Original Research Article||

Determinants of modern box hive technology adoption in Benishangul Gumuz Regional State, western Ethiopia

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Abstract

Beekeeping is among the most common enterprises in the Benishangul Gumuz region. However, honey production is still traditional where beehives are placed on trees and harvesting honey is done by destroying the colony. Therefore, this study was conducted to determine factors affecting the adoption of modern box hive technology in the region. Both primary and secondary data sources were utilized. Data were collected from 165 randomly selected beekeepers in nine kebeles based on honey bee colony potential and road access. Descriptive statistical analysis and an econometric model were employed to identify the factors affecting the adoption of modern box hive technology. The results revealed that the gender of the beekeepers, level of education, total landholding, livestock ownership, number of the traditional colonies , location, awareness of beekeeping practices, and contact with extension agents were the major factors that significantly affect modern box hive adoption. Therefore, all stakeholders along with the extension system should work on promotion, training, designing improved packages of beekeeping practices, and building the capacity of beekeepers to improve the dissemination and adoption level of new technologies by the beekeepers. Finally, stakeholders engaged in the research and development consortium should work together to improve extension services, thereby providing information and innovation to beekeepers, extension agents, and experts.

Key words: Beekeepers, box hive, adoption, forest beekeeping, traditional hive

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INTRODUCTION

Ethiopia has a longstanding beekeeping practice and produces a significant amount of honey and wax for the export market. The production system in the country is mainly characterized by forest and backyard style beekeeping systems (Shenkute et al., 2012). The sector is a promising off-farm livelihood, which directly and indirectly contributes to smallholders' income in particular and the nation's economy in general. It plays a significant role in generating and diversifying the incomes of subsistence Ethiopian smallholder farmers, mainly the landless (Sahel et al., 2018). In Ethiopia, the beekeeping sector is constrained by a lack of knowledge, a shortage of trained manpower, a shortage of beekeeping equipment, pests, and predators, and inadequate research and extension services (Sahel, 2006).

Traditional beekeeping accounts for more than 95 percent of the honey and beeswax produced in Ethiopia (Yirga and Teferi, 2010). The productivity of honeybees from this system is very low and only an average of 8.35 kg of honey could be cropped per hive per year. However, it has been observed that the average honey yield obtained from timber-made box hives is 20 kg/hive (CSA, 2013). Compared to a traditional beehive, a modern hive needs to be checked regularly for better production enhancement because an old comb is known to harbor numerous contaminants that may be detrimental to the brood's health.

Beekeeping is among the most common businesses in the Benishangul Gumuz region due to its favorable climatic condition. Over 60% the region is covered with forest including bamboo, eucalyptus and rubber trees, incense, and gum forests as well as indigenous species (Bekele et al., 2015). In the Benishangul Gumuz region, beekeepers use traditional hives which are very difficult to manage honeybees and to produce honey and honey products in the required quality and quantity. A previous study showed beekeepers contain a high number of colonies (average 12.98) as compared to other potential regions of Ethiopia (Tarekegn, 2022).

However, the productivity of the sector is far below its potential due to the high cost and limited availability of modern beekeeping equipment and accessories, inferior quality of honey, presence of honeybee enemies, inadequate research and extension services, and shortage of skilled man power (Abebe et al., 2016). In the Benishangul Gumuz region, beehives are hanged on trees and harvesting honey is done by destroying the colony, a practice that is not only affecting the quantity and quality of harvested honey, but also greatly reducing the number of colonies in the area.

Governmental and non-governmental organizations have been trying to introduce improved beekeeping practices for cooperatives and individual beekeepers. The interventions aim to improve honey bee productivity, poor honey bee colony management, and honey quality by introducing modern beekeeping technologies. Nevertheless, studies show that in different areas of the region, 91.8% of beekeepers use traditional and inefficient hives, and only 4.1% use modern hives, and another 4.1% use transitional hives (Fikadu, 2018). Additionally, the report from the relevant office of the region the Bureau of Agriculture and Rural Development (BOARD) (2011, unpublished) indicated that only 4.5% of colonies were being hived in improved box styles.

