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The drivers and intensity of adoption of beekeeping in northwest Ethiopia

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Abstract

Background: Beekeeping activity is carried out in most parts of Ethiopia. However, despite the favorable agro-ecology for beekeeping practices and the high number of bee colonies the country is endowed with, the level of beekeeping adoption is low.

Methods: This study was conducted to identify determinants of the decision to adopt beekeeping, and the intensity of adoption by using a cross-sectional data collected from 772 rural households in Northwest Ethiopia. Stratified random sampling method was used to select the households, and the data were collected using a questionnaire. To achieve the objectives, Heckman two-stage sample selection model was used.

Results: The result of the first step Heckman model revealed that age and educational level of the household head, household size, extension visits, training, incentive, home consumption of honey, major economic activities of the household, perception towards better hives, distance to the nearest marketplace, the number of years the household stayed in the village, and location were the significant variables influencing rural households' beekeeping adoption decision. The second step Heckman model revealed that livestock holding of a household head, number of extension visits, credit use, presence of honey bee pests, whether a household is engaged in swarm catching practices, and major economic activities of a household head were the variables that influence the intensity of beekeeping adoption significantly.

Conclusions: The findings of the study can be used to make evidence-based policy interventions to improve beekeeping adoption and the intensity of beekeeping adoption by rural households, which could also help to improve their livelihoods.

Keywords: Determinant, Rural household, Beekeeping adoption, Intensity of adoption, Heckman two-stage

Background

Beekeeping refers to the breeding and use of honeybees (*Apis mellifera* L.), and meliponiculture refers to the breeding and management of native stingless bees (NSBs) (family Apidae, tribe Meliponini) [1, 2]. Beekeeping is an important venture used for strengthening the livelihood of rural communities. It generates a variety of production assets [2]. It is a promising non-farm activity that can contribute to improve smallholder's income and the national economy. It has a substantial role in generating and diversifying the income of Ethiopian smallholder farmers and youth who do not have land. Ethiopia is the home of diverse fauna due to its varied ecological and climatic conditions that are suitable for beekeeping practices [3].

Ethiopia is known for its tremendous variation of agro-climatic conditions and biodiversity that favored the existence of diversified honeybee flora and huge number of honeybee colonies [4]. Ethiopia hosts around 6 million managed honey bee colonies and nearly 10 million feral colonies [5]. This made Ethiopia number one in natural

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honey production in Africa and the tenth in the world. However, there are several marketing, natural, and financial constraints that hinder beekeeping adoption in Ethiopia [6].

Amhara region is one of the major potential regions in Ethiopia, where beekeeping activity is carried out due to the availability of diversified honey bee flora. The agro ecology of the region is characterized as midland (about 45%) which is more appropriate for commercial beekeeping. In addition, the diverse agro ecologies of the region (500–4620 masl), the encouraging government policies and strategies, the presence of active and engaging NGOs, the establishment of Lalibela National Apiculture Museum, and the presence of Jarie and Gorgora queen rearing and beekeeping training centers made the region a potential place for apiculture produce [7].

According to CSA [8] in Amhara region, the total honey production was 11,118,249 kg, which is 22.82% of the national production, and the total number of bee colonies in the region was 1,361,329 with 380,320 beekeepers. According to the administration office of Awi zone, in 2019 there were 109,686 colonies and 23,375 households who practice beekeeping in all districts of the zone, of which 22,755 households were in rural districts. The total honey production in the zone was 1,683,399 kg; however, there is a great potential for producing more. Although there is a high potential of beekeeping practices in Amhara region of Ethiopia, particularly in Awi zone, there are many factors that hinder beekeeping adoption and the degree of adoption in this area. Therefore, it is necessary to determine the factors affecting beekeeping adoption and intensity of adoption.

In the area of the beekeeping sector, various studies have been conducted to identify the challenges facing the beekeeping sector, and the determinants of box hives technology adoption, innovative bee products, the profit of small-scale beekeepers, marketing of honey, efficiency in honey production, and colony loss rate. For example, Amanuel and Alemayehu [9] conducted a study on beekeeping practices and challenges in Hadiya Zone of Southern Ethiopia. However, their study was not able to show the factors affecting households in beekeeping adoption decision and the degree of beekeeping adoption. The study by [10] showed that purchasing wax from outside their own operations is associated with higher colony loss rates in Austria. Furthermore, several researchers studied various issues related to beekeeping practices and honey production, but none of them examined the determinants of beekeeping adoption and intensity of adoption [11–19]. This study will add to scientific knowledge on the areas of beekeeping research in that it deeply investigates the factors affecting beekeeping adoption and the intensity of adoption. The factors affecting the intensity of beekeeping adoption was not studied before.

Rural households face two decisions regarding beekeeping practices. The first decision is the decision to adopt beekeeping or not. The second decision is the decision to adopt how many honey bee colonies. To estimate the determinants of such a two-way decision facing rural household's two competing models are available in the literatures. These are the Heckman two-stage and the Craggs double hurdle model. The difference between Heckman two-step model and Craggs double hurdle model is that Heckman two-step model assumes that in the second stage, there will be no zero observations once the first stage is passed, whereas the double hurdle still considers that there might be a possibility of a zero observation which may arise from the individual's choice. In this study, the first stage decision is the decision of farmers to adopt beekeeping, the second stage is the decision on how many number of colonies to be adopted. In this case, there will not be a possibility of zero observation. Therefore, this study was conducted to answer the following research questions: (1) what are the factors preventing smallholder farmers from beekeeping adoption? and (2) what are the factors that affect the intensity of beekeeping adoption? by employing Heckman two-stage sample selection model.

