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RESEARCH ARTICLE

Assessment of Factors Influencing Use of Insecticide among Smallholders Farmers in Dale Sadi District of Kellem Wallega Zone, Ethiopia

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Abstract
The research aimed to evaluate influences upsetting the application of insecticide among smallholder farmers in Dale Sadi District. The data collection method is employed by randomly selecting 138 farmers, and the data type used is a cross-sectional type of data. Descriptive and econometric analysis was employed for data analysis. Descriptive analysis revealed that 72.46% percent of sample respondents applied insecticide, and the rest, 27.54%, did not apply it. Probity model analysis revealed that education status, farm size, total livestock owned, credit access, frequency of extension contact, and farmer's experience in the use of chemical pesticides have a positive influence and significantly affect the probability of being an insecticide user. Therefore, stakeholders should focus in enhancing continuous training, conserving existing farmland, improving market infrastructure, and increasing access to credit services, enhance the use of chemical insecticide to increase farm productivity among smallholder farmers with less cost to transform and enhance the role of agriculture.

Keywords: Insecticide Adoption; Probit Model; Agricultural Technology; Intensity; Smallholder Farmers; Ethiopia.

Introduction

Agriculture continues to be at the heart of the economies of the countries of developing countries(Habtamu R, 2020). The sector plays an important role in economic development, environmental responsibility, and social progress; with 60percent of the people in the global less developing countries depending on agriculture, it still provides livelihoods for the majority, in particular in developing countries, and holds the labor and help as raw material for the development of the industries and services sectors (Adhikari *et al.*, 2020). For instance, agriculture supplies food for the people as well as a major resource source of industry, e.g., fiber crops for the manufacturing of ropes and strings. Agricultural production in less developing countries is often characterized by low production due to less awareness to adopt agricultural technology, such as a limited skill base, application of technology, high vulnerability insects and pests of the commodities, high fluctuations in production, and high state dependency (Shita *et al.*, 2018).

In Ethiopia, agriculture is source of income for more than 85% of the total population, and about 15 million smallholder farmers use agriculture as their source of job opportunities. Agriculture plays a vital role and is the last option to take off poverty and maintain the national economy of the country (Abate *et al.*, 2015). Therefore, the sector was a key sector both for poverty alleviation and materializing growth and transformation plans in Ethiopia. Role of agriculture discussed above placed the sector at the center of development and policy interventions(Damtew, 2017). The problem of weeds and insects potentially reduces crop productivity if the application of insecticides is not undertaken both before harvest and post-harvest for

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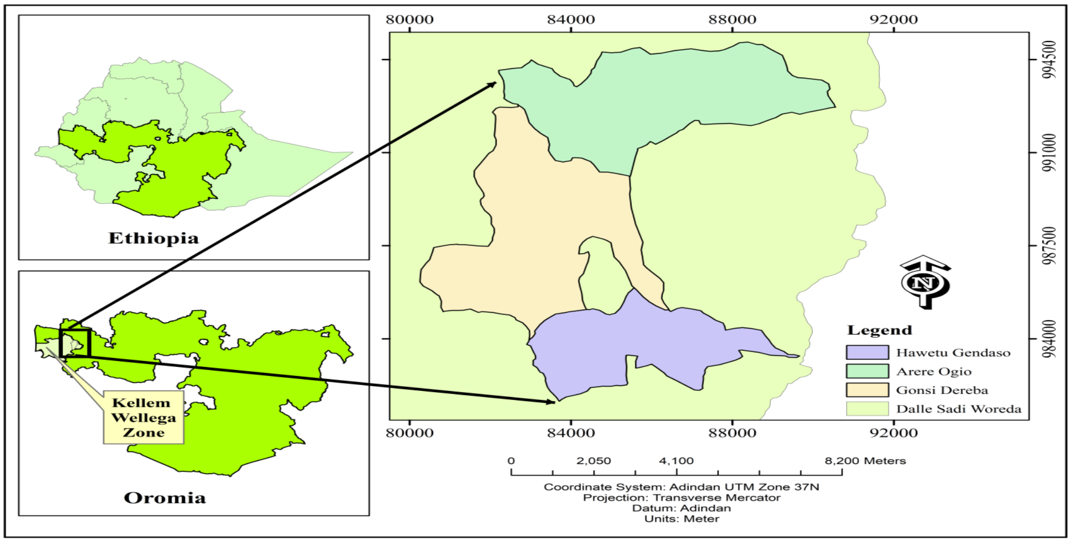


Figure 1: Map Selected Kebeles (source: GIS)

insecticide. Therefore, it's recommended for farmers apply pesticides on crops after harvest to promote long life for crops and use it in the future and have to protect against insects & diseases by using insecticides (Abate *et al*., 2015).