But little intervention was made to improve the existing traditional and inefficient honey production system. In the potential district of the region, study showed that the honey yield per hive per year from the traditional hives (3.3- 6.5 kg) is lower as compared to the modern hive (14.3- 15.7 kg) (Abebe et al., 2016). In the study areas, adoption level of the modern hive and other beekeeping technologies remain low, necessitating the assessment of the relevant personal attributes, environmental factors, and institutional as well as socioeconomic characteristics in the adoption of modern hive technology as a critical dimension. Moreover, factors that limited the adoption of box hive technology by beekeepers in the area were unknown. Therefore, this study was designed to identify factors that influence the adoption of modern box hives and suggest proper intervention options to improve adoption of modern beekeeping technologies for a better livelihood impact in the Benishangul Gumuz region.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in the Assosa zone (Bambasi and Homosha) and Mao-Komo special woreda of the Benishangul Gumuz regional state. Assosa town, the capital of Benishangul Gumuz, is located 670 km west of Addis Ababa. Bambasi is located 45 km south of Assosa, Mao-Komo special woreda is located approximately 105 km south of Assosa town and Homosha is located about 35 km west of Assosa town. Benishangul Gumuz regional state is located between geographical coordinates of 10° 38' 20.45" N latitude and longitude 35° 43' 58.92" E with altitudes ranging from 1272 to 1573 m above sea level. The mean annual rainfall and temperature in the region range between 700 to 1450 mm and 21 to 35°C, respectively (AMS, 2008). Major crops grown in the areas are sorghum, maize, finger millet, soya bean, and groundnut. Minor crops produced include noug (*Guizotia abyssinica*), tef (*Eragrostis tef*), haricot bean, hot pepper, sweet potato, banana, and coffee. The livestock species commonly kept are goats, cattle, chickens, and donkeys in their orders of importance.

Sample Size and Sampling Technique

A three-stage sampling technique was applied to select the respondents. From seven districts of the Assosa zone, the first two districts and Mao-Komo (special woreda) were purposely selected taking into account their potential for honey production. Subsequently, three kebeles from each district and special woreda were selected based on honey bee colony potential and road access. The beekeepers were stratified into two groups which constitute adopters and non-adopters of improved box hives. Within each kebeles, 15-20 beekeepers were selected purposely from adopters and non-adopters. The sampling frame consisted of the list of beekeepers in the kebeles identified in collaboration with the Development Agents. The beekeepers who adopted one or more modern hives technology before and during 2019 were considered as adopters, while non-adopters were those who used traditional hives only. This definition may exclude those who stopped using of the technology and those who have intestinally adopted it. For this study 66 adopters and 99 non-adopters (total of 165 beekeepers) were selected randomly from the lists of beekeepers.

Data Source, Type and Collection Techniques

Formal survey methods were used to collect the required data and informal surveys were conducted to develop a rapid understanding of beekeepers' circumstances and problems. Both primary and secondary data were used in this study. Primary data were collected from sample household heads, while secondary data such as the number of bee colonies, amount, and type of bee hives were collected from agricultural offices of the respective study districts. Structured and semi-structured questionnaires were used to collect primary data. The interview was held on their respective farms using a local language. The survey was carried out from January to June 2019.

Data Analysis

The data collected from beekeepers were analyzed using descriptive statistics, a two-tailed T-test, and a logistic regression model using the Statistical Package for the Social Sciences (SPSS) 23 and Stata/SE 12.0. Rank index calculation was employed to identify important challenges and major pests and predators for honeybee keeping in the study areas. The rank index can be calculated as:

$$Index = \frac{(R_n \times C_1)+(R_{n-1} \times C_2)\ldots+(R_1 \times C_n)}{\sum\left((R_n \times C_1)+(R_{n-1} \times C_2)\ldots+(R_1 \times C_n)\right)} \quad 1$$

Where, $R_{n=}$ value given for the least ranked level (for example if the least rank is 5th, then R_n = 5, R_{n-1} = 4, R_1 = 1). C_n = counts of the least ranked level (in the above example, the count of the 5th rank = C_n, and the count of the 1st rank = C_1).

Model Specification

Different models have been employed to analyze factors affecting participation like the adoption of improved honeybee technology. The studies often involve qualitative factors necessitating a choice between the logit and probit models.

The logit model was used for this study since it represents a close approximation to the cumulative normal distribution and is easy to work with. The cumulative logistic probability model is econometrically specified as follows (Pindyck and Rubinfed, 1981).

$$P_i = F(Z_i) = F\left(\alpha + \sum \beta_i X_i\right) = \frac{1}{1+e^{-\left(\alpha + \sum \beta_i X_i\right)}} \quad 2$$

Where e is the base of the natural logarithm,
X_i represents the ith explanatory variables
P_i is the probability that an individual is being an adopter of improved beehive technology or not given X_i.

β_i and α are regression parameters to be estimated

For ease of exposition, we write as

$$P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^z}{1+e^z} \quad 3$$

The odds ratio is the ratio of the probability that an individual or household would be adopting (P_i) to the probability of a household being non-adopter $(1-P_i)$. In our case, as the beekeepers are adopting modern technology or not.

$$(1-P_i) = \frac{1}{1+e^{Z_i}} \quad 4$$

$$\left(\frac{P_i}{1-P_i}\right) = \left(\frac{1+e^{Z_i}}{1+e^{Z_i}}\right) = e^{Z_i} \quad 5$$

$$\left(\frac{P_i}{1-P_i}\right) = \left(\frac{1+e^{Z_i}}{1+e^{Z_i}}\right) = e^{\left(\alpha + \sum B_i X_i\right)} \quad 6$$

Taking the natural logarithm

$$Z_i = \ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n \quad 7$$

If the disturbance term U_i is taken into account, the logit model becomes:

$$Z_i = \alpha + \sum_{n=i}^{n} \beta_i X_i + U_i \quad 7$$

The limitation of the logit regression model used does not indicate the magnitude/intensity of the adoption of improved beehive technology. It only indicates the sign i.e. positive or negative relationship between adoption and other explanatory variables of beekeepers.