Empirical literatures

Various studies have been conducted by many scholars regarding the adoption decision and extent of beekeeping adoption of smallholder rural households by employing different methods of analysis. A study conducted on the socio-economic analysis of beekeeping and determinants of box hive technology adoption in the Kingdom of Saudi Arabia by employing a descriptive statistical analysis showed that the educational level of the household positively influences the adoption of box hives, and the absence of rain, shortage of bee forage and honey bee enemies are the major constraints of beekeeping [19]. A study by Gyau et al. [18] employed Logit model and found consumers who are married and have reached at least the level of secondary education have a strong preference for local forest and savannah honey in Democratic Republic of Congo.

The search for new markets, proactiveness, discovery and exploitation of opportunities, investments in promotion and advertising, risk taking, higher turnover and the diversification of distribution channels and sold products were the determinants of innovative bee products in France and Romania [17]. A study showed that the exploitation of oilseed rape nectar by bee colonies was found to be influenced by the amount of secreted sugar, as well as by the temperature conditions and the strength of the colony during flowering in Denmark [20]. Total rainfall prior to flowering, in addition to both the relative humidity and the difference between night and day temperatures in the period of secretion is of importance for the sugar secretion rate in Denmark [21].

The profit of small-scale beekeepers is determined by changes in the cost of labor and materials, such as wire and color paint for beehives. In addition, contacts and follow-up by beekeeping extension officers and access to beekeeping training on improved management practices were the main factors that had a significance influence on the economic efficiency of small-scale beekeepers in Tanzania [16]. A study conducted on the determinants of honey producer market outlet choice in Chena District, Southern Ethiopia by employing a multivariate probit regression model revealed that the quantity of honey sold, frequency of extension contact, beekeeping experience, distance to the nearest market, market information about each outlet, cooperative membership, and trust in buyers determine market outlet choice decision of honey producers [15].

A study conducted in Turkey found that the existance of pure race bee in colony, education level of a farmer, hive numbers, beekeeping subsidies, age of a farmer, type of beehive and the number of migratory activity were the major determinant factors of technical inefficiency in honey production in Nigde province [13]. Apiaries with high Varroa infestation level before treatment were more likely to suffer higher mortality rates and those beekeepers who used illegal or homemade products (or those that are legal but are not applied according to label instructions) to treat varroa, had more probabilities of having higher losses rate than those who did not treat them at all [14].

Providing weak colonies for almond pollination results in lower fees collected by the beekeeper and beekeepers that experience high winter mortality rates are also likely to receive lower per colony almond pollination fees due to low delivered colony strength [12]. According to the finding of Underwood et al. [11], beekeepers' willingness to use in-hive chemicals and the number of colonies in their operations are non-randomly associated with other aspect of beekeeping management practices. Purchasing wax from outside their own operations is associated with higher colony loss rates in Austria [10].

In light of the above empirical literatures, this study aimed to identify the factors affecting beekeeping adoption decision by rural households and the intensity of beekeeping adoption in Northwest Ethiopia. Heckman two-stage sample selection model was employed to account for sample selection bias.

Methods

Description of the study area

This study was conducted in Awi Zone of Amhara regional state, Ethiopia. The zone is one of the 11 zones of Amhara regional state of Ethiopia. The zone is bordered on the west by Benishangul–Gumuz region, on the north by North Gondar Zone, and on the east by west Gojjam. The Zone has 12 districts, of which 9 are rural. The Administrative center of Awi zone is Injibara. Topographically, Awi Zone is relatively flat and fertile, whose elevation varies from 1800 to 3100 masl with an average altitude of 2300 m. This study was conducted in Awi zone, because the zone is one of the major potential zones of Amhara region for beekeeping activities. Although the zone has a high potential for beekeeping practices, only a few rural households practice beekeeping relative to the total number of rural households of the zone.

Population and sampling method

The population of this study is composed of all households in the nine rural districts of Awi Zone. Two stage stratified random sampling method was used to select the samples. In the first stage, the nine districts were stratified into 3 strata according to the volume of their honey production based on the 2018/2019 Awi zone animal resource development office (the first stratum had Guangua, Dangila Rural and Zigem districts that produce over 170 tones, the second stratum had Fagta Locoma, Guagussa Shikudad and Ayo Guagussa districts that produce between 150 and 170 tones, and the third stratum had Jawi, Ankesha and Banja districts that produce less than 150 tones), and one district was selected randomly from each stratum. Accordingly, Dangila, Ayo Guagussa, and Jawi were selected. Figure 1 shows the map of these three selected districts.

