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ADOPTION AND INTENSITY OF MODERN BEE HIVE IN WAG HIMRA AND NORTH WOLLO ZONES, AMHARA REGION, ETHIOPIA

Wag Himra zone is one of the Amhara Regional State which has a potential honey production and it is a quite suitable for apiculture activities. The objectives of the study were (1) quantifying the determinant factors of the probability of adoption, (2) evaluating the intensity use of modern beehive and (3) identifying the major constraints of modern beehive production in wag Himra and north Wollo zones, Amhara Region, Ethiopia. Multi-stage sampling methods were employed. 268 rural beekeepers were interviewed for *this study with proportional random sampling method from adopters and non-adopters. Among the 268 beekeepers, 97 (36.19%) and 171 (63.81%) were non-adopters and adopters respectively. Descriptive analysis and econometric (double-hurdle model) were applied using SPSS-22 and STATA-12, respectively. The first hurdle result revealed that age, the number of livestock owned, educational level, the number of local hives beekeepers possessed, training provided, the the total annual income of beekeepers, credit service, distance to Woreda agricultural office, extension service and participation in off-farm activities are the main factors that affect the probability of adoption decision. Moreover, the second hurdle revealed that age, the number of local hives beekeepers possessed, training access, credit service, and distance to Woreda agricultural office are the main factors that affect the intensity use of modern beehive. Additionally, Pests and predators, drought and lack of bee equipment and accessories are ranked as the first, second and third major constraints of beekeeping respectively which lead the bee colony to abscond and reduction of honey yield. According to the finding the authors safely recommended that those significant factors in adoption decision and intensity use of modern beehive should be considered by policy makers and planners of governmental and NGOs in setting their policies and strategies of honey production improvement interventions.*

Key words: *Adoption, Modern beehive, double-hurdle Model, Intensity.*

Acronyms

- Kebele: the smallest administrative unit in the political structure of Ethiopia.
- DA's: Development Agents
- Woreda: the administrative unit in the political structure of Ethiopia next to Kebele
- k.g: kilogram which used for weight measurement.
- SPSS: Statistical Package for Social Science
- Tuaf: is a material prepared from honey which used for the religious purpose in the local area.
- TIRET: the name of the private company which is the honey and beeswax factory

Note: The author used the Gregorian calendar throughout the manuscript.

Introduction and review of literature. Beekeeping in Ethiopia is common and one of the agricultural activities. Honey and beeswax are the major bee products used

for export earnings, and also play a source of cash income for the rural community. Ethiopia, with around 23.6 % of African and 2.1 % of the world production, is the leading honey producer in Africa and is one of the ten largest producers in the world [13]. Honey is used for the preparation of traditional beer (*Tej*) and traditional medicine; whereas, beeswax is used for a preparation of traditional candle (*Tuaf*) which is used for the religious purpose in the local area. In addition to preparation of beeswax and honey, bees used for pollination of fruit, vegetable, and cereal crops thereby contribute to improving production and productivity of food crops.

In recent years, Ethiopian government under its agricultural led development policy gave due attention to apiculture. Apiculture development is one of the development strategies of Amhara region which is categorizing the areas based on the prioritized potential. For instance, Wag-Lasta area development strategy focused on small ruminant and apiculture development. To this effect, different private and public institutions such as Amhara Agricultural Research Institute, Small and Medium Enterprises, Amhara Region Agriculture Bureau and other non-governmental Organizations have been involved in technology generation and adaptation, modern bee hive box production, and dissemination respectively. Moreover, public and private companies such as Lalibela Honey and Bees Wax Museum and TIRET (private company) honey and beeswax factory are being established.

In the last 7-10 years, to increase production and productivity of honey and beeswax, different improved technologies have been used. Some of the technologies are transitional bee hive, modern bee hive, honey presser, water sprayer, smoker, glove, honey extractor, and veil. Modern bee box hive has been disseminated to the farmers through the office of agriculture and different governmental and nongovernmental organizations to improve the production potential of bees through creating favorable working and living environment.

The modern bee hive box has a production potential of 20-30 kg per colony of honey while the traditional bees hive produce 5-10 kg per colony of honey [12]. Through different organizations strive to disseminate modern bee box hive, the adopters are not comparable what efforts have been excreted, this might have different reasons such as institutional, socioeconomic and biophysical. Such information's might be different from according to the circumstances in which the farmers are living and working, and still, no information has been generated on socioeconomic, institutional and biophysical determinants of adoption of improved beehives in Amhara Region. Therefore, this study has paramount importance to generate such information and develop policies and strategies in line with the unique characteristics of the study area.