Classes of Variables

The status of the adoption of modern box hive technology in the study is the dependent variable. The large number of factors expected to affect beekeepers' adoption of box hive technology are presented as follows (Table 1).

Table 1. Description of variables used in the study

Variable name	Type	Variable description	Measurement	Expected effect
Dependent				
Adoption		Adoption of modern hives	1 if yes, 0 otherwise	
HBC		Number of honeybee colonies per HH	Number	
HWC		Hives without colony	Number	
Independent				
GE	Dummy	Sex of the respondents	1 if male, 0 otherwise	+/-
AG	Continues	Age of the HH	Years	+/-
LEHH	Dummy	Level of education of the HH	Literate=1,0 otherwise	+
TLU	Continues	Household's total livestock ownership	Number of TLU	+/-
FS	Continues	Farm size	Hectare	+/-
BKE	Continues	Beekeeping experience of HH	Number of years	+/-
FSH	Continues	Family size of the household	No. of HH member	+/-
CEA	Dummy	Contacts with extension agents	1 if yes, 0 otherwise	+
VDS	Dummy	Visiting a demonstration site	1 if yes, 0 otherwise	+
FDB	Dummy	Field day on beekeeping	1 if yes, 0 otherwise	+
BT	Dummy	Beekeeping training	1 if yes, 0 otherwise	+

HH= household head, TLU= Tropical Livestock Unit

RESULTS AND DISCUSSION

Demographic Characteristics

The study indicated that the age of adopters and non-adopters was significantly different *($p < 0.01$)* (Table 2). In the study areas, the adoption of box hive technology increases with the ages of the beekeeper's, which might be the fact that the older beekeepers would have accumulated more experience, knowledge, and skill in apiary practices than the younger ones. According to Gebiso (2015), the other possible reason for the increase in adoption of beehive technology with age may be due to the fact that most resources are in the hands of older people and most young farmers may not have enough backyards for beekeeping and living around the town in most cases.

The average family size is defined as the number of individuals who live in the respondent's household. The present study found no difference in average family size between adopters and non-adopters. However, the figurative result shows that adopters have a relatively large family size and they are also in a better position for adoption status (Table 2). In agreement with this study, Mulatu *et al*. (2021) reported that as household size increases, adoption is also expected to increase and positively correlate. Large family sizes are assumed to indicate more labor availability in the household. The mean years of beekeeping experience in both categories are nearly equal (Table 2). Furthermore, the result shows that the adopters have more *($p < 0.001$)* livestock holdings in terms of Tropical Livestock Unit (TLU) than the non-adopters. A similar result was found in a study conducted in the South-Eastern part of Oromia Regional State, Ethiopia, which showed that households with higher TLU for the adopter and lower TLU for non-adopter beekeepers (Gebiso, 2015).

Table 2. Mean age, family size, beekeeping experience (year), land holding (ha), and livestock ownership (TLU) of sample respondents

Variables	Adopters N=66	Non-adopters N=99	Combined N=165	t
Age	43.07(12.47)	39(12.06)	40.58(12.75)	-2.045**
Family Size	8.14(4.23)	7.57(4.24)	7.80(4.23)	-0.835
Beekeeping Experience	11.24(9.19)	12.96(9.53)	12.28(9.4)	1.144
Landholding	2.49(2.22)	2.21(2.25)	2.31(2.23)	-0.776
TLU	2.77	1.24	1.86	-3.31***

*** Significant at p < 0.001;** significant at p < 0.01; * significant at p < 0.05, standard deviation (), TLU= T ropical Livestock Unit

Gender and Educational Status

The survey result indicates that of the total sample households interviewed, 89.7% of beekeepers were male. A previous study by Abebe *et al.* (2016) showed 95% of the sample household beekeepers were male-headed. The survey result showed that the gender of adopter and non-adopter beekeepers was significantly different ($p < 0.001$) (Table 3) which might be due to traditional hives mostly managed in the region hanging on the tree, which is difficult to work for females. In contrast, improved box hives are typically managed in backyards. The adopter sample respondents were more literate than the non-adopters (Table 3).