The sample size for the participant (among 6060 households in the three districts) and for the non-participant (among 61,551 households in the three districts) was determined using Yamane's [22] sample size determination formula at 5% precision level as follows:

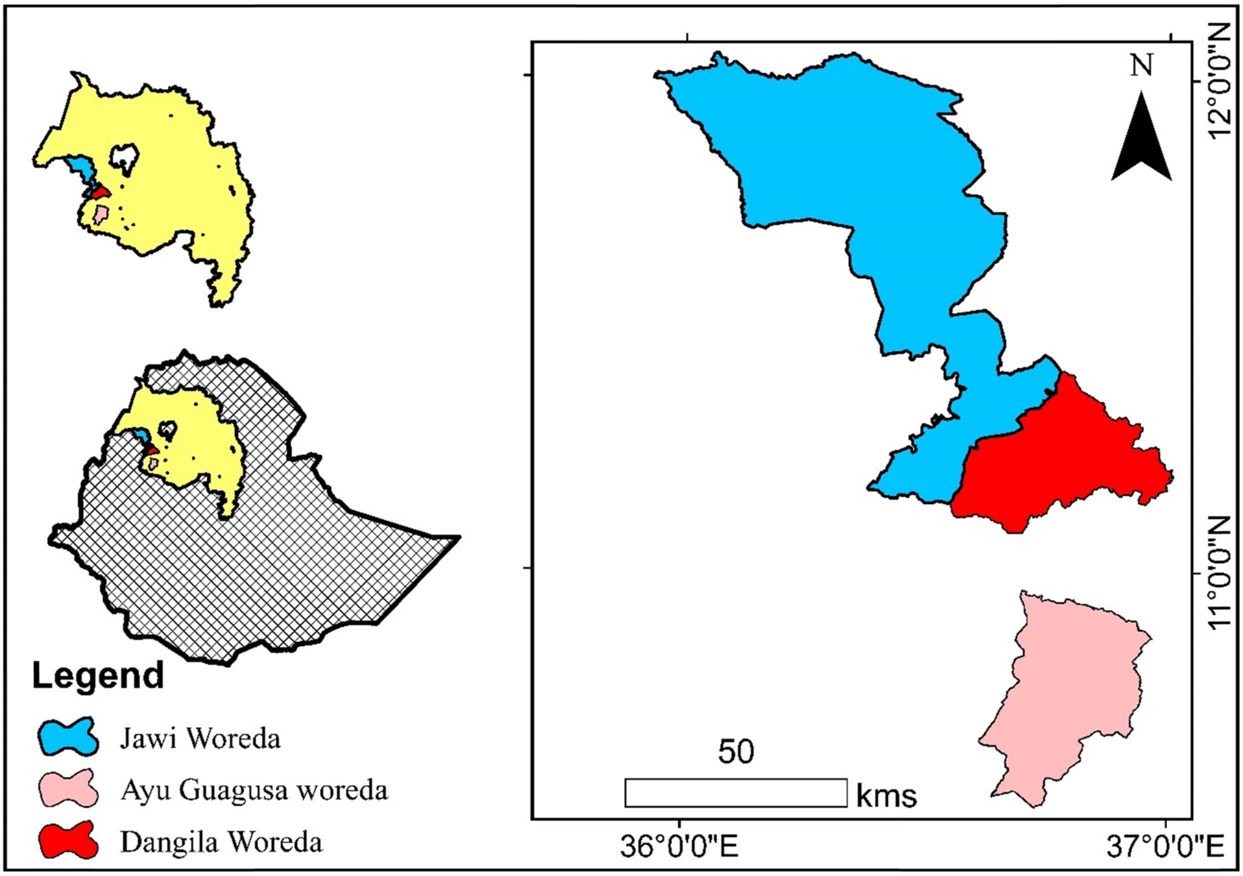

Fig. 1 Location of the three randomly selected districts (woredas)

$$n = \frac{N}{1 + N(e)^2} = \frac{6060}{1 + 6060(0.05)^2} = \frac{6060}{16.15} = 375 \text{ (the total sample size for participant households),}$$

$$n = \frac{N}{1 + N(e)^2} = \frac{61,551}{1 + 61,551(0.05)^2} = \frac{61,551}{154.8775} = 397, \text{ (the total sample size for non-participant households).}$$

These sample sizes ($n=375$ for participant, and $n=397$ for non-participant rural households) were allocated proportionally to the three districts ($n_i = \frac{n \times N_i}{N}$) and the households were selected using the simple random sampling method. To collect the appropriate data for this study, a structured questionnaire was developed, and the data were collected by well-trained enumerators.

Method of data analysis

In this study, inference about the difference between two means of numerical variables measured from beekeepers and non-beekeepers was conducted using two-sample *t* test, and the relationships between different categorical demographic, socio-economic, and institutional characteristics of beekeepers and non-beekeepers were determined using χ^2 test of independence. Then, econometric analysis was conducted to determine the determinants of beekeeping adoption and the intensity of the adoption.

In the econometric analysis, the behavior of market participation model proposed by Barrett [23] was used to estimate the coefficients of the factors that affect market participation decision of farmers. The key assumption of this model is the decision of rural households to participate in the market is based on the principle of utility maximization. In other studies, a two-step analytical approach was followed to determine the factors affecting beekeeping adoption. The main reason for following this approach is that beekeeping adoption decision involves two-way decision: the decision to adopt and the actual degree of adoption. The decision to adopt is a categorical binary variable that takes either 1 (adopting decision) or 0 (non-adopting decision). The two well-known methods are Heckman selection model and Cragg's double hurdle model [24]. Hence, this decision can be modeled by a binary response model, specifically the probit model. The second decision, the degree of adoption, is represented by how many bee colonies were adopted, which is a numerical variable measured in the number of bee colonies adopted. Honey bee colonies are the number of bee workers that are characterized by a continuous increase in number through colony reproduction (i.e., production of drones and queens) [25]. Hence, the second step decision can be modeled by a multiple linear regression model whose parameters can be estimated by using the Ordinary Least Squares (OLS) method.