Research on rising herbicide use and its driving forces in China showed that migration, irrigation, farmers' education were positively associated to herbicide use (Huang *et al*., 2017). The result of truncated model revealed to measure volume of chemical fertilizers applied being male, model farmers, family size, land size, livestock ownership, access to credit, number of extension contact and distance of farmers to input market are determinant's of commercialization of input market as buyer (Chala & Chalchisa, 2017).

Studies conducted in Ethiopia concentrated on the adoption of chemical fertilizers and varieties of improved seeds like wheat, maize, teff, and others (Mutale *et al*., 2017). However, scanty literature concerning the application of insecticide to conserve crops for long life after post-harvest, and little information is available on types of insecticide and intensity of use of the product. The district has consisted of low technology users and low agricultural extension served, which leads to low productivity seen at most. Therefore, this study proposed to answer factors affecting the application of insecticides by farmers of Dale Sadi Woreda Kellem Wollega Zone, where such a study has not been conducted before to fill the gap.

Methodology

Description of the District

Dale Sadi district of Kellem Wollega Zone is found about 600 kilometers away from the capital city of Ethiopia in the west and was purposively selected to undertake the study. The district found approximately between 3506'34.49" E & 35011'15" E longitude and 8043'35"N and 9007'15"N latitude. The population of the district is projected to be 101,850, from which 54347 and 47513 are female and male, respectively. The annual average temperature of the woreda is estimated to be 27°C. According to the agro-ecology classification, the study area is categorized into 2 (two) climatic zone. Among this, about 63% is in midland/weyna dega and 37% lowland/kola. District economic activity was characterized by a mixed farming system which is crop & livestock production (Dale Sadi Agricultural Office, 2022). Map of selected kebeles are illustrated in Figure 1.

Data Type and Sources

Primary data was collected using a structured survey questionnaire that consists of a questionnaire pre-tested to evaluate the simplicity, appropriateness, understanding as well as relevance of the questionnaire in line with objectives. Data collection was undertaken from January 2022 to April 2023. Subordinate data was composed from various sources like book, journal, and article to support primary data.

For this study, two-stage random sampling techniques were used to select sample respondents. 1st, kebeles (peasant association) in the study area were categorized into midland & lowland based on their agro-climatic zone of 27 total kebeles. In the woreda, 17 kebeles and 10 kebeles were found in the midland and lowland, respectively. From 17 midland kebeles, Awetu Gendaso and arere Ogiyo were nominated arbitrarily, and Gonsi Dereba was nominated among low land strata. In the second stage, from a total of three(3) selected kebeles, a total of 138 agriculturalists were dogged using the Cochran formulae given by

$$N = \frac{Z^2 \ pq}{e^2} \qquad (1)$$

Table 1: Representative sample Kebeles and Samples house holds in the Kebeles

Study area		*Sampled kebeles grounded on a 10% probabilities levels*		
		Name of kebeles	*Total hhs of Kebeles*	*Sample size using PPS*
Kellem Wallaga Zone	Dale Sadi district	Awetu-Gandaso	480	54
		Arere-Ogiyo	320	40
		Gonsi-Daraba	362	44
Total			1162	138

Sources: Private computations, 2022

N-sample respondents,
Z -value of deviation under t-table at 95%

$$z_{\frac{\acute{a}}{2}} = 1.96$$

p-` percentage of population consisted in the sample (0.25); q = 1-p; q = 0.75 and e = putative error level which is = 0.05. When the estimated value of P = 0.1, q =1-p = 0.9, Z = 1.96 at 95% confidence level (Cochran, 1997). Therefore, $N = \frac{1.96^2(0.1)(0.9)}{(0.05)^2}$ = 138. The number of respondents for the study kebele was limited by probability proportional to the size of the population (table 1).