Table 3. Gender and educational status of study households

Variables			Adoption status		Total	χ2
			Non-adopters N= 99	Adopters N = 66		
Gender	Female		1	16	17	22.97***
	Male		98	50	148	
Education	Illiterate	No	64	45	109	0.177
		Yes	35	21	56	
	Read and write	No	89	60	149	0.184
		Yes	10	6	16	
	Elementary	No	53	39	92	0.530
		Yes	46	27	73	
	Literate	No	92	54	146	4.736**
		Yes	7	12	19	

*** Significant at P<0.001;** significant at P<0.01; * significant at P<0.05

Honeybee Colony Ownership

The survey result revealed that the number of honeybee colonies and hives without colonies was significantly different between adopters and non-adopters *($p < 0.05$)* (Table 4), where non-adopters had a larger number of honeybee colonies and traditional hives without colonies which could be associated with differences in honey yield, the cost of hives, and hive accessories as well as production systems. Moreover, non-adopters can easily access or produce bamboo-made traditional hives cheaply compared to modern box hives. Moreover, the collection of traditional hives after honey harvest for the next season is highly practiced by non-adopters (Figure 1) where the hive management, higher colonies abscond and migrate every year. The last five years of data indicate that adopters produce higher quality honey from a few colonies, but non-adopters harvest a large quantity of honey of lower quality.

Table 4. Colonies and hives without colonies in the study areas.

Variables	Adopter (N= 66)	Non-adopter (N= 99)	Combined (N=165)	t
Honeybee colony	9±12.5	16.73±18.91	13.68±13.07	2.91***
Traditional	7.01±12.21	16.73±18.91	-	-
Modern	2.03±2.97	-	-	-
Hives without colony	10.69±18.49	16.81±18.49	14.4±17.22	2.257**
Traditional	9.02±14.85	16.81±18.49	-	-
Modern	1.15± 2.28	-	-	-
Honey yield in the last 5 year				
Traditional hives (kg)	151.25±158.57	371.39 ±478.34	-	-
Modern hives (kg)	133.43±172.18	0.00	-	-

*** Significant at $p < 0.001$;** significant at $p < 0.01$; * significant at $p < 0.05$, 2015-2019= the last five year total honey yield per beekeepers

Figure 1. Bamboo-made traditional hive collected after honey harvest

Types of Bee Keeping

Majority of beekeepers in the study areas practice forest beekeeping followed by backyard beekeeping (Figure 2). As Compared to adopters majority (91.9%) of non-adopters keep honeybee colonies in the forest by hanging traditional hives on trees up to harvest. Some adopters had both traditional and modern hives, placing modern hives in the backyard and traditional hives in a forest. A large chunk of the beekeepers (71.5%) harvest all the available products in the traditional hives collected to a point that causes colony migration. The main reason reported for keeping honeybee colonies in the forest area is to protect family, neighbors, and livestock from bees attack as the honeybee race in the region (*Apis mellifera scutallata)* has aggressive behavior (Amssalu *et al*., 2004).