The two well-known methods appropriate for modeling the decision of beekeeping adoption and the actual level of adoption are Heckman selection model and Cragg's double hurdle model [24]. The Heckman sample selection happens when rural households select either to adopt or not to adopt beekeeping. The decision of rural households is based on their behavior, which in turn is affected by several factors [26]. The decision of a household is affected by several interrelated factors including education, gender, assets needed for production, external environment, socioeconomic, institutional, and policy [26–28].

Model specification

A rural household is said to participate in beekeeping if he/she adopts beekeeping practices. The decision to participate in beekeeping adoption solely depends on the household's discretion. The beekeeping adoption decision of rural households, which estimates the probability of a household's head to adopt beekeeping, can be estimated using the probit model [29] as follows:

$$Y_i = \beta X_i + U_i \tag{1}$$

where Y_i = dummy dependent variable (1 = adoption, 0 = non-adoption) showing beekeeping adoption of the ith rural household, β = a vector of coefficients of the explanatory variables, X_i = a vector of the explanatory variables that affect adoption decision measured on the ith household, and U_i is the ith error term.

In the second step, the number of bee colonies adopted by a rural household as a proxy for the degree of adoption was estimated by the following equation by including an estimate of the Inverse Mill's Ratio (IMR, λ_j) [30] as

$$Y_j = \beta_j X_j + \lambda_j \mu + u_j \tag{2}$$

where Y_j = the number of bee colonies adopted by a household as a proxy for degree of beekeeping adoption by rural households, β_j = a vector of coefficients that need to be estimated in the outcome equation, X_j = explanatory variables that are expected to affect the degree of beekeeping adoption, and λ_j = selection bias correction factor (IMR), and U_j is the jth error term.

To estimate the factors affecting beekeeping adoption decision of rural households, Heckman two-step approach is an appropriate model that corrects the problem of simultaneity. It is established in the literature that Heckman two-step approach [29] can only be used when the correlation between the two error terms is greater than zero so that it will correct the problem of selection bias [31–33]. According to [34], this approach is based on the restrictive assumption of normally distributed error terms. In the first step of this two-step approach, probit model is used to identify the factors affecting participation in beekeeping adoption (Eq. 1), and in the second step, OLS method is used to determine the significance of the factors affecting the degree/intensity of participation in beekeeping (Eq. 2).

Probit model fitted in the first step also provides the value of IMR (λ), which is defined as "the ratio of the ordinate of a standard normal distribution to the tail area of the distribution" [30]:

$$\lambda_i = \varphi(\rho + \alpha X_i) \div \emptyset(\rho + aX_i) \tag{3}$$

where φ is standard normal density function, and $\varnothing$ = Standard normal distribution function.

According to [30], the IMR term corrects the problem of selection bias. If the term (λ_i) is not statistically significant, then sample selection bias is not a problem [29]. A statistically significant value of λ_i means that significant difference exists between the rural household's that adopt beekeeping and those that did not adopt. The definition of the explanatory variables that were used in the model are listed in Table 1.

Results and discussion

Characteristics of the respondents

Equality of the means obtained from non-adopter and adopter rural households was tested using a two-sample t test. Normality of the sampling distribution of the means that is required for the validity of the results was verified. The results showed a highly significant (p value < 0.01) difference between the average ages of non-adopter (33) and adopter (46) heads of the rural households, which indicates that heads of the households who adopt beekeeping are older than those who do not adopt (Table 2). The average

Table 1 Description of explanatory variables used in the study

No	Description of the variable	Type	Category
X_1	Gender of the household head	Categorical	1 = Male 0 = Female
X_2	Age of the household head (in years)	Numerical	
X_3	Marital status of a household head	Categorical	1 = Single 2 = Married 3 = Divorced 4 = Widowed
X_4	Household size (in number of persons)	Numerical	
X_5	Livestock holding of a household head (in tropical livestock unit)	Numerical	
X_6	Educational status of a household head	Categorical	1 = Illiterate 2 = Basic education 3 = Primary education 4 = Secondary education 5 = Diploma or above
X_7	Number of extension contact visits during the year	Numerical	
X_8	Availability of accessories	Categorical	1 = Yes 0 = No
X_9	Use of credit in the production season	Categorical	1 = Yes 0 = No
X_{10}	Has the household head taken beekeeping training?	Categorical	1 = Yes 0 = No
X_{11}	Presence of honey bee pests	Categorical	1 = Yes 0 = No
X_{12}	Availability of bee feeds around the area, where beekeeping is practiced	Categorical	1 = Yes 0 = No
X_{13}	Is the household engaged in swarm catching practices?	Categorical	1 = Yes 0 = No
X_{14}	Is there incentive to adopt beekeeping?	Categorical	1 = Yes 0 = No
X_{15}	Does the household use honey produce for home consumption?	Categorical	1 = Yes 0 = No
X_{16}	Major economic activities of a household head	Categorical	1 = Beekeeping 0 = Otherwise
X_{17}	Household's perception towards better hives	Categorical	1 = Traditional 2 = Modern 3 = Transitional
X_{18}	Distance to the nearest market place (in km)	Numerical	
X_{19}	The number of years the household stayed in the village/district (in years)	Numerical	
X_{20}	Location		1 = Dangila 2 = Ayehu Guagusa 3 = Jawi

household size of adopters (5) and non-adopters (6) were also highly significantly different indicating bigger households are less likely to adopt beekeeping. The difference between the average number of tropical livestock holdings of non-adopters (4.7 units) and adopters (5.8 units) was marginally significant (p value < 0.1). However, there was no significant difference between the mean number of extension visits, which was 3 times per year for both non-adopters and adopters. In addition, there was no significant difference between the mean distance to the nearest marketplace for the adopters (5.57 km) and non-adopters (5.41). However, the difference between the average number of years the non-adopter (37) and adopter (47) households stayed in the area was highly significant (p value < 0.01).

