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Research Article

Determinants of Modern Agricultural Technology Adoption for Teff Production: The Case of Minjar Shenkora Woreda, North Shewa Zone, Amhara Region, Ethiopia

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Agriculture is one of Ethiopia's economic cornerstones, although its production remains low. Since then, the implementation of modern agricultural technologies has remained a promising strategy in Ethiopia for increasing agricultural production, achieving food security, and reducing poverty. The objective of the study is to examine the determinants of modern agricultural technology adoption for teff production in Minjar Shenkora woreda. The data were collected from the representatives of 362 rural households. This study employed both descriptive statistics and multinomial logit model. The estimations of the multinomial logit model revealed that sex, age, marital status, tropical livestock units, educational level of household head, distance to market, extension contact, active household members, access to credit, off-farm activities participation, and cultivated land size are the determinants of modern agricultural technology adoption for teff production in Minjar Shenkora woreda, North Shewa Zone, Amhara Region, Ethiopia. Therefore, this study recommended that the country's federal and regional governments, agricultural development offices, nongovernmental organizations, and donor agencies should collaborate with farm households to improve access to information, access to credit, encourage off-farm participation and provide training and consulting services to increase the adoption of modern agricultural technologies.

1. Introduction

In sub-Saharan Africa, agriculture is a powerful option for stimulating growth, overcoming poverty, and increasing food security. It is critical to raise awareness in farming communities about future climate change and the risks associated with the existence of extreme weather events [1]. Thus, improving the productivity, profitability, and sustainability of small-scale agriculture is the main way out of poverty [2]. Agriculture is by far the largest sector of Ethiopia's economy serving as a basis for the country's food security and source of livelihood for over 80% of its people. It accounts for about 34.1% of the gross domestic product (GDP), employs 79% of the population, accounts for 79% of foreign earnings, and is the major source of raw material and capital for investment and market [3]. It has been hampered by periodic droughts, overgrazing, deforestation, high population density, and weak infrastructure that often make it difficult and expensive to transport agricultural input and outputs [4]. Therefore, improving the productivity of the agricultural sector plays an important role in the country, where poverty alleviation and maintenance of food security are key government programs. The Ethiopian government is promoting the adoption of several agricultural technologies to improve the productivity of the agricultural sector [5]. The adoption of modern agricultural technologies offers a mass of potential benefits to increasing the productivity and income of smallholder farmers. In the case of Ethiopia, the agricultural development policy aims at the efficient use of modern agricultural inputs such as organic and inorganic fertilizers, pesticides, herbicides, and improved seeds by research and extension systems [6].

Crop production is a major component of the country's agricultural sector. Specifically, cereal crops account for a large share of both total land area and output. From the total area of land, 79.88% is covered by cereals crops such as teff, maize, sorghum, and wheat. Teff accounts for 22.95% of the area of land and is followed by maize, which is 16.91% of the land. Cereal crops accounted for 86.68% of the total agricultural production. Teff production accounts for 16.76% of cereal crop production [7]. Teff is a cereal crop that is widely grown in Ethiopia with an annual area of about 2.8 million hectares. This crop has properties that are particularly useful to both producers and consumers. It is the most expensive grain grown in Ethiopia and an attractive cash crop for farmers. Ethiopia has a good chance of ensuring food security, poverty reduction, and economic growth by stimulating teff production and exports by adopting teff technologies [8]. Fikadu et al. [9] stated that teff has many benefits and high nutritional value for baking in jera and well-known traditional food in Ethiopia. The income obtained from teff is much higher than income obtained from other cereals crops and even 34% higher than income obtained from coffee, and it is the major export crop in Ethiopia [10].

Teff yields are low due to low use of modern agricultural inputs, traditional sowing methods, lack of access to market information, postharvest losses, and lack of high-yielding cultivars [11]. In response to climate change, Pakistani farmers use a variety of adaptation strategies, including changing fertilizer, crop variety, pesticide, seed quality, water storage, farm diversification, planting shade trees, irrigation practices, off-farm activities, permanent and temporary migration, and asset sales [12]. In different regions, there is evidence that the adoption of row planting, pesticide, insect side, fertilizer, improved seed, and herbicide for teff production is very low at the national and regional levels [13]. The low prevalence of farmers' adoption decisions is often determined by socioeconomic, institutional, demographic, and psychological factors [14, 15]. However, in most rural areas, Ethiopian farmers are adopting a single, mixed technology instead of all existing methods [14].