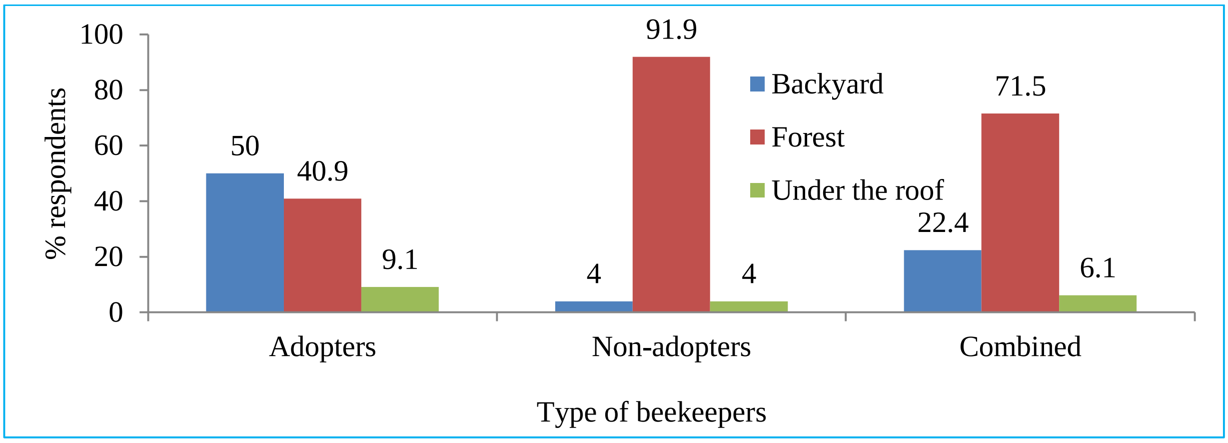

Figure 2. Type of beekeeping system in the study area

Challenges of Beekeeping in the Study Areas

The major challenges of keeping honeybees in the study areas are indicated in Table 5. Honey bee pests and predators were the most important challenges of keeping honeybees for both adopter and non-adopter respondents. These include ants, spiders, hive beetles, honey badgers, wax moths, monkeys, lizards, and likes in order of importance. This finding is in agreement with Abebe *et al*. (2016) who previously reported similar pests and predators of honey bees in three agro-ecology of Benishangul Gumuz. Shortage of beekeeping materials, especially modern beekeeping equipment, and accessories was the second most important constraint for adopter beekeepers. These include; a box hives, casting molds, frame wires, honey extractors, and containers. Lack of extension support, indiscriminate application of agrochemicals, and the unaffordability of beekeeping equipment and accessories were among the top-ranked challenges for adopter beekeepers. Similarly, absconding, lack of extension support, and shortage of beekeeping materials were among the most important challenges for non-adopter beekeepers. Thus, alleviating these constraints could be an important breakthrough to enhance the production and productivity of the beekeeping sector in the region.

Table 5. Challenges of beekeeping in the study areas

Challenge	Adopter		Non-adopter	
	N(Index)	Rank	N(Index)	Rank
Shortage of beekeeping materials	46(0.162)	2	40(0.078)	5
Death of colony	1(0.005)	13	3(0.005)	12
Drought	6(0.018)	11	7(0.010)	10
Marketing	6(0.013)	12	10(0.020)	9
Beekeeping skill	10(0.029)	8	18(0.036)	8
Lack of credit facility	1(0.003)	14	0(000)	14
Low-quality beekeeping materials	8(0.023)	10	4(0.006)	11
High cost of beekeeping materials	39(0.100)	5	28(0.038)	6
Disease, pest, and predators	60(0.250)	1	97(0.289)	1
Shortage of bee forage	16(0.041)	7	15(0.003)	13
Reduction of honey bee colonies	12(0.026)	9	24(0.038)	7
Indiscriminate application of agro-chemicals	38(0.11)	4	65(0.158)	2
Lack of extension support	41(0.14)	3	67(0.147)	4
Absconding	29(0.080)	6	74(0.149)	3

N= number of respondent

Availability of Honeybee Technology

The survey result indicates that beekeepers have faced difficulty to access different beekeeping facilities. Thus, of the total adopters, 98.13% have no honey extractors, casting mold, or queen excluders due to the absence of a supplier in the region. Moreover, observation showed that previously distributed modern hives by governmental and non-governmental organizations did not have the full packages.

Honey Bee Pests and Predators

The major honeybee pests and predators in the study areas are indicated in Table 6. Ants were the most important pest in the study areas followed by spiders regardless of adoption level. Hive beetles, honey badgers, and wax moths in order of importance were among the most concerning pests and predators of honey bees for adopter beekeepers. In the same manner, honey badgers, monkeys, and hive beetles in order of importance were among the critical pests and predators of beekeeping for non-adopters in the study areas. Similar results were reported by Abebe *et al.* (2016) in the same region though the importance of some of the pests and predators varied. The results of the present study are also in agreement with the findings of Keralem (2005), who reported that ants, honey badgers, bee-eater birds, wax moths, spiders, and beetles were the most harmful pests and predators, challenging beekeeping in the Amhara region.

Table 6. Major honeybee pests and predators in order of importance in the study areas

Pest/predator	Adopters		Non-adopters	
	N(Index)	Rank	N(Index)	Rank
Ant	67(0.386)	1	88(0.336)	1
Spider	56(0.231)	2	63(0.167)	2
Honey badger	26(0.090)	4	39(0.126)	3
Wax moth	27(0.080)	5	30(0.066)	7
Monkey	1(0.004)	8	30(0.097)	4
Birds	9(0.019)	7	41(0.079)	6
Lizard	22(0.059)	6	27(0.041)	8
Hive beetles	41(0.131)	3	42(0.088)	5

Institutional Factors Influencing Adoption

The institutional factors influencing modern box hive technology in the study areas are indicated in Table 7. Benishangul Gumuz regional state has huge potential for honey production due to its larger colony ownership and high coverage of forest, shrubs, grass, and weeds which blooms year-round and is used as a source of bee flora. However, the sampled beekeepers of the study areas indicated that they are not benefited from the sector as to its potential due to different institutional factors (Figure 3). As compared to the adopters (18.2%) the majority (64.6%) of the non-adopters did not get any extension service on honeybee production. The contact of beekeepers with extension agents for adopters was significantly higher ($p < 0.001$) than for non-adopters.

Access to beekeeping training and visiting demonstration sites was also higher ($p < 0.001$) for adopters than non-adopters. The government of the region has invested in and built Farmers Training Centers (FTCs) to transfer knowledge and skills on new technologies and innovations from researchers, development agents (DAs), experts, and farmers. However, this study indicated that 97% and 51% of non-adopters and adopters respectively, did not visit farmer demonstration sites on beekeeping.