Table 2 Two-sample *t* test between numerical variables and beekeeping adoption decision

Continuous explanatory variables	Beekeeping adoption		Overall mean	*p* value
	Non-adopter	Adopter		
Age of the household head in years	33	46	39	< 0.001***
Household size measured in number of persons in a household	6	5	5	< 0.001***
Livestock holding of a household measured in tropical livestock unit	4.7	5.8	5.4	0.053*
Number of extension contact	3	3	3	0.208
Distance to the nearest market place in km	5.41	5.57	5.49	0.227
The number of years the household is staying in the village/district	37	47	42	< 0.001***

*** $p < 0.01$ and *$p < 0.1$ represent significance at 1% and 10% level of significance, respectively

Results of the χ^2 test of independence between the categorical variables and beekeeping adoption decision by rural households are shown in Table 3. The decision to adopt beekeeping was not significantly associated to the gender of the household head, marital status of the household head, beekeeping training, availability of bee feeds, major economic activities of the household head, and hive preference (Table 3). However, the association was highly significant (p value < 0.01) with the educational status of the household head (more education leading to adoption), swarm catching practices (most of the households who practice swarm catching did not adopt beekeeping), using honey produce for home consumption (more of those who use honey produce adopted), incentive to adopt beekeeping (those who received incentives adopted), and location (more of those located in Dangila adopted) (Table 3). Beekeeping adoption was significantly (0.01 < p value < 0.05) associated with access to credit (higher percentage of those who have access adopt beekeeping) and presence of honey bee pests (lower adoption, where there are pests) (Table 3). The association between decision to adopt and availability of accessories was marginally significant (p value = 0.064), and more of the rural households who have accessories adopted beekeeping (Table 3).

Econometric analysis

The first step Heckman regression model

The factors that influence the decision of households to adopt beekeeping practices were determined in the first step Heckman analysis (probit model) using maximum likelihood estimation method, where the significance of the factors influencing the binary decision (either to adopt beekeeping or not) of rural households was determined. The results shown in Table 4 revealed that eight variables have highly significant (p value < 0.01), three variables have significant (0.01 < p value < 0.05) and two variables have marginally significant (0.05 < p value < 0.1) effect on beekeeping adoption.

The coefficient of age of the household head was positive and highly significant, which indicates that an increase in the age of the household head increases the chance of beekeeping adoption. This positive effect may be because of the lower effort needed to practice beekeeping that attracts older people to harness the beekeeping knowledge they gained over the years and adopt beekeeping. A study by Tulu et al. [35] identified age of the household as a determinant factor for adopting improved beekeeping technology.

The coefficient of household size was negative and highly significant indicating rural households with large family size are less likely to adopt beekeeping. This finding is not consistent with what was reported for southern Ethiopia [9], where the researchers reported that beekeepers with a larger family size produce more honey because of the availability of more hands to look after the honey bee colonies. On the other hand, Amulen et al. [36] reported no significant relationship between household size and beekeeping adoption decision in Uganda. These inconsistencies confirm that the dependence of beekeeping adoption on household size is location specific.

The educational status of the household head is a highly significant determinant of beekeeping adoption decision of rural households. Since the dummy value was "Illiterate", the negative coefficient implies that being illiterate decreases the chance of beekeeping adoption. This could be because illiterate households are less knowledgeable about the marketing of honey and the necessary inputs needed to practice beekeeping. According to the findings of Amanuel and Alemayehu [9], household heads who completed at least high school understood the proper management of honey bee colonies, while those who did not complete did not manage honey bee colonies properly and did not know how to handle pesticides

Table 3 Test of independence between the categorical variables and beekeeping adoption decision of rural households

Categorical variables used in the model	Category	Beekeeping adoption		*p* value
		Non-adopter (%)	Adopter (%)	
Gender of a household head	Male	38	42	0.265
	Female	9	11	
Marital status of the household head	Single	3	2	0.334
	Married	30	31	
	Divorced	14	11	
	Widowed	4	5	
Educational status of the household head	Illiterate	37	2	< 0.001***
	Basic	9	6	
	Primary	2	18	
	Secondary	2	17	
	Diploma	1	6	
Availability of accessories	Yes	14	30	0.064*
	No	36	20	
Access to credit	Yes	13	19	0.031**
	No	36	32	
Whether the household head has taken beekeeping training	Yes	12	16	0.465
	No	37	35	
Presence of honey bee pests	Yes	38	28	0.017**
	No	12	22	
Availability of bee feeds	Yes	9	11	0.536
	No	42	38	
Swarm catching practices	Yes	39	27	< 0.001***
	No	12	22	
Using honey produce for home consumption	Yes	3	46	< 0.001***
	No	49	2	
Major economic activities of the household head	Beekeeping	8	13	0.302
	Others	42	37	
Incentive to adopt beekeeping practices	Yes	6	44	< 0.001***
	No	45	5%	
Hive preference	Traditional	33	30	0.304
	Modern	15	17	
	Transitional	2	3	
Location (district)	Dangila	18	30	< 0.001***
	Ayehu Gua	19	10	
	Jawi	14	9	

* $p < 0.1$; **$p < 0.05$; ***$p < 0.01$ represent significance at 10%, 5% and 1% level of significance, respectively

safely. Education increases the knowledge of beekeepers about improved technologies as education provides them more access to information on improved technology and increases the understanding of the technology which in turn helps to easily apply it [35]. A study by Andaregie and Astatkie [6] found that being a literate increases the probability of being an adopter of beekeeping.