Definition and concept of adoption. Adoption was defined by [8] as the degree of use of new innovation by a farmer when he has got full information about the new innovation and its potentials. The author classified adoption of new technology into two as individual and aggregate adoption. Accordingly, they defined Individual adoption as the farmer's decisions to incorporate a new technology into the

production process and the aggregate adoption as the process of diffusion of a new technology within a region or population. Furthermore, [18] defined technology adoption as the decision made by a farmer to use a new technology as the best course of action he ever practiced. Adoption of new technology in agriculture, occurs due to behavioral changes like desirable changes in knowledge, understanding and ability to apply technological information, changes in feeling behavior such as changes in interest, attitudes, aspirations, values and the like; and changes in overt abilities and skills, is determined by many socio-economic factors [17] and [19]. Adoption is not a simple and overnight activity, but it is a mental process which an individual farmer (decision-maker or group of decision maker's family members) goes through for decision-making. To ensure adoption of new innovation the fulfillment of specific economic, technical and institutional conditions are required. From the farmers' perspective, the new technology should be economically more profitable than the existing alternatives. Moreover, the new technology should also be technically easily manageable by small holders and adaptable to the surrounding socio-cultural situations and availability of the new technology and all other necessary inputs to smallholders at the right time and place and in the right quantity and quality are necessary conditions [7]. In general adoption is a function of five characteristics of the technology which are a relative advantage or profitability, compatibility or riskiness, complexity, trialability/divisibility, or initial capital requirements, and observability or availability [18].

Empirical Review of determinants for adoption of modern beehives. A lot of studies shown that some demographic and socioeconomic factors that influenced the adoption of different technologies among smallholder farmers in developing countries. For instance, Study by [9] shows that the main determinants of modern beehive adoption in Arsi zone, Ethiopia are farmyard size, a number of local beehives beekeepers possessed, training provided participation on demonstration, wealth status of beekeepers and participation of beekeepers on nonfarm income sources [9]. Moreover, chemical application, bee predators, lack of knowledge and skill on modern beehives, lack of modern beehive accessories, lack of bee forage and lack of capital were the major beekeeping bottlenecks [9] and [23], found that credit, Knowledge on practical activities of the technology, education level of household head, positive perception on modern beehive technologies and apiary visit demonstration were most determinant factors of adoption of improved box hive. The study was done on adoption and profitability of Kenya transitional beehive which may be the first study in Ethiopia, by [15] as cited in [9]. Adoption study also evidenced that household farm experience, the perception of timely supply of the technology, extension contact, and visit to apiaries are major adoption determinants. [5] inferred that different demographic and socioeconomic characteristics of farm-household are associated with technology adoption such as age, education and personal characteristics of the household head; size, location and tenure status of the farm; availability of cash or credit for farm investment and access to markets for farm produce; and so on. Studies by [6] in Ethiopia and [16] in sub-Saharan Africa cited at

[9] identified plot size, previous experience with fertilizer, supply of fertilizer, farm size, amount of rainfall, household size, and the ratio of price of main crop to cost of fertilizer as well as accessed to credit as factors constraining fertilizer demand among arable crop farmers.[8] in their research report stated that credit, farm size, risk, labor availability, and human capital, land tenure and education are main factors affecting technological adoption.

The purpose of the article. General objective: to assess the adoption and intensity use of modern beehive with its determinant factors. Specific objective: to analyze the factors affecting adoption of a modern beehive; to evaluate extent and intensity of adoption; to identify the constraints of modern beehive adoption.

Results and discussion.

Description of the study area. This study was conducted at Wag himra and North Wollo zones of Amhara National Regional state. Particularly, Sekota (Aybra and Woleh) and Gazgibla (Zarota and Asketama 01) and Ziquala (Ziquala 01 and Ziquala 02) districts of Wag himra zone and Lasta (Yimraha, Blbala and Debre Loza) and Bugna (Kidus Harbie, Laydba and Birko) districts of North Wollo found inside Tekeze basin growth corridor of Amhara region; in 2015 production years.