The contribution of this study to the existing literature is fourfold. First, many researches have conducted on the determinants of agricultural technology adoption in different parts of the country and in different types of crops, for instance [6, 16–20]. However, this study examined the determinants of modern agricultural technology adoption for teff production in Minjar Shenkora woreda. Second, limited studies have been conducted on the impact of agricultural technology adoption on household income and expenditure in different parts of the country, for example [21–23]. However, this study aims to examine the determinants of modern agricultural technology adoption for teff production in the study area. Third, most of the studies employed the logit model, Tobit and Ordinarily List Square, and propensity score matching, for example [6, 15, 21, 22]. But, the scanty study employed a multinomial logit model to estimate agricultural technology adoption on other crops in different parts of the region, for example [24–26]. Though, this study employed a multinomial logit model to estimate the determinants of modern agricultural technology adoption for teff production in the study area. Fourth, most of the studies relied heavily on substantiating a single agricultural technology decision and did not take into account the complementarity of multiple agricultural technologies adoption decisions, for example [15, 27, 28]. However, this study tries to use comprehensive multiple agricultural technologies with the specific crop. Therefore, the application of the model of applying multiple agricultural technologies to teff production is the main contribution of the study. Finally, given the significant knowledge and research gaps, this study aimed to examine the determinants of modern agricultural adoption for teff production in Minjar Shenkora woreda, North Shewa Zone, Ethiopia.

2. Literature Review

2.1. Empirical Studies and the Conceptual Framework. Different studies have been undertaken by scholars to understand the determinants of modern agricultural technology adoption for teff production. The following table shows different related empirical literature (see Table 1).

2.2. Conceptual Framework. An empirical review of the literature on technology adoption in Ethiopia reveals that the various factors that influence technology adoption can be grouped into the following four broad categories factors related to the demographic characteristics of the farmers, factors related to the economic aspects, institutional factors, and infrastructural factors. The conceptual framework is presented in Figure 1 as follows [33].

3. Methodology of the Study

3.1. Study Area Profile. This study was mainly focused on and conducted in the Minjar Shenkora district, one of 24 woredas located in the northern area of Shewa, in the southern part of the Amhara region. The geographical location of the study area extended from 8°42′46″ N to 9°7′37″ N latitude and from 39°12′57″ E to 39°46′53″E longitude. Minjar Shenkora district, located farther to the southern part of the North Shewa Zone, is bounded by Hagere Mareym and Berehet wearda to the north, and the remaining boundary of Minjar Shenkora is shared with parts of Oromia to the west, south, and east. The study area is located to the south towards Debre Berhan, the administrative town of the North Shewa region at a distance of 260 km. Minjar Shenkora district is located east of the Ethiopian capital Addis Ababa, with a distance of 130 km between them [34]. The district includes 29 kebeles, of which 27 kebeles are part of a rural area. Regardless of their region, Balchi and Ararti are the only two towns located in Minjar Shenkora district. The population of this region is 128,879 people, of which 66,918 are men and 61,961 are women, but 12,237 are city residents. There are 29,359 households living in the district [35]. Of the total area of 159,682.9 hectares of land, 55,860.38 hectares of land is arable. Minjar Shenkora district is covered with flat reliefs with relatively flat surfaces. Due to the very low inclination, this area has great potential for the application of modern agricultural mechanization, minimizing soil erosion, and waterlogging and can be affected when

Table 1: Empirical literature review.

Author (year)	Location	Method	Result
[29]	Minjar shenkora woreda	Multinomial logit (MNL) model	The result from MNL analysis showed that age of the household, farmers' experience, total annual income, access to credit, training, and perception are those variables that positively and significantly influenced the likelihood of adoption of teff row planting among farmers whereas education level, farming experience, training, access to technology input supply and perception towards row planting positively and significantly influenced the intensity of adoption of teff row planting. On the other hand, while landholding size negatively affected the intensity of adoption of teff row planting, the age of household head and land holding size negatively and significantly influenced the adoption of teff row planting.
Fahad and Wang [1]	Charsadda, Peshawar, Mardan, and Nowshera of Khyber-Pakhtunkhwa (KP) province of Pakistan	Contingent valuation (CV) method	The study's findings revealed that farm households in the study area faced a variety of challenges in adopting certain adaptation measures to deal with climate variability, including a labor shortage, insecure land tenure, lack of market access, poverty, lack of governmental support, lack of access to assets, a lack of water sources, a lack of credit sources, and a lack of knowledge and information. The findings of this study provide helpful information to those in charge of policy implementation.
Dalango and Tadesse [30]	Southern Ethiopia, gena district in Dawro zone	Heckman two-stage model	In the first stage of probit regression, results of the study show that the adoption decision of chemical fertilizer use was driven by factors such as farm size, size of family, family labor, education, access to credit, access to information, and distance to the near market place. In the second stage, the intensification of chemical fertilizer application was influenced by the membership to cooperative, availability of extension service, access to credit, size of farm land, size of a family member, family labor, educational status, and sex of head. The policies that expand the accessibility of credit service, dissemination of productive agricultural technology information, and creating the opportunity of education for farm house hold have the potential to increase the chance of chemical fertilizer adoption decisions and strengthen the level of adoption among smallholder farmers.
[31]	Mlali ward, Tanzania	Descriptive and regression analyses	Results revealed that respondents' education level, family size, farming experience, availability of sunflower market, and frequency of contacting extension officers significantly influenced the adoption of sunflower farming innovations. However, the sex of the respondent, respondent's age (years), respondent's marital status, and livestock ownership did not significantly influence the adoption of sunflower farming innovations.
[27]	Toke kutaye district, oromia regional state	Descriptive statistics and econometric model (tobit)	The model result revealed that variables such as farm size, off-farm income, and livestock asset were positively and significantly influenced agricultural adoptions.