Table 7. Institutional factors influencing box hive adoption in the study area

Variables		Adopter N (%)	Non-adopter N (%)	χ2
Contact with an extension agent	Yes	54(81.8)	35(35.4)	34.41***
	No	12(18.2)	64(64.6)	
Contact with extension agent per month	No contact	18(27.3)	73(73.7)	39.65***
	Once a week	10(15.2)	2(2)	
	Fortnightly	11(16.4)	8(8)	
	Monthly	15(22.4)	11(11)	
	Other	12(17.9)	5(5)	
Visiting a demonstration site	Yes	15(22.7)	3(3)	15.8***
	No	51(77.3)	96(97)	
Field day on beekeeping	Yes	11(16.7)	4(4.1)	9.53***
	No	55(83.3)	95(95.9)	
Beekeeping training	Yes	36(54.55)	7(7.07)	49.58***
	No	30(45.45)	93(92.3)	

*** Significant at $p < 0.001$;** significant at $p < 0.01$; * significant at $p < 0.05$

Figure 3. Poorly managed box hive and top bar hive

Determinants of Adoption of Beehive Technology

From the estimated logistic regression model, 9 variables were found to be the important factors influencing the adoption of improved beehive technology (Table 8), which included demographic factors (sex and educational level of the beekeeper households); resource endowments (livestock holding, landholding size, traditional colony ownership, and district); and institutional factors (access to training, awareness, and contact with Development Agents (DAs)).

The households' demographic factors like age, education level, and sex of the beekeepers affected the adoption of an improved box beehive. The age of the beekeepers had significance ($p < 0.05$) and positively affects the adoption of a modern beehive. However, the marginal effect showed that, holding other factors constant as age increases by one year the probability of adoption of beehives increases by 0.011, which indicates that, as beekeepers age increases, the adoption of the technology may increases because they have accumulated experience, knowledge, and skill in apiary practices. The gender of the beekeepers was also significant ($p < 0.01$) and positively related to the adoption of improved beehives for the male-headed households than their female counterparts. The odds ratio indicated that the probability of being adopter increases by a factor of 0.037 for being male-headed compared to female-headed counterpart in the beekeeper households holding other factors constant. The marginal effect of the sex of the beekeepers also indicated that the probability of being male-headed would increase the probability of adoption approximately by 66.3% more than their female counterparts.

The education level of the beekeepers had a positive effect on the adoption of improved beehives. The logistic model result revealed that the educational status of household heads is positive and significantly ($p < 0.01$) correlated with adoption compared to illiterate household heads. The possible reason is that beekeepers with higher educational backgrounds may increase access to information and their knowledge to understand the use and importance of the technology. Literate beekeepers know of new technologies better. The marginal effect showed that beekeepers who are literate have a 60.1% higher probability of adopting modern beehives than their illiterate counterparts. Furthermore, the odds ratio also indicates that literate households had a factor of 16.36 in favor of adoption compared to their counterparts. The result is in line with those previously reported in the literature (Workneh *et al*., 2008; Workneh 2011; and Tadele 2016).

Resource endowments and access may positively or negatively affect the adoption of modern beehive technology based on the nature and relationship with apiculture farming. Hence, the land is one of the factors of production in agriculture and the total land area has been found to negatively affect the adoption of modern beehive ($p < 0.05$). The odds ratio in favor of adopting an improved box hive has decreased by a factor of 0.592 for beekeepers who had a large total land area. The marginal effect showed that as the area of land holding decreased by one hectare, the probability of adoption of improved box hives increased by 10.6%. This may be because farmers with large land holdings may be engaged in crop production and other livestock farming rather than beekeeping while households with a small parcel of land may practice beekeeping farming since apiary needs small land and adopt modern box hives to enhance and diversify their income. However, the result of the present study contradicts to the report of Tadele (2016) and Sheleme (2017), calling for further investigation.

Livestock ownership in TLUs had positively determined modern box hive adoption ($p < 0.01$). The odds ratio of the probability of the household adopting a modern beehive is increased by a factor of 1.587 for a unit increase in the beekeeper's TLU. The marginal effect showed that as the TLU of the beekeepers increases by one unit, the probability of the household adopting a modern box hive increases by 9.4%. Thus, livestock holding is considered a proxy for farmers' wealth status, wealthy farmers can earn more cash income that might enable them to intensify improved apiculture and create a capacity to buy modern box hives, which is in line with the reports in the literature (Bayissa 2010; Belets 2012).

The traditional colony possession had a negative significant effect on the adoption of modern box hives at a 10% level of significance. This may be due to the beekeepers with a large number of the traditional colony may think modern box hive is costly and refraining from adoption. The odds ratio and marginal effects showed that by holding other things constant, the probability in favor of adopting modern box hives decreases by 0.94 and 1.0%, respectively. Though it was not significant, this result is in line with the reports by Gebiso (2015).