Expressive analyzes

To describe explanatory variables for each user and non-user of insecticide-based farm activity, descriptives statistics like percentages(%), mean, standard deviation, minimu, maximu, figures, as well as cost-benefit analysis for comparison of insecticide application were used. Furthermore, the t-test and chi-square test were applied to determine whether or not there were substantial variances in house hold adopters of insecticide in terms of incessant as well as definite variable, correspondingly.

Econometrics analyzes

In this study, probit-model analysis was applied to estimates the likelihood of decision to apply insecticides for crops to sustain the durability of agricultural output. Limited dependent models like the restrictive Tobit model, Double hurdle models, and Heck-man two stage models were employed to analyze participation decisions(Verbeek, 2017). Therefore, depending on the natures of the dataset and underlying assumption of the model, appropriate models were used among them for the study. The Tobit model was used to analyze under the assumption that the two decisions (participation and non-participation) are influenced by the same set of factors adjusts the Tobit models to over-come the restrictives assumptions characteristic in it, specifically, he suggested the "double hurdle" models challenges the problem of too numerous zeros in survey data by generous special treatments to the participations decisions. The Double-hurdle and Heckman models are similar in identifying the rules governing the discrete (zero or positive). However, the Heckman model assumes that only non-participant respondents can report zero intensity of market participation. The model extra assumes that personages who contribute in the markets do not reports zeros values at all (Cragg, 1971). For these reasons, this approach was not considered for our analysis.

The doubles hurdles models described zero standards in both result phases. In the first stage, it described zero coming from non-participants, and those in the 2nd phases arise from non-sales because of the respondent's thoughtful decisions or randoms circumstances[25]. In this regards, the double hurdles models can be measured as an enhancement both on the standards Tobits as well as Heckman models. The DHM has two(2) phases; the first stages (contribution decisions) and the second (intensity of participations). The data were investigated using Stata Version 15.0 software. The structures of the double hurdle model is as follows:]

$$Y_1^* = \beta_1 X_i + \varepsilon_i \tag{2}$$

$$Y^*_1 = \begin{cases} 1 \textit{ if smallholder farmers use insecticide}; Y^* > 0 \\ 0 \textit{ if } Y^* \le 0 \textit{ otherwise} \end{cases} \tag{3}$$

Y_1^* is a concealed reliant on variables that indicates a decisions to use insecticide. Take 1(one) if user and zero other-wise; X_i implies descriptive variable that might affects the decision, β_1 indicate vector of parameter and ε_i represent random error (Verbeek, 2017).

The probit and logit model differs in the requirement of dissemination of errors term 'ε'. If the errors terms in equation '2' charts a normal distributions, it is a probit-models and logit if random distribution. Similar to the logit model, the advantage of the probit model was those predicted probabilities are limited between zero and one. For the probit model, $F(z)$ is the increasing distributions functions (CDF) of the standards normals distributions (φ .).

$$F(z) = \varphi(X'\beta) = \int_{-\infty}^{X'\beta} \varphi(z)\,dz \tag{4}$$

Where $\varphi(z)$. is standard normal density; $\varphi(z) . = 2\pi^{-\frac{1}{2}}$. $\exp\frac{-Z^2}{2}$. (5)

The log=likely-hood functions for the double- hurdle model is:-

Table 2: Independent variables were included, and a hypothesis formulated

Code of variables	*Description*	*Type*	*Measurement*	*Expected effect*	*Supportive studies*
APPIn	Application Decision of Insecticides	Dummy dependent	1=yes & 0 if not		
EDUHH	Education of household	Continuous	Schooling	Positively	Naidu & Gurmu, 2021
FAMSH	A family member of the household	Continuous	Adult equivalent	Negatively	Jebesa, 2017
OFFICO	Income from off-farm activities	Dummy	1=yes, 0= otherwise	Positively	Eschen et al., 2024
FREXC	Frequency of extension contact	Continuous	1=model, 0= if not	Positively	Tadesse et al., 2022
HCRED	Household access to credit	Dummy	1=yes, 0= if not	Positively	Sci & Res, 2018
LIVPO	Livestock possessed/handled	Continuous	TLU	Positively	Ikuemonisan, 2024
TFMSI	Total farm size owned	Continuous	Hectare	Positively	Gurmu & Weldeabzgi, 2023
EXCAG	Experience in the use of agrochemical	Continuous	Number of years	Positively	Chala & Chalchisa, 2017
MARINF	Market information	Continuous	1=yes, 0= if not	Positively	Nhamo et al., 2024
NEMAR	nearest market distance in an hour	Continuous	Walking on foot	Negatively	Habtamu et al., 2024
SEXHH	Sex of sampled household	Dummy	1=male, female = 0	Negatively	Keba, 2019