Table 1: Continued.

Author (year)	Location	Method	Result
[32]	Duna district	Using binary logit regression	Results revealed that land holding, livestock ownership, and off-farm income use had all significant positive associations with households' adoption decisions
[21]	West wellega, gulliso district	Binary logit model and PSM model	The selection result showed that farm size, livestock asset, and the perception of farmers about the cost of inputs and off-farm income influence the adoption decision of farm households positively and significantly

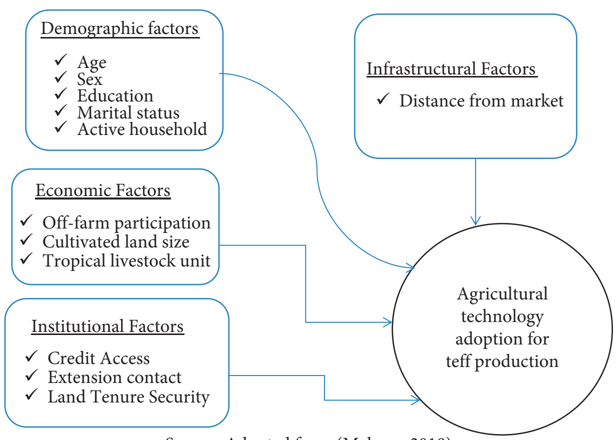

Figure 1: Conceptual framework. Source: adopted from.

pouring water. The longitudinal extent of the study area is home to three agro-climatic zones Kola, Woinadega, and Dega [36]. The soil is Vertisol type having clay textural class. The area has annual rainfall ranging between 800 and 1000 mm [37].

3.2. Sources and Method of Data Collection. The study used both primary and secondary data. Primary data were collected through self-administered structured questionnaires from rural households whereas secondary data were collected from Minjar Agriculture Office Shenkora woreda, publish articles, and books.

3.3. Sampling Technique and Sample Size Determination. The data were collected from households who are living in Minjar Shenkora woreda. A multistage sampling procedure was employed in this study. First, Minjar Shenkora woreda was purposefully selected based on maximum teff arable land and is well known for its teff production from the districts of the North Shewa Zone. In the second phase, 4 Kebeles (Kebele (Amharic word) means the lowest administrative unit in Ethiopia [38]) namely Choba, Amora Bet, Kombolcha, and Bolo Giorgis were randomly selected from 19 rural Kebeles of Minjar Shenkora woreda. Thirdly, simple random sampling was used to select 362 households from each selected Kebeles. The study employed Yamane's formula to determine the sample size [39]. The formula is expressed as

$$n = \frac{N}{1 + N\left(e^2\right)}, \tag{1}$$

$n = 3860/1 + 3860\,(0.0025) = 362$; where $n=$ is the sample size; $N=$ is the population; $e=$ is the error tolerance or margin of error. Using a 5% level of error or 95% level of confidence 362 sample sizes will take from households who are engaging in farming through a random sampling technique. Finally, proportionate sampling was utilized to determine the sample size for each stratum, with Choba, 33, Amora Bet, 122, Kombolcha, 74, and Bolo Giorgis 133 samples selected from each stratum.

3.4. Method of Data Presentation and Analysis. After the collected data are coded and edited, it is presented in tabular form. In this study, descriptive and econometric data analysis techniques were used. In the descriptive analysis of this study, statistical measures of mean and percentage were used to summarize the demographic, socioeconomic, and institutional characteristics of the respondents. In this study, the multinomial logit model was used to estimate the determinants of the adoption of modern agricultural technologies for teff production in the study area.