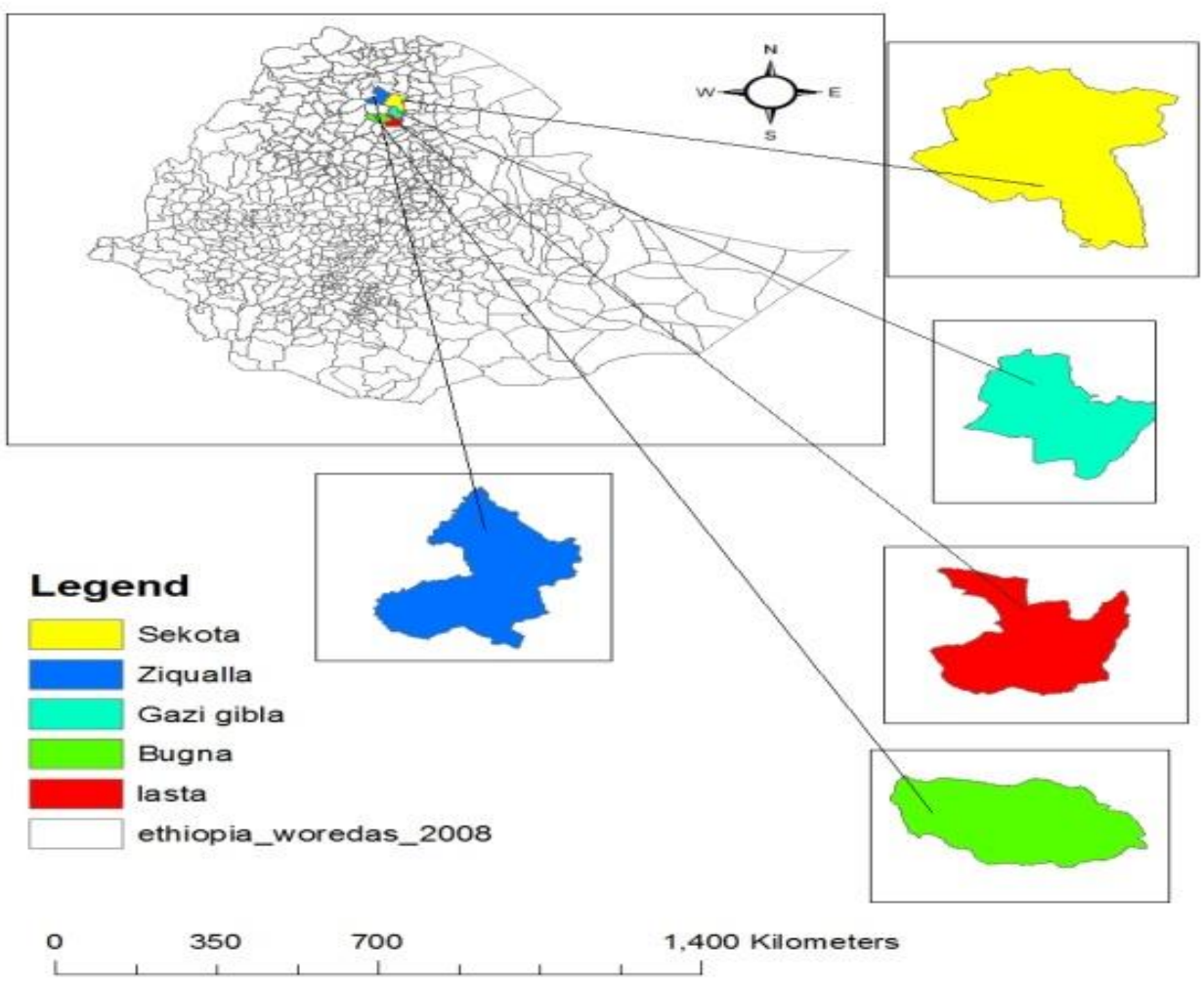

Fig. 1. Map of the study area

Sampling techniques. According to [14], multi-stage sampling techniques were employed. At the first stage, five districts were selected purposively based on beekeeping potential and modern beehive technology promoted through secondary data from zonal agriculture office. Accordingly; Sekota, Gazgibla and Ziquala districts from wag himra and Lasta and Bugna districts from North wollo zones were selected. Then at the second stage, twelve kebeles were selected purposively in which modern box beehive was promoted. Accordingly, Woleh, Aybra, Asketama 01, Zarota, Ziquala 01 and Ziquala 02 kebeles from wag himra zone and Debre Loza, Yimraha, Blbala, Kidus Harbie, Laydba and Birko Kebelle from North Wollo were selected. At the final stage, 268 respondents were selected for a formal interview with proportional random sampling techniques from adopters and non-adopters at those sample kebeles.

Method of data collection. Primary and secondary data were employed and the data were collected primarily from beekeepers through the interview and focus group discussion. Moreover, primary data were collected from district agriculture experts; kebele DA's and model farmers through key informant interview. A preliminary survey was conducted to assess the potentials of each district in beekeeping and the potential challenges of beekeeping in the study area so as to incorporate into the questionnaires. At the second stage-structured questionnaires were prepared for formal interview and interview was conducted. Secondary data were collected from the zone, district and kebele Agriculture offices working documents.

Method of Data analysis. The Data were analyzed with descriptive statistics and econometric models. The descriptive statistics were a percentage, mean; standard deviations were used whereas for inferential statistics t-test, x^2-square were used for continuous and categorical data respectively with SPSS V-22 [20]. The double hurdle model with Stata V-12 [21] was employed to analyze the determinants and intensity of adoption of a modern bee hive.