Incentive to adopt beekeeping practices has a highly significant positive effect on beekeeping adoption decision. This result confirms that the incentives are delivering the expected outcome, which is beekeeping adoption. A study by Vapa-Tankosic et al. [37] also showed that beekeepers who use incentives provided by the state or the province develop their beekeeping. A study on the innovative potential of beekeeping production in AP Vojvodina [38], showed that providing adequate and relevant agricultural advisory services, providing credit services to beekeepers for purchasing modern equipment, and incentives encourage beekeepers to make innovations in beekeeping.

Whether the produced honey was used for home consumption or not was a highly significant factor that

Table 4 First step Heckman probit model results

Explanatory variables	Coefficients	*p* value
Gender of the household head (male dummy)	0.280	0.502
Age of the household head in years	0.216	< 0.001***
Marital status of the household head	0.194	0.822
Household size measured in number of persons in the family	− 0.801	< 0.001***
Livestock holding of the household in tropical livestock unit	0.022	0.731
Educational status of the household head (Illiterate dummy)	− 1.192	0.005***
Number of extension visits in a year	0.259	0.072*
Availability of accessories (Yes dummy)	− 0.483	0.296
Use of credit in the production season (Yes dummy)	− 0.518	0.324
Whether the household has taken beekeeping training (Yes dummy)	1.420	0.018**
Presence of honey bee pests (Yes dummy)	− 0.359	0.608
Availability of bee feeds around the residence (Yes dummy)	0.802	0.246
Engagement in swarm catching practices (Yes dummy)	− 0.167	0.668
Incentive to adopt beekeeping practices (Yes dummy)	2.594	< 0.001***
Do you use honey produce for home consumption? (Yes dummy)	3.200	< 0.001***
Major economic activities (Beekeeping dummy)	1.906	0.069*
Household's perception of better hives (Traditional hive dummy)	− 1.821	0.002***
Distance to the nearest marketplace in km	− 0.082	0.027**
Number of years the household stayed in the village/district	0.076	< 0.001***
Location (Dangila dummy)	1.275	0.016**
Constant	− 5.369	0.006***

* $p < 0.1$; **$p < 0.05$; ***$p < 0.01$ represent significance at 10%, 5% and 1% level of significance, respectively

has a positive effect on beekeeping adoption decision of rural households. Since the dummy used is "Yes", the result shows that households who consume honey produce have a higher chance of adopting beekeeping practices than the households who do not consume honey produce. A study by Kiros and Tsegay [39] conducted in West Gojjam Zone, which is close to the study area, showed that most beekeepers utilize honey for household consumption.

The sign of the coefficient of household's perceptions towards better hive types (using traditional hive as dummy) was negative and highly significant. This indicates that households who perceive traditional hives as better hives are less likely to adopt beekeeping practices. This could be because households who consider traditional hives as better than modern beekeeping face colony losses, which could discourage beekeeping adoption. However, this is not the case in the southern part of Ethiopia, where half of the respondents preferred transitional hives and the other half traditional hives [40].

The number of years in which the household stayed in the village/district has a highly significant positive influence on beekeeping adoption decision by rural households. This could be because living in the same district/village for a long time helps households to know the suitability of the environment for different activities, and to learn from the experience of beekeepers in the neighborhood. According to the findings of Kiros and Tsegay [40], the contribution of neighbors in sharing beekeeping experience was high, indicating that beekeeper-to-beekeeper knowledge exchange is important in the dissemination of improved beekeeping technologies.

Receiving beekeeping training had a significant positive effect on beekeeping adoption decision. This is because the training would make the household heads familiar with the adoption process, the necessary inputs, the techniques of adoption and practicing beekeeping, its market demand, profitability, and other benefits. This result agrees with that of Amulen et al. [36] who reported that the inability of beekeeping to improve well-being status can in part be attributed to a lack of both training in bee husbandry and protective equipment provision, such as suits, gloves, and smokers. In addition, Kuboja et al. [16] reported that access to beekeeping training on improved management practices significantly influences the economic efficiency of small-scale beekeepers in Tabora and Katavi regions of Tanzania.

Distance of the household residence from the nearest marketplace has a significantly negative influence on beekeeping adoption decision by rural households. This implies that households who reside far away from the nearest marketplace are less likely to adopt beekeeping practices. This may be because households who reside far away have limited access to useful information and face difficulty in accessing the necessary inputs for practicing beekeeping. This result is consistent with that of Tarekegn et al. [15] who reported that distance to the nearest market negatively influences market outlet choice of honey producers. Hecklé et al. [41] also reported that access to the nearest market is the main factor affecting the decision of smallholder farmers to take up beekeeping. Location has significant effect on beekeeping adoption. The positive sign of the coefficient indicates that rural households located in Dangila (the dummy variable) are more likely to adopt beekeeping (Table 4).