Source: Own manipulation from literature (2022)

$$\log L = \sum \ln\left[1 - \Phi\left(\alpha Zi\left(\frac{\beta X_i}{\sigma}\right)\right) + \sum \ln \Phi(\alpha Zi)\frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X_i}{\sigma}\right)\right] \quad . \quad (6)$$

Where Φ and ϕ are the standards normals cumulatives distributions functions as well as densities functions, correspondingly, log-like-lihood estimations is predictable using the maximu likely-hood estimatiosn (MLE) techniques.

Variables & Expected hypothesis

Application of Insecticide (APPIn)

It is a dummy type of dependent variable which characterizes the likelihood of applying insecticide. It is '1'if the user and '0' if not. Autonomous variable applied in Models analyzes are listed le 2).

Result and Discussion

In this part, the results of descriptive and econometric analysis of the data collected were presented. A descriptive analysis of survey results is shown by using tabular and figures of insecticide applied.

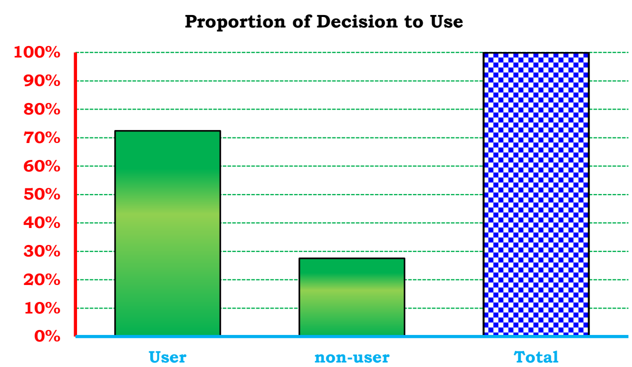
Descriptive Analysis

The proportion of households

Out of a total of 138 respondents, 100(72.46%) farmers were reported as a user of insecticides, while 38(27.54%) farmers were non-user of insecticides (Figure 2).

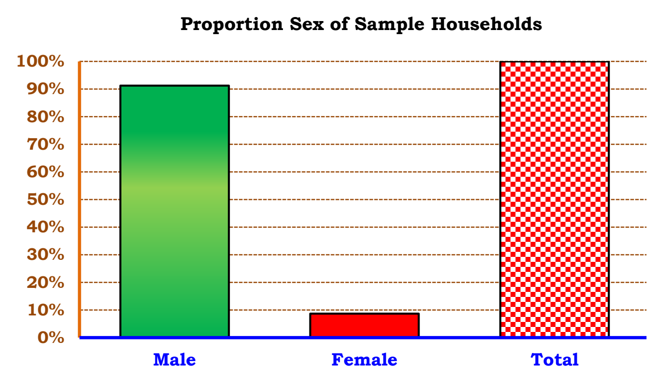
Concurrently, from the total sample households included in the sample, 126 and 12 were male-headed and female-headed households, respectively (Figure 3).

Education status, farm size, total livestock owned, credit service, frequency of extension contact & experience in the use of chemical pesticides were statistically significant to the application of insecticide.



Source: Data computation (2024)

Figure 2: The graphical representation-based decision to use



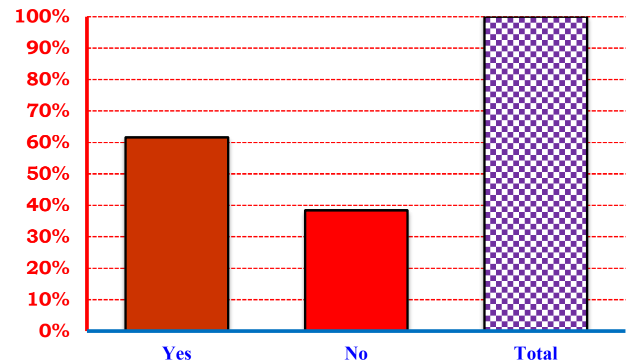
Source: Data computation (2024)

Figure 3: Graphical representation of the sex of respondents

Economic effectiveness analysis was aimed at comparing the cost of applying specific technology. Economic benefit analysis is useful in such activities as agricultural productivity and crop protection, and it is sometimes easier to measure benefits in physical output. Therefore, we might receive higher benefits by applying agricultural technologies for better production and long life. Farmers undecided about applying insecticide to their crops early harvesting lose 100% of cash from their crops within three months. Accordingly, to (Abate *et al.,* 2015), the technology can increase crop productivity if added to the crops on the field (table 3).