3.5. Econometrics Model Specification. The choice of model to study the determinants of adoption is based on the amount of technology used for the study. The choice model describes the functional relationship between the probability of applying some technology and different explanatory variables. This study used a multinomial logit model to estimate demographic, socioeconomic, and institutional factors that affect the applications of modern agricultural technology adoption for teff production. On this basis, the present study states the standard multinomial logit model specified as follows:

$$\begin{aligned} \text{Adoption} = {} & \beta_0 + \beta_1 \text{sex} + \beta_2 \text{age} + \beta_3 \text{mstr} + \beta_4 \text{educ} \\ & + \beta_5 \text{cultivated land size} + \beta_6 \text{off} \\ & - \text{farm participation} + \beta_7 \text{tlu} \\ & + \beta_8 \text{land tenur} + \beta_9 \text{distance from market} \\ & + \beta_{10} \text{credit} + \beta_{11} \text{extension visit} + \beta_{12} \text{lan tenure} \\ & + \beta_{13} \text{activehhd} + \epsilon . \end{aligned} \tag{2}$$

The dependent variable (adoption) is modern agricultural technology adoption for teff production just categorized as nonadopter, improved seed, herbicide, row planting, improved seed + herbicide, improved seed + row planting, improved seed + herbicide + row planting. The parameters for this study are gender (sex), age (age), marital status (mstr), education (educ), cultivated land Size, off-farm participation, livestock unit (tlu), market distance (distancefrommkt), credit access (credit), extension visit (extensionvisit), land tenure security (lantenur), and active household member(activehhd), and ε represents the error term. Therefore, the probability of modern technology adoption j ($j = 0$ nonadopter; $j = 1$ only improved seed; $j = 2$ only herbicide; $j = 3$ only row planting; $j = 4$ improved seed herbicide; $j = 5$ improved seed + row planting; $j = 6$ combinations of improved seed, herbicide, and row planting) is given by the following multinomial logit model:

$$\text{prob}\,(Yi = j) = \frac{\exp\left(\chi ij'\beta j\right)}{\sum_k \exp\left(xik'\beta k\right)} \quad \text{For } j \text{ and } k = 1, 2, 3. \tag{3}$$

The multinomial probability model assumes that the possible distinct states are exhaustive in that they cover all possibilities.

The likelihood function for a sample of Nindependent observations is then

$$LN = \prod_{i=1}^{N}\prod_{j=1}^{M} Pijyij, \tag{4}$$

where the subscript i denotes the i^{th} of N individuals, and the subscript j denotes the j^{th} m alternatives. The log-likelihood function is

$$L = \ln\, LN = \sum_{i=1}^{N}\sum_{j=1}^{M} YijLnPij, \tag{5}$$

where $Pij = Fj\,(xi, \beta)$ is a function of parameters β and explanatory variables. More generally, the number of alternatives may vary across different individuals, so that m choices become mi choices.

The first-order conditions for the Maximum likelihood estimator β are that it solves

$$\frac{\Delta L}{\Delta \beta}\sum_{i=1}^{N}\sum_{J=1}^{M}\frac{yij}{pij}\frac{\Delta pij}{\Delta \beta ij} = 0. \tag{6}$$

This is usually nonlinear in β. The distribution of yi-is necessarily multinomial which ensures consistency as then $E[yij] = pij$.

Maximizing the log-likelihood function with respect to the parameters:

$$\frac{\Delta LL}{\Delta k} = \sum i[yik - pik].$$
$$\frac{\Delta pik}{\Delta \beta j} = pijxij - pijpijxi \quad \text{forj} \neq \text{k}, \frac{\Delta pij}{\Delta \beta j} = -pijpij. \tag{7}$$

The second-order condition becomes

$$\frac{\Delta L}{\Delta \beta i}\frac{\Delta L}{\Delta \imath k} = -\sum_{i=1}^{N}\sum_{j=1}^{j} pij(\delta ij - pij)xix\imath i, \tag{8}$$

where δij is an indicator variable equal to 1 if $j = k$ and equal to 0 if $j \neq$ k.

Unlike the standard regression analysis, the parameter value (β) is not directly interpretable as the effect of the change in the explanatory variable on the mean or expected value of the dependent variable. In particular, for multinomial logit models, a positive regression parameter does not mean that an increase in the explanatory variables leads to an increase in the probability of that alternative. Instead, interpretation for the multinomial logit model is relative to the reference or base category group, in which this study used nonadopter as a base category [40] (see Table 2).

3.6. Description, Measurement, and Hypothesis of the Study. The measurement and description of variables are shown in the following table.

4. Results and Discussion

4.1. Introduction. This chapter presents the results of the descriptive and multinomial logit model regression analysis of the study. The first part provides descriptive statistics, while the second part presents a regression analysis where an examination of the results based on the equation specified in the model specification section is presented. The descriptive analysis made use of tools such as mean, percentage, and standard deviation. Multinomial logit was used to estimate the determinants of modern agricultural technology adoption in the study area.