The number of extension visits has a marginally significant positive influence on beekeeping adoption decision, which suggests that smallholder farmers who were frequently visited by extension agents during the production season are more likely to adopt beekeeping practices. This could be because of the useful information related to inputs, production, and marketing provided by extension agents. This result is consistent with that of Amulen et al. [36] who reported that beekeepers tended to adopt beekeeping following contact with non-government organizations and access to training. According to the findings of Kuboja et al. [16], extension contact was the main factor that had a significant influence on the economic efficiency of small-scale beekeepers in Tanzania. In addition, frequency of extension contact significantly determines market outlet choice decision of honey producers [15].

Among the major economic activities (beekeeping, crop production, charcoal production, animal rearing, and/or two or more) of the household heads, beekeeping has a marginally significant positive effect on beekeeping adoption. This may be because households whose major activity is beekeeping practice are more knowledgeable about the benefits and are more comfortable to expand their beekeeping practices.

Table 5 shows the significance of the marginal effects of the explanatory variables on beekeeping adoption decision of rural households. Ten of the variables have a highly significant (p-value < 0.01) effect on beekeeping adoption. Accordingly, other things remaining constant, an increase in the age of the household head by 1 year increases the probability of beekeeping adoption by 8.6%. Other things remaining constant, an increase in the size of the household by one person decreases the probability of beekeeping adoption by 31.9%. Being illiterate decreases the chance of a household's decision to adopt beekeeping practices by 44.8%, other things remaining the same. Receiving training related to beekeeping practices increases the probability of beekeeping adoption by 50.7%. Incentive to adopt beekeeping practices increases the likelihood of beekeeping adoption by 80.5%, citrus paribus. Consuming honey produce at home increases

Table 5 Marginal effects of the explanatory variables on beekeeping adoption decision

Explanatory variables	Dy/dx	*p* value
Gender of the household head (male dummy)	− 0.111	0.499
Age of the household head in years	0.086	< 0.001***
Marital status of the household head	− 0.078	0.819
Household size measured in number of persons in the family	− 0.319	< 0.001***
Livestock holding in tropical livestock unit	− 0.009	0.731
Educational status of the household head (Illiterate dummy)	0.448	0.001***
Number of extension visits in a year	0.103	0.072*
Availability of accessories (Yes dummy)	0.191	0.287
Access to credit in the production season (Yes dummy)	0.204	0.312
Whether the household has taken beekeeping training (Yes dummy)	0.507	0.003***
Presence of honey bee pests (Yes dummy)	0.142	0.600
Availability of bee feeds around the residence (Yes dummy)	− 0.298	0.183
Engagement in swarm catching practices (Yes dummy)	0.066	0.667
Incentive to adopt beekeeping practices (Yes dummy)	0.805	< 0.001***
Do you use honey produce for home consumption? (Yes dummy)	0.888	< 0.001***
Major economic activities (Beekeeping dummy)	0.579	0.002***
Household's perception of better hives (Traditional hive dummy)	− 0.620	< 0.001***
Distance to the nearest marketplace in km	− 0.033	0.026**
Number of years the household stayed in the village/district	0.030	< 0.001***
Location (Dangila dummy)	0.476	0.006***

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$ represent significance at 10%, 5% and 1% level of significance, respectively

the probability of adopting beekeeping practices by 88.8%. In addition, having beekeeping activities as the major economic activity of the household increases the chance of beekeeping adoption by 57.9%, other things remaining the same. Household's perception towards traditional hives decreases the probability of adopting beekeeping practices by 62%, other things remaining the same. An increase in the number of years the household stays in the village by 1 year increases the probability of beekeeping adoption by 3%, and being located in Dangila increases the probability of beekeeping adoption by 47.6% (Table 5).

An increase in the distance between the household's residence and the nearest marketplace by 1 km decreases the probability of beekeeping adoption by 3.3%, and this effect is significant. Number of extension visits has a marginally significant positive effect, where for each additional visit, the chance of the beekeeping adoption increases by 10.3%. The marginal effect of the other six variables was not significant (Table 5).

Second step Heckman regression model

The OLS estimates of the parameters of the second step Heckman two-step regression model that uses the number of bee colonies adopted by the rural households as a proxy for the intensity of beekeeping adoption dependent variable are shown in Table 6. The value of the IMR was negative and marginally significant (p-value = 0.055, Table 6), which indicates that the error terms of both the selection equation and the outcome equation are negatively correlated. That is, beekeeping adoption decision is correlated with the intensity of beekeeping adoption. This further shows the presence of sample selection bias and, therefore, justifies the use of Heckman two-step model.

The coefficient of four of the variables (livestock holding, number of extension visits, presence of honey bee pests, and major economic activities) were highly significantly (p-value < 0.01) different from zero (Table 6). The positive coefficient of livestock holding indicates that households who have a larger number of livestock adopt substantially higher number of honey bee colonies. This could be because they have more resources to finance the purchase of more honey bee colonies. According to the finding of Amanuel and Alemayehu [9], beekeepers use the income obtained from beekeeping to purchase livestock, such as sheep, goat, and poultry, and those who do not practice swarm catching sell their livestock or crops to purchase honey bee colonies. The coefficient of frequency of extension visits is positive, which indicates that the technical support and information shared to the beekeepers helps them to increase their honey bee colonies.