Districts may affect the apiculture business. Hence, the beekeepers located in the Bambasi district had a negative effect on adopting modern box hives compared to those in Mao-Komo ($p < 0.05$) and had a factor of 0.13 less in favor of adopting the technology. The results of the marginal effects revealed that the beekeepers located in the Mao-Komo district had a 35.1% probability of adopting modern box hives compared to households in the Bambasi district. The reason might be due to the availability of suitable agroecology for apiculture in Mao-Komo special district than in Bambasi.

Access to extension services affects the adoption of technologies. The results revealed that awareness of beekeeping practices had a positive and significant effect on modern beehive technology ($p < 0.01$). The odds in favor of adopting an improved box hive increased by a factor of 22.95 for beekeepers who have awareness of beekeeping practices. Further, the logit model showed that the probability of adopting a modern beehive increased by 91.8% for the beekeepers who have got some awareness of beekeeping practices. Thus, it helps the beekeepers to enhance their knowledge and understanding of the importance and application of the technologies as also reported previously by Tadele (2016) and Sheleme (2017).

The results, further indicate that contact with extension agents has positively affected modern beehive adoption ($p < 0.01$). The odds in favor of adopting a modern box hive increased by a factor of

9.08 for beekeepers who have had contact with extension agents and thus showed that contact with development agents had increased the probability of adoption by 39.6%. This can be justified by the fact that farmers who have contact with development agents may have information and access to the modern box hive due to their relationship with the development agents and could improve the adoption of the technology.

Table 8. Determinants of Improved Beehives technology adoption

Variables		Coefficient	Robust SE	Odds Ratio	Marginal effect dF/dX	Marginal effect SE
Households characteristics						
Age (years)		0.055**	0.027	1.05	0.011*	0.005
Sex (1=Male; 0=Female)		-3.297***	0.845	0.037	-0.663***	0.014
Family size (No.)		0.112	0.185	1.120	0.227	0.018
Beekeeping experience (years)		-0.017	0.039	0.983	-0.003	0.006
Education level	Read and write	0.337	0.965	1.400	0.072	0.246
	Elementary	0.347	0.760	1.416	0.071	0.142
	Literate	2.794***	1.115	16.36	0.601***	0.161
Resource endowment of the beekeepers						
Land size (ha)		-0.523**	0.208	0.592	-0.106**	0.049
Livestock ownership (TLU)		0.462**	0.156	1.587	0.094**	0.04
Traditional Colony owned (No.)		-0.056*	0.030	0.94	-0.010*	0.005
Location	Bambasi district	-2.051**	0.882	0.130	-0.351**	0.138
	Homosha district	-0.231	0.787	0.793	-0.046	0.145
Access to Extension services						
Awareness of beekeeping practices		3.133***	0.670	22.95	0.618***	0.099
Access to training		0.825	0.669	2.282	0.179	0.161
Contact with Extension Agents		2.089***	0.601	9.08	0.396***	0.112
Constant		-2.232	2.132	0.011		
Observations		165				
Log likelihood		-46.61				
LR chi^2 (15)		95.49				
Pseudo R^2		0.5855				
Prob>chi^2		0.0000				

NB: SE= standard Error, dY/dX if for discrete change of dummy variable from 0 to 1, 1*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, No.= Number, TLU= Tropical Livestock Unit.

CONCLUSIONS

In summary, the results of descriptive statistics and econometric models showed that the determinants of adopting modern box hives include demographic, resource endowments, and institutional factors specific to the beekeepers and support institutions. In the Benishangul Gumuz region, the major determinant factors influencing adoption of modern box hives include the gender of the beekeepers, level of education, total land, and livestock ownership, the number of the traditional colonies , location, awareness of beekeeping practices, and contact with extension agents. The results further revealed that there is a high gender influence where male beekeepers are more likely to adopt the technologies compared to the female counterparts. Therefore, a policy message can be drawn that to fill the gender gap in modern bee hive adoption, priority and special support should be mechanized for female-headed households during the provision of the technology as women have less access to and control over factors of production. Moreover, all stakeholders along the extension system should work on promotion, training, designing improved packages of beekeeping practices, and building the capacity of beekeepers to improve the dissemination apiculture technologies. Further, the study indicated that livestock resources could complement modern box hive uptakes while a higher land area owned by the beekeepers has a negative influence on adoption. Finally, stakeholders engaged in the research and development continuum should work together to improve the extension services thereby providing information and innovation to the beekeepers, extension agents, and experts.

CONFLICTS OF INTEREST

Authors declare that they have no conflicts of interest regarding the publication of this paper with the Journal of Science and Development.