4.2. Descriptive Statistics

4.2.1. Demographic, Socioeconomic, and Institutional Characteristics of the Households. Table 3 shows that the mean age of the household is 43.475 years with a standard deviation of 11.082. The average cultivated land size of the household head is 1.854 hectares with a standard deviation of 1.233. The mean distance from the market is 8.98 kilometers with a standard deviation of 9.356. The mean of active household members is 1.812 people with a standard deviation of 1.183. The mean of tropical livestock units is 6.382 units with a standard deviation of 4.232. The mean of extension contacts is 0.994 with a standard deviation of .434. The information in the table above shows that out of a total of 362 households in the sample, 93.37% are male-headed households. Of the sample households, 90.6% of household heads are married. Of the sample households, 45.3% of household heads are engaged in off-farm activities. Similarly, 48.1% of sample households are access to credit. Of the sample households, 67.1% of household heads have certified land ownership. Finally, of the sample households, 44.8% of household heads are literate.

Table 4 shows that 219 (60.5%) households did not apply new agricultural technology, 34 (9.39%) households were used improved seeds, 43 (11.88%) households were apply herbicides, 29 (8.01%) households were used row planting,

Table 2: Measurement, description of variables, and expected sign.

Name of variable and symbol	Description of variable	Measurement of variables	Expected sign I	H	R	IH	IR	IRH	Sources
Dependent variable	—	—							
Adoption	Categorical variable	0 = nonadopter; 1 = improved teff variety; 2 = herbicide; 3 = row planting; 4 = improved seed + herbicide; 5 = improved seed + row planting; 6 = improved seed + herbicide + row planting							
Independent variable									
Gender (sex)	Dummy variable	0 = female 1 = male	+	+	+	+	+	+	[28]
Age (age)	Continuous variable	Measured in year	+	+	+	+	+	+	[41–44]
Marital status (mstr)	Dummy variable	0 = Single 1 = married	+	+	+	+	+	+	[28]
Education (educ)	Dummy variable	0 = illiterate 1 = literate	+	+	+	+	+	+	[18, 45, 46]
Cultivated land size	Continuous variable	Measured in hectors	+	+	−	+	+	+	[28, 46, 47]
Off-farm participation	Dummy variable	0 = No 1 = Yes	+	+	+	+	+	+	[6, 20, 48, 49]
Livestock unit (tlu)	Continuous variable	Total livestock owned (in TLU)	+	+	+	+	+	+	[14, 15, 50]
Market distance (distancefrommkt)	Continuous variable	Measured in kilometers	–	–	–	–	–	–	[25, 27]
Credit access (credit)	Dummy variable	Access to credit service (1 if yes)	+	+	+	+	+	+	[20, 46, 50, 51]
Extension visit (extensionvisit)	Continuous variable	Measured in the number of contact by extension agents per year.	+	+	+	+	+	+	[46, 52]
Land tenure security (lantenur)	Categorical variable	0 = not certified 1 = certified	+	+	+	+	+	+	[46, 50, 53]
Active household member (activehhd)	Continuous variable	Measured in number	+	−	+	+	+	+	[54]

Note: I = improved seed, H = herbicide, R = row planting, IH = improved seed + herbicide, IR = improved seed row planting, IRH = improved seed + row planting + herbicide.

Table 3: Description and summary statistics of the variables used in the analysis.

Variable	Description of variable	Mean	Standard deviation
Sex	Sex of the household head (male = 1)	0.934	0.249
Age	Age of household head (years)	43.475	11.082
Educational level	The educational level of the household head (literate = 1)	0.448	0.498
Marital status	Marital status of household head (married = 1)	0.906	0.292
Off-farm participation	Off-farm participation of household head (yes = 1)	0.453	0.498
Cultivated land size	Cultivated land size of household (hectors)	1.854	1.233
Distance from market	Distance from the market (in kilometers)	8.98	9.356
Credit access	Access to credit (yes = 1)	0.481	0.5
Extension contact	Extension contact (number)	0.994	0.434
Tropical livestock	Tropical livestock unit (number)	6.382	4.237
Active household member	Active household member (number)	1.812	1.138
Lantenur security	Land tenure security of household head (certified = 1)	0.671	0.47

12 (3.31%) households used improved seeds + herbicides, 12 (3.31%) households were applied improved seeds + row planting, and the remaining 13 (3.59%) households were applied improved seeds + herbicides + row planting.

4.3. Econometric Analysis. Before going into the basic steps of regression and model interpretation, it is imperative to check whether the data set suffers from multicollinearity. Therefore, the study tests for multicollinearity for both categorical and continuous explanatory variables by using the test of contingency coefficient and variance inflation factors. For continuous explanatory variables, the mean-variance inflation was found to be less than 10, and the contingency coefficient or correlation coefficient between all categorical explanatory variables was found to be lower than

Table 4: Percentage distribution on choice variable.