Description from table 4 presented below shows that the mean household head education of users of insecticide is 7.59, and that of non-user was about 2.73 years of schooling. There is a substantial mean variance available between users & non-user of insecticides in their education level with a t-value (t = -10.29) indicating significance at a 1% significance level. Similarly**,** the survey results in table 3 show that application of insecticides, the mean family size of user & non-user was about 5.47 & 6.50 adult equivalents, respectively, concerning family members with a t-value of (t= 3.83) which is significant at 1% significances levels.

Accordingly, the mean years of sample respondents in the application of agrochemicals we about 4.75 & 1.29 years for users & non-user, respectively. The (t = -8.13) in the table indicates that the experience of farmers in the use of agrochemicals was statistical significants at a 1% probabilities levels. Likewise, in terms of farm size, table 4 below show there is a significant mean difference between user & non-use at a 1% probability level with a t-value (t = -8.89). Accordingly, the result of the survey also shows mean livestock units of users & non-user of insecticides were about 5.92 & 2.38 TLU, respectively (Table 3).



Source: Data computation (2024)

Figure 4: The proportion of accessed Credit service

The result from the table below shows that about 113(81.88%) farmers reported having access to market information, whereas 25(20.29%) of the respondents reported they faced a lack of formal market information (see table 4). On the other hand, the variable was statistically significant by chi2 – value (χ^2 . = 58.96) & substantial at 1% significances level to the application of insecticide. Accordingly, the statistical mean difference reflects that smallholder farmers far from the market center resulted in less adoption of insecticides. The result from the inferential t-value (t= 12.33) for insecticides shows the statistical mean difference among the user and non-user farmers at a 1% probabilities levels.

Consistently, the result described in the below figure from sampled households, 85(61.60%) accessed credit

Table 3: Summary of Descriptive Statistics

(N= 138)	*User of insecticide*		*The non-user of insecticide*		*Total*				*ttest/ χ^2*
	(n = 100)		*n = 38*		*(n = 138)*				
Variables	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Min	Max	
Continuous									
EDUHH	7.59	2.67	2.73	2.50	6.25	3.40	0.00	13	-9.7***
FAMSH	5.47	1.27	6.50	1.72	5.75	1.48	2.00	12	3.83***
TFMSI	2.85	1.05	1.23	0.63	2.40	1.20	1.18	6.00	-8.89***
LIVPO	5.92	2.91	2.38	1.81	4.94	3.09	0.00	13.52	-7.00***
DMARK	1.80	1.12	4.37	1.02	2.57	1.59	0.50	6.00	12.33***
EXCAG	4.75	2.45	1.29	1.49	3.79	2.71	0.00	12.00	-8.13***
Dummy									
HACER	0.86	0.35	0.18	0.38	0.55	0.49	0	1	96.76***
MARINF	0.96	0.20	0.48	0.51	0.85	0.35	0	1	59.58***
FREXC	0.86	0.35	0.18	0.38	0.49	0.54	0	1	30.41***
OFINCO	0.96	0.20	0.48	0.51	0.28	0.45	0	1	5.95***

***, ** and * represent 1%, 5% and 10% significance level respectively
χ^2 = test for dummies
t-test = test for continuous
NS = not significant

services, and about 53(38.4%) respondents reported a lack of access to credit services. The variable was significant by ($\mathbf{x}^2$ = 96.76) to insecticide application at a 1% probability level (Figure 4).

Econometric Analysis

The econometric result was explained through bordering effect of independent variable and the likelihood of insecticide applied by farmers affecting unit intensification for incessant variable and being in the achievement for imitation independent variable. The analysis of primary data collected from sample households was carried out by Stata 15.0. A multicollinearity tests were accompanied as well as originate no thoughtful multicollinearity problem among the self-governing variables, designated by a means VIF of 2.57, which is less than 10. In additions, to alleviate the problems of hetero-scedasticity, standardizing robust standards errors were used. Breusch Pagan /Cook-Weisberg tests for heteroscedasticities tests also shows there were no problems with heteroscedasticities. Among eleven (11) independent variables used in probit model analysis, 6 (six) were significantly affecting the likely-hood of the decisions to use insecticides (table 4). The independent/explanatory were formal education household, a total unit of livestock, farm size, credit, frequency of extension to farmers, and experience in the use of chemical fertilizer.