REFERENCES

Abebe, A., Tadesse, Y., Yohannes, E., Faji, M. and Habtamu, A. 2016. Analysis of honey production systems in three agro-ecologies of Benishangul-Gumuz, Western Ethiopia. Journal of Agricultural Extension and Rural Development, 8: 29-38. 10.5897/JAERD2014.0705. [Scholar Google]

Amssalu, B., Nuru, A., Radloff, S.E. and Hepburn, H.R. 2004. Multivariate morphometric analysis of honeybees (Apis mellifera) in the Ethiopian region. Apidologie, 35(1): 71-81. [Scholar Google]

AMS (Assosa Metrological Station). 2017. Climatic data. Assosa Meteorological Station (AMS), Benishangul Gumuz Regional State of Ethiopia, Assosa.

Bayissa, G. 2010. Adoption of improved sesame varieties in Meisso district, West Hararghe zone, Ethiopia.M.Sc. Thesis, Haramaya University, Ethiopia. [Scholar Google]

Bekele, M., Tesfaye, Y., Mohammed, Z., Zewdie, S., Tebikew, Y., Brockhaus, M. and Kassa, H. 2015. The context of REDD+ in Ethiopia: Drivers, agents and institutions, (127). CIFOR. [Scholar Google]

Belets, G. 2012. Analysis of Improved Box Hive Technology Adoption By Smallholder Farmers: The Case Of AhferomWoreda, Central Zone Of Tigray Region, Ethiopia.M.Sc. Thesis, Haramaya University, Ethiopia. [Scholar Google]

BOARD (Bureau Agriculture and Rural Development). 2011. Report of Benishangul Gumuz Region Agriculture and Rural Development Office, Assosa, Ethiopia (unpublished).

CSA (Central Statistical Agency). 2013. Agricultural Sample Survey 2012/13 report on livestock and livestock characteristics (private peasAnt holdings). Volume Π, statistical bulletin 570, Addis Ababa, Ethiopia.

Fikadu, T. 2018. Assessing Factors Associated With Honey Production in Wombera Wereda, Metakel Zone, Benishangul- Gumuz Region, Ethiopia. MSc. Thesis submitted to Addis Ababa University, Ethiopia.

Gebiso, T. 2015. Adoption of Modern Bee Hive in Arsi Zone of Oromia Region: Determinants and Financial Benefits. Agricultural Sciences, 6: 382-396. http://dx.doi.org/10.4236/as.2015.63038. [Scholar Google]

Keralem, E. 2005. Honey bee production system, opportunities and challenges in Enebse Sar Midir Wereda (Amhara Region) and Amaro Special Wereda (Southern Nations, Nationalities and peoples Region). Alemaya University. [Scholar Google]

Mulatu, A., Marisennayya, S. and Bojago, E., 2021. Adoption of Modern Hive Beekeeping Technology: The Case of Kacha-Birra Woreda, Kembata Tembaro Zone, Southern Ethiopia. Advances in Agriculture. [Scholar Google]

Pindyck, S. and Rubinfeld, L. 1981. Econometric Models and Economic Forecasts, Second Edition. Macmillan Pub.Co. New York.

Sheleme, R. 2017. Assessment of Factors Affecting Adoption of Modern Beehive in East Wolega Zone, Western Oromia. International Journal of Engineering Research &Technology, 6(01). [Scholar Google]

Shenkute, A., Getachew, Y., Assefa, D., Adgaba, N., Ganga, G. and Abebe, W. 2012. Honey production systems (Apis mellifera L.) in Kaffa, Sheka, and Bench-Maji zones of Ethiopia. Journal of Agricultural Extension and Rural Development, 4(19): 528-541. [Scholar Google]

Sahel, S.O.S. 2006. Community Initiative Promotion (CIP): Kaffa Development Programme (KDP). Synopsis of the study of selected sub-sector in Kaffa Zone Ethiopia (Forest coffee, Honey and Cardamom). [Scholar Google]

Tadele, A. 2016. Factors Affecting Adoption of Modern Beehive in Saese Tsaeda District of Tigray Ethiopia. Journal of Energy Technologies and Policy, 6(2). [Scholar Google]

Tarekegn, A. 2022 Traditional Forest Beekeeping and Its Challenge in Benishangul Gumuz Regional State, Ethiopia. Bee Studies, 14(1): 27-34. [Scholar Google]

Workneh, A., Puskur, R. and Karippai R.S. 2008. Adopting improved box hive in AtsbiWemberta district of Eastern Zone, Tigray Region: Determinants and financial benefits. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 10. ILRI (International Livestock Research Institute), Nairobi, Kenya. 30 pp.

Workneh, A. 2011. Financial Benefits of Box Hive and the Determinants of Its Adoption in Selected District of Ethiopia. American Journal of Economics, 1(1): 21-29. [Scholar Google]

Yirga, G. and Teferi, M. 2010. Participatory technology and constraints assessment to improve the livelihood of beekeepers in Tigray Region, northern Ethiopia. Momona Ethiopian Journal of Science, 2(1). [Scholar Google]