Modern agricultural technology adoption	Freq.	Percent
Nonadopter	219	60.50
Improved seed	34	9.39
Herbicide	43	11.88
Row planting	29	8.01
Improved seed + herbicide	12	3.31
Improved seed + row planting	12	3.31
Improved seed + herbicide + row planting	13	3.59
Total	362	100.00

0.85. Therefore, there is a free from multicollinearity problem in both categorical and continuous explanatory variables. Additionally, the goodness of fit was conducted by using Hosmer Lemeshow, and the result of the test suggested that the model has acceptable measures of fit. Finally, independent irrelevance alternatives were tested to check whether deleting or removing one alternative outcome variable does not affect the model, and the result of the test revealed that adding or removing substitutions from the model does not affect the percentage difference between the remaining results. Therefore, this study confirms that the multinomial logit model is appropriate and applicable. Finally, robust regression has been used to control the problem of heteroskedasticity and nonnormality.

4.3.1. Determinants of Modern Agricultural Technology Adoption for Teff Production. The parameter estimates from the multinomial logit model were used to estimate the factors affecting farmers' adoption of modern agricultural technology adoption for teff production. The results of the multinomial logit model have been presented in Table 5. The base category is nonadoption, where results of alternative packages are compared. The model's validity was tested using a variety of postestimation tests. The Wald test is used to ensure that all regression coefficients are jointly equal to zero and is rejected with $[\chi^2\ (78) = (2175.98);\ P > 0.001]$. The outcome of the Hausman test for the IIA assumption reveals that all of the alternative packages are distinguishable in terms of the model variables. To test for multicollinearity, the VIF for continuous variables and the correlation matrix for categorical variables were also computed, and the results show that there is no major multicollinearity problem across the explanatory variables. Finally, the problem of heteroscedasticity and nonnormality was addressed using robust regression.

Based on the estimated result, the sex of household heads has a positive and significant effect on improved seeds, improved seeds + row planting, and improved seeds + herbicides + raw plantations packages of agricultural technologies. This is because male-headed households are more motivated to apply all packages of modern agricultural technologies. If the households are the male head, then the probability of applying improved seeds, improved seeds + row planting, and improved seeds + herbicides + raw plantations increases by 5.7%, 5.1%, and 7.1%, respectively, compared to those who do not use all other things being equal. It can be explained that male-headed households have better access to information, agricultural inputs, information, extension, and credit services than female-headed households. This study is consistent with [28, 55].

The coefficient of the age of household heads has a positive and significant effect on the adoption decision of modern agricultural technologies packages. This is because the experienced farmers in Minjar Shenkora woreda are more likely to adopt farm technology and have greater flexibility in accepting new ideas, other things being constant. The marginal effect indicated that when the age of the household head increases, then the probability of applying improved seeds + herbicides + raw planting technology increases by 3.1%, keeping other variables constant. This is consistent with the study of [41–44, 56].

The variables of the educational level of the household head have a positive and significant effect on the adoption of herbicide and improved seed + row planting technologies at a 5% level of significance. This is because farmers in Minjar Shenkora woreda with the literate household head are more likely to adopt as they were able to acquire, analyze, and evaluate information on modern technology, market opportunity, and its implied benefit. So, education was expected to strongly encourage the adoption of households. The marginal effect shows that the farmers are literate, then the probability of applying herbicides and improved seed + row planting technology increases by 8.5% and 3.5%, respectively, while other things remain constant. This study is in line with the study of [18, 46].

The coefficients of the marital status of household heads have a positive and significant effect on the application of improved seeds + row planting and improved seeds + herbicides + raw plantations packages of modern agricultural technology adoption at 1% level of significance. The positive sign is that married farmers are more likely to adopt all packages of modern agricultural technologies in the study area, other things constant. The marginal effect indicates that if the household is married, then the probability of applying improved seeds + row planting and improved seeds + herbicides + raw plantations increases by 2.7% and 1%, respectively, compared to singles, all else being equal. This shows that the adoption decision of the household head is influenced by the attitude and readiness of the spouse to technology, so it is easier for the married household to use modern agricultural technology and work together with a spouse to increase teff productivity. This result is in line with the study of [28, 57].

The coefficient of off-farm activities of the household heads has a positive and significant effect on the adoption decision of improved seed + herbicide + row planting technologies packages of modern agricultural technologies in the study area at a 10% level of significance. This is because farmers also cope with risk by generating incomes from off-farm activities and solving the liquidity constraints of the farmers. The marginal effect shows that when rural households are participating in off-farming economic activities, then the probability of adopting improved seed + herbicide + row planting technologies increased by 3.4%, relative to counterfactual. This study is consistent with the study of [6, 20, 48, 49].

Table 5: Multinomial logit coefficients and marginal effect nonadopter is reference or base category.