Table 6 Second step Heckman regression model results

Explanatory variables	Coefficient	*p* value
Gender of the household head (male dummy)	0.019	0.944
Age of the household head in years	0.011	0.448
Marital status of the household head	− 0.056	0.893
Household size measured in number of persons in the family	0.075	0.238
Livestock holding in tropical livestock unit	0.137	< 0.001***
Educational status of the household head (Illiterate dummy)	0.924	0.106
Number of extension visits in a year	0.734	< 0.001***
Availability of accessories (Yes dummy)	0.156	0.574
Access to credit in the production season (Yes dummy)	0.960	0.011**
Whether the household has taken beekeeping training (Yes dummy)	− 0.308	0.445
Presence of honey bee pests (Yes dummy)	− 1.374	< 0.001***
Availability of bee feeds around the residence (Yes dummy)	− 0.462	0.354
Engagement in swarm catching practices (Yes dummy)	0.569	0.026**
Major economic activities (Beekeeping dummy)	3.966	< 0.001***
Household's perception of better hives (Traditional hive dummy)	− 0.214	0.624
Distance to the nearest marketplace in km	− 0.005	0.871
Number of years the household stayed in the village/district	0.004	0.725
Location (Dangila dummy)	− 0.016	0.959
Constant	7.909	< 0.001***
Inverse Mill's ratio (λ)	− 1.279	0.055*
Wald $\chi^2 = 1190.3$ Prob > $\chi^2 < 0.001$***		

[*] $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$ represent significance at 10%, 5% and 1% level of significance, respectively

The negative coefficient of the presence of honey bee pests that used "yes" as dummy indicates that households who are exposed to honey be pests have lower number of bee colonies as compared to their counterparts. As expected, the coefficient of major economic activities that used "beekeeping" as dummy is positive, which indicates that households whose major economic activity is beekeeping have a larger number of honey bee colonies or higher degree of beekeeping adoption (Table 6). In Awi zone, there are other major economic activities practiced by the rural households, such as charcoal production, cereal production, animal rearing or a combination of them. The finding of this study revealed that those rural households who practiced beekeeping as their major economic activity have a large number of honey bee colonies as compared to those who practiced the other economic activities.

Use of credit during the production season and whether a household is engaged in swarm catching practices ("yes" as dummy for both variables) have a significantly positive impact on the intensity of beekeeping adoption (Table 6). Rural households who have access to credit have larger number of colonies, because they are able to purchase bee colonies and necessary inputs for beekeeping adoption. Households who are engaged in swarm catching practices have large number of bee colonies, because swarm catching is a great source of honey bee colonies. Catching swarm was the dominant source of honey bee colonies in Hadya zone of southern Ethiopia as well [9]. The other variables did not have a significant effect on the degree of beekeeping adoption (Table 6).

Conclusions

The objective of this study was to identify the determinants of beekeeping adoption decision and the intensity of beekeeping adoption in Northwest Ethiopia. Results of the first step Heckman two-step analysis showed that age of the household head, household size, educational status, number of extension visits, whether a household have taken beekeeping training, incentive to adopt beekeeping, whether a household uses the honey produce for home consumption, major economic activities of a household head, households perception towards better hives, distance to the nearest market place, the number of years the household stayed in the village, and location are the significant determinants of beekeeping adoption decision of rural households. Results of the second step Heckman two-step regression model revealed that livestock holding of the household (measured in tropical livestock unit), number of extension visits, credit use, presence of honey bee pests, whether the household is engaged in swarm catching practices, and major economic activities of the household are the significant variables that influence the intensity of beekeeping adoption decision in Northwest Ethiopia.

Northwest Ethiopia is one of the regions that have a high potential for beekeeping. Despite many challenges, beekeeping is a viable business that contributes significantly to increasing and diversifying the income of many rural households in the area. Moreover, beekeeping provides a means of supplementary business and self-employment opportunities for many families especially for rural households of Ethiopia. To enhance the development of the beekeeping sector by improving beekeeping adoption, which will help to improve the livelihoods of rural households, the findings of the study suggest that governmental and non-governmental organizations should consider the following interventions: (1) provide a strong extension service and incentives to enhance the adoption of beekeeping among the non-beekeepers, and (2) expand the intensity of adoption of beekeeping by increasing the number of colonies, organizing beekeepers for efficient marketing of bee products, and providing beekeeping related trainings, supplying improved and modern hives, practicing good honey bee pest management practices, increasing the educational level of farmers so that they can have better access to information, good beekeeping management, and adaptation of new honey production methods. In addition, local and regional bodies such as Agriculture bureau of the region and agriculture directives of the zone should create a fertile ground to rural households to participate in beekeeping practices so that they can get honey produce at least for their home consumption. This will further help to improve the health of rural households.

Abbreviations

CSA: Central Statistical Agency; EAB: Ethiopian Apiculture Board; IMR: Inverse Mills Ratio; NGOs: Non-governmental organizations; OLS: Ordinary Least Square.

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Author contributions

AA, AW, AW and LA analyzed and interpreted the data collected from rural households. TA improved the statistical part of the study, and was a major contributor in writing and preparing the manuscript. All authors read the draft version of the manuscript. All authors read and approved the final manuscript.

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