intervention to sustain smallholder farmers' AD plantation in Awi zone and to expand areas with similar socio-economic and ecological conditions.

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Conflicts of Interest

The authors declare that they have no competing interests.

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