New agricultural technology adoption choice												
Variables	Improved seed		Herbicide		Row planting		IH		IR		IHR	
	Coef. (SE)	dy/dx	Coef. (SE)	dy/dx	Coef. (SE)	dy/dx	Coef. (SE)	dy/dx	Coef. (SE)	dy/dx	Coef. (SE)	dy/dx
Sex	2.974** (1.391)	0.057	0.511 (0.613)	0.086	0.845 (1.024)	0.045	0.679 (1.302)	0.013	13.47*** (0.766)	0.051	14.29*** (1.024)	0.071
Age	0.0252 (0.0225)	0.041	0.00270 (0.0193)	0.071	0.0097 (0.0215)	0.031	0.0272 (0.0324)	0.051	0.0167 (0.0323)	0.21	0.082*** (0.0242)	0.031
Education	0.153 (0.444)	0.013	0.841** (0.395)	0.085	0.374 (0.437)	0.021	0.312 (0.635)	0.011	1.680** (0.820)	0.035	0.503 (0.663)	0.051
Marital status	0.0597 (0.600)	0.016	0.332 (0.639)	0.035	0.358 (0.828)	0.029	1.392 (1.146)	0.064	13.08*** (0.681)	0.027	14.27*** (0.963)	0.010
Off-farm participation	0.396 (0.462)	0.020	0.114 (0.356)	0.012	0.133 (0.434)	0.011	0.632 (0.822)	0.017	0.226 (0.653)	0.041	1.343* (0.707)	0.034
Cultivated land size	0.370 (0.259)	0.017	0.249* (0.132)	0.035	−0.472** (0.216)	−0.034	0.544* (0.301)	0.013	0.572* (0.302)	0.061	0.686** (0.310)	0.024
Distance from market	−0.105*** (0.0187)	−0.075	−0.0170 (0.0245)	−0.01	−0.0201 (0.0224)	−0.051	−0.0014 (0.0367)	−0.010	−0.0218 (0.0282)	−0.011	−0.0285 (0.0463)	−0.013
Credit	0.883** (0.449)	0.043	0.302 (0.367)	0.041	0.156 (0.412)	0.019	0.669 (0.722)	0.017	1.335* (0.805)	0.053	0.748 (0.620)	0.023
Extension contact	1.202** (0.561)	0.046	0.716 (0.511)	0.051	1.398*** (0.383)	0.089	1.180** (0.500)	0.023	0.961 (0.608)	0.061	0.480 (1.036)	0.021
Tropical livestock unit	0.136** (0.0611)	0.017	0.00373 (0.0456)	0.041	0.0813** (0.040)	0.026	0.0462 (0.0737)	0.031	0.136* (0.0694)	0.061	0.0166 (0.0597)	0.012
Active household	0.412** (0.184)	0.016	−0.461*** (0.145)	−0.043	0.153 (0.199)	0.034	0.342 (0.209)	0.046	0.291 (0.259)	0.021	0.640** (0.260)	0.011
Land tenure security	0.0426 (0.454)	0.063	0.359 (0.374)	0.043	0.243 (0.504)	0.020	0.163 (0.660)	0.035	0.872 (0.796)	0.012	0.0105 (0.823)	0.001
Constant	6.14*** (1.970)		2.427** (1.194)		5.02*** (1.684)		−5.7*** (1.706)		34.4*** (2.504)		34.23*** (2.979)	

Note. HI = herbicide + improved seed, IR = improved seed + row planting, IHR = improved seed + herbicide + row planting Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Multinomial logistic regression: log pseudolikelihood = -398.58937; the number of obs = 362; Wald chi2(78) = 2175.98; prob > chi2 = 0.001; pseudo $R2$ = 0.1701.

The coefficients of distance from the market have a negative and significant effect on the adoption of improved seed agricultural technologies. The negative association indicates that profiling people living far from markets is less likely to adopt improved seed technology. The rationale is that farmers' proximity to roads and all-weather markets is essential for the timely provision of inputs and output processing and leads to a reduction in input market transportation costs, output, and market information. The marginal effect indicates that if the distance to the market is increased by one kilometer, the probability of adopting an improved seed decreases by 7.5%, compared with non-adopters, keeping all other variables constant. This study is consistent with the study of [23, 25, 27].

The extension contact has a positive and significant effect on the applications of improved seed and improved seed + herbicide at 5% level of significance and row planting agricultural technologies at 1% level of significance. The positive association indicated that households frequently contacted by extension agents will increase the likelihood of adopting improved seed, row planting, and improved seed + herbicide technology, respectively. The marginal effect shows that as the frequency of extension contacts increases, the probability of applying improved seed, row planting, and improved seed + herbicide increases by 4.6%, 8.9%, and 2.3% respectively, relative to nonadopter, and all other variables remain unchanged. This implies that frequent contact with extension agents creates opportunities for farmers to promote effective dissemination of complete agricultural information to farmers, thereby helping farmers to make informed decisions about the application of new and modern agricultural technology. This study is consistent with the study of [46, 52, 58].