Education level of sample respondents

The education status of smallholder farmers affects the likelihood of insecticide application positively & significantly. One grade increase in formal schooling of respondents increases the likelihood of adoption of insecticides by 1.1%, which is significant at a 5% probability level (table 4). This might be due to educated households having better skills, enough access to information, and being better aware of adopting new agricultural technology than less educated ones. The justification for this result indicates that as a farmer's education level increases, so does his ability to obtain, process, and apply relevant information, resulting in more intensive use of a new technology (Gurmu *et al*., 2024) "support this finding by reporting the positive role of education for the adoption of agricultural technologies use intensity in agricultural production activity operations".

Farm size

Holding other variables constant, the land size of household head owned had been positively and significantly associated with the application of insecticides. Thus, (table 4) shows an increase in a hectare of farmland might increases the likelihood of the decision to use insecticides on average by 2.8% & significant at a 10% significance levels. The optimistic sign of this variables suggests that households with larger farm sizes could have more tendencies to use pesticides than farmers that cultivate small hectares of land. Therefore, farmers who cultivate large hectare of land for production use large volume of insecticide, which in-turn increases the likely-hood of the decisions to habit new agricultural technology. Current investigation on factors of the decisions to use herbicide among small holder farmers in the Dale Sadi district of Kellem Wollega shows that education status, land size, and membership of a cooperative society influence positively and significantly (Eschen *et al*., 2024). Also, they concluded in their finding that farmer who applies herbicide increases their farm productivity like wheat than their counterpart non-users of herbicides. Concurrently, education enhances decisios architects by enabling them to reflect disapprovingly and custom evidence proficiently (Naidu & Gurmu, 2021).

Livestock owned

Analysis of the probits models consequence shows that the total unit of live-stock possessed by the respondent has a optimistic influence on the use of an insecticide. The bordering effects outcome presented that an increase on average by one unit total unit of livestock resulted in increasing the probability of adoption of insecticides by 1.3% & economically significant at a 5% probability levels (table 4). The optimistic influences of this variable indicates that farmers with a higher number of total live stock units possessed could have a higher chance to use insecticide than fewer owners since livestock may be castoff as a sources of revenue when selling live livestock and livestock product to afford the cost of buying pesticide, and livestock is considered among operating capital. The outcome is reliable with a discovery of (Abamagal, 2020) that entire live stock possessed by house hold bonces had a optimistic and substantial impacts on to uses of improved agricultural technologies.

Access to credit

The consequence underneath table shows credit service use among institutional factors, which have a optimistic and substantial effects on the application of insecticide at a 1% probability level. Citrus paribus, the shift from being lack to credit service to having credit service had led to an increase in the likelihood of chance to use insecticides by a 6.6% significance level (table 4). It suggests that admittance to recognition solves farms household's financial problems of adopting pesticides. The outcome also agrees with (Negatu *et al*., 2019), who state that credit uses were initiate to have a optimistic and substantial influences on the probabilities of adoptions as well as intensities uses of wheat row implanting.

Frequency of extension contact

This explanatory variable was meant to inspire technology uptake by farm households. Consistently, table 4 showed that being one more unit increment in extension contact

Table 4: Probit model estimation result of the decision to use

	If insecticides applied = 1, 0 = if not			
Variables	*Coefficient*	*Standard Deviation*	*Marginal effect (dy/dx)*	*p> |z|*
Gender of house hold head	-0.73	0.515	-0.041	0.219
Education status of household	0.193**	0.078	0.011	0.037
Family size	0.11	0.127	0.006	0.347
Farm size of household head	0.498**	0.241	0.028	0.08
Total livestock	0.235*	0.141	0.013	0.033
Distance of nearest market in an hour	-0.027	0.161	-0.002	0.865
Credit service	1.171***	0.489	0.066	0.002
Extension contact frequency	0.448***	0.221	0.025	0.007
Market information	0.385	0.506	0.022	0.424
Grower experiences in the use of pesticides	0.282**	0.105	0.016	0.029
Income from off-farm activities				
Constant/sigma	-4.381***	1.672		0.009
	Number of Respondents = 138			
	Waldchi2 (10) =38.85			
	Prob > chi2 = 0.000			
	pseudo R square = 0.8345			
	log pseudolikelihood = -13.44499			