The variables of tropical livestock units have a positive and significant effect on the adoption of improved seed and row planting at 5% level of significance and improved seed + row planting technologies at 10% level of significance. The positive association indicates that as farmers have more tropical livestock, then the probability of adopting improved seed, row planting, and improved seed + row planting technology increases. The marginal effect indicates that as farmers have more livestock production units, the likelihood of adopting improved seed, row planting, and improved seed + row planting practices increases by 1.7%, 2.6%, and 6.1%, respectively, in ration to nonadopter, while all other variables remain unchanged. This shows that having a flock of livestock also encourages the adoption of agricultural technology because farmers who possess a flock of livestock can have a large source of income and serves as a source of inputs (organic fertilizer, herbicide, and pesticide). Furthermore, the presence of tropical livestock units would be important for the users of animal manure to increase soil fertility, but it is an obstacle for adopting chemical fertilizer where farmers do prefer utilizing manure without incurring product and transportation costs. This result is confirmed with the study of [14, 15, 45, 50].

The variables of access to credit have a positive and significant effect on the adoption of improved seed at 5% level of significance and improved seeds + row planting technologies in the study area at 10% level of significance. This means that if the households have got credit facilities, then the farmers become more motivated to adopt improved seeds and improved seeds + row planting. This implies when farmers have enough credit, they can purchase improved seeds when needed and in the desired quantities and qualities. The marginal effect indicated that when rural households are access to credit, then the probability of adopting improved seed and improved seed + row planting increased by 4.3% and 5.3%, respectively, relative to non-adopters, while keeping other variables constant. This study is in line with the study of [20, 46, 51].

The variables of cultivated land size have a positive and significant effect on the adoption decision of all packages of modern agricultural technologies except row planting technology. This is because when farm size increases, the likelihood of farmers considering farming activity as full time or way of life increases and hence more likely motivated towards adopting new agricultural technologies except for row planting technology. The marginal effect shows that if the farmers are with more cultivated land, then the probability of applying herbicides, improved seeds + herbicides, improved seed + row planting, and improved seeds + herbicides + raw planting technology results in increases by 3.5%, 1.3%, 6.1%, and 2.4%, respectively. This implies that greater land size serves as a security against the risk of crop failure. This result is consistent with the study of [40, 46, 47]. But, when the size of the cultivated land is increased, then the adoptions of row planting are decreased by 3.4%, keeping other variables constant. This result is consistent with the study of [59].

The variables of active household members have a positive influence on the application of all packages of modern agricultural technologies except row planting technology. This is because when the number of active household members is increasing, then the likelihood of adoption of labor-saving technology is decreasing and decided to adopt labor-intensive technology. So, that adoption is less attractive for those with limited family labor or those operating in areas with less access to labor markets. If an active household member increases by one person, then the probability of applying improved seed and improved seed + herbicide + raw planting increases by 1.6%, and 1.1%, respectively. This study is consistent with the study of [48, 60]. However, if the active household members increased by one person, then the probability of the adoption of herbicide technology is decreased by 4.3% relative to counterfactual. This study is consistent with the study of [54].

5. Conclusion and Recommendation

5.1. Conclusion. The adoption of modern agricultural technologies is influenced by many factors. These factors differ between farmers living in different geographical environments and different socio-cultural perspectives and in different economic environments with different agricultural investments. The data were collected from 362 rural households. This study employed descriptive statistics and multinomial logit models. A multinomial logit model estimation result revealed that sex of household head, distance from market, access to credit, extension contact, number of tropical livestock unit, number of active household members, educational level of household head, cultivated land size, marital status of household head, off-farm activities participation, and age of household heads are the determinants of modern agricultural technology adoption for teff production in the study areas.

5.2. Recommendation. Based on the finding, this study recommended the following points. The federal and regional government of the country, agricultural development office, nongovernmental organizations, and donor agencies should work in collaboration with the farm households to increase access to information, increase the availability and quality of extension contact, access to credit, encourage off-farm participation, and provide training and consulting services to increase the adoption of modern agricultural technologies. The government should pay special attention to women's empowerment by treating them as a special agricultural extension contact, facilitating women's special loans, easily accessible to increase the uptake of agricultural technologies. Concerning distance from the market, the government should give more attention to improving the existing market centres in the study area by building roads and providing good means of transport for farmers to improve the acquisition of improved seeds, herbicides, and crops for teff production to increase teff production in Minjar Shenkora woreda.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Consent

All participants gave consent.

Conflicts of Interest

All the authors declare no conflicts of interest.

Authors' Contributions

All authors contributed to the conceptualization of the study, data analysis, and/or write-up of the manuscript. All authors read and approved the final manuscript.

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