* ,** & *** denote 10%, 5% & 1% level of probability respectively
Source: Computed from stata software, 2024,

increase the likelihood of practicing insecticide on average by 2.5% and significant at a 1% probability level. The farmers that frequently contact with developmental agents of the district have better access to information, and they have been able to adopt new technology to maximize their production and return. This is due to information, and technical help from extension workers may motivate farmers to adopt agricultural technology. The effect of frequencies of extensions exchange in-line with the finding of revealed that frequencies of extensions contacts was definitely associated to the adoptions of enhanced agrarian technologies. Though, the outcome contradicts the discovery revealing that household extension service was negatively related to the adoption decision of enhanced agrarian technologies amongst rice growers in Ghana (Denkyirah *et al.,* 2016).

Farmer's experience

Farmers' experience influenced the decision to apply insecticide significantly and positively at a 5% probability level. A year increment of farmers' experiences in the application of chemical products to crops led to an increase in the probability of sample respondents' adoption by 1.6% (table 4). The possible reason is that having more experience and knowledge on the use of chemical pesticides would increase the likelihood of application of insecticide to their field among smallholder farmers in agriculture. In this specific area, farmers' experience in the use of chemical pesticide plays a great role in the adoption of new agricultural technology since experience accumulated over time support to use of efficient technology in order to increase production. This show that farmers who have more experience in the use of chemical pesticides, which accumulated over time, might increase the probability of adopting agricultural technology when compared with a less experienced one. The result agrees with an investigation that experienced farmers have better access to production resources & can use amended agrarian efforts, and are predictable to be quicker in approving different inputs when compared with less experienced farmers (Senbeta & Worku, 2023).

Conclusion

Agricultural science is the back bone of the Ethiopian economy, and the development of the country is mainly dependent on the growth of this sector. Therefore, the application of technologies like insecticides, chemical fertilizers, and others were important elements of agricultural inputs and hence enhanced the development of agricultural transformation, thereby can promote the food security of the country's population. The outcome of the research might help different sectors like agricultural and related offices, input suppliers, and NGOs in assessing the major determinants of supportive technology like insecticides, herbicides, and fungicides in the study area and the need to strengthen access to credit services available and helps to bring equipment nearer to smallholder agriculturalists might affect the probability of using insecticide to crops and the field, in doing so could increase productivity per hectare and increase durability stored crops of smallholder farmers and thereby promote food security. Probit model results showed that education, farm size, livestock ownership, credit access, extension contact, and prior experience with agrochemicals significantly and positively influenced adoption. Among these, access to credit and frequency of extension services exhibited the strongest effects, underlining the importance of institutional support in facilitating technology uptake.

The results underscore that adoption of insecticide is not solely a matter of resource availability but also shaped by knowledge, institutional linkages, and farmers' prior exposure to modern inputs. Farmers with larger farm sizes and greater livestock assets were more willing to invest in insecticide use, suggesting that economic capacity plays a role in adoption decisions. Overall, enhancing agricultural productivity and ensuring food security in Ethiopia requires strengthening both human capacity (through education and training) and institutional capacity (through extension and credit services).

Generally, the result of the study recommended:

Enhance Farmers' Education and Training

Adult education programs, farmer field schools, and continuous training on integrated pest management (IPM) should be promoted to improve farmers' decision-making capacity.

Expand Access to Credit

Policymakers and financial institutions should design affordable and farmer-friendly credit schemes that reduce collateral requirements and enable smallholders to invest in inputs such as insecticides.

Improve Market Infrastructure

Investments in rural roads, input supply chains, and nearby marketplaces are essential to reduce transaction costs and ensure timely access to insecticides and related technologies.

Leverage Livestock Assets

Since livestock ownership positively influences adoption, linking livestock income with crop input financing (e.g., through cooperative savings and credit systems) could help farmers channel resources toward input purchases.

Encourage Experience Sharing

Experienced farmers should be engaged as "model farmers" in local extension programs to demonstrate the benefits of insecticide use and mentor less experienced peers.

Consent to Publication

All authors agree and consent for the article to be published

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Data Availability

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

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