Analytical Model. Specification of Econometric models. In principle, the decisions of whether to adopt and how much to adopt can be made jointly or separately. It can be argued that adoption and intensity of use decisions are not necessarily made jointly [3]. The Tobit model used to analyze under the assumption that the two decisions are affected by the same set of factors [10]. On the other hand, in the double hurdle model, both hurdles have equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of one. Most prominently, a variable appearing in both equations may have opposite effects in the two equations. The double hurdle model initially developed by [4]. Later, a lot of studies has been extensively applied this econometric model. For instance [22] who employed double hurdle in studying improved poultry breeds adoption in Ethiopia. The double hurdle model is a parametric generalization of the Tobit model, in which two separate stochastic proces determine the decision to adopt and the level of adoption of technology. The double hurdle model has an adoption (D) equation:

$$Di = \alpha Zi + Ui \quad (1)$$

Where Di is a dummy variable that takes the value 1 if the farmer adopts modern beehive and zero otherwise, Z is a vector of household characteristics and α is a vector of parameters.

The level of adoption (Y) has the following equation:

$$Yi^* = ßXi + Vi$$
$$Yi = Yi^* \text{ if } Yi^* > 0 \text{ and } Di > 0$$
$$Yi = 0, \text{ otherwise} \quad (2)$$

Where Yi is the observed variable to be the proportion of modern beehive (frame hive)

X is a vector of the individual's characteristics and ß is a vector of parameters.

$$Yi = \frac{\text{number of modern (frame) hive owned}}{\text{totla number of beehive (frame+traditional+trnsitional) owned}}$$

The error terms Ui and Vi are distributed as follows:

$$\begin{cases} Ui \sim N \\ Vi \sim N \end{cases} \begin{matrix} (0,1) \\ (0,\sigma^2) \end{matrix} \quad (3)$$

Finally, the observed variable Yi in the double hurdle model is determined by

$$Yi = Di\ Yi^* \quad (4)$$

The log-likelihood for the double hurdle model is:

$$LogL = \sum_0 \ln\left[1 - \Phi(\alpha Zi'[\tfrac{ßXi'}{\sigma}]\right] + \sum_+ \ln\left[\Phi(\alpha Zi')\ \tfrac{1}{\sigma}\phi[\tfrac{Yi - ßXi'}{\sigma}]\right] \quad (5)$$

Where 0 indicates summation over the zero observations in the sample, while + indicates summation over positive observations, and Φ (.) and ϕ (.) are the standard normal cumulative distribution functions and probability distribution functions respectively. Under the assumption of independence between the error terms Vi and Ui, the model as originally proposed by [4] is equivalent to a combination of a truncated regression model and a univariate Probit model. The Tobit model, as presented above arises if $\lambda = \frac{ß}{\sigma}$, and X = Z

A simple test for the double hurdle model against the Tobit model can be used. Therefore, one simply has to estimate the truncated regression model, the Tobit model and the Tobit model separately and use a likelihood ratio (LR) test. The LR statistics can be computed using [11] (Green, 2000).

$$\Gamma = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \sim \chi^2_K \quad (6)$$

Where L_T – is a likelihood for the Tobit model; L_P – is a likelihood for the Probit model; L_{TR} –is likelihood for the truncated regression model and K is the number of independent variables in the equations. If the test hypothesis is written as: $H_0: \lambda = \frac{\beta}{\sigma}$, and $\lambda \neq \frac{\beta}{\sigma}$. H_0 will be rejected on a pre- specified significance level if $\Gamma > \chi^2_{K.}$

Hypotheses and definition of working variables. The authors used sixteen independent variables and two dependent variables. The author hypothesized that those independent variables affect the probability of decision to adopt or not and the intensity use of modern beehive positively or negatively before data analysis. The detail explanation was incorporated in Table 1.

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Table 1

List of dependent and independent variables employed in double hurdle model

Variables	SPSS Code	Type	Measurement	Expected sign
Adoption decision of modern beehive	ImprBHive	Dummy	Adopter = 1 and non-adopter = 0	-
Proportion of modern beehive holding	ProportionFH	Continues	Number	-
Sex of respondents	Sex	Dummy	Male = 1, female = 0	+ve
Age of respondents	Age	Continues	Number of years	-ve
Education level of respondents	Educ	Dummy	Literate = 1, illiterate = 0	+ve
Number of family labor of the respondents	FamLabor	Continues	In terms of man equivalent	+ve
Total farm land	TFland	Continues	Measured in hectare	+ve
Livestock holding of respondents	LivstockHold	Continues	Measured in TLU	+ve
Supplementary feeding	Suppfeed	Dummy	Yes = 1 and No = 0	+ve
Number of traditional beehive	NoTdH2007	Continues	Measured in number	+ve
Beekeeping experience with modern beehive	HLKFrHive	Continues	Measured in number of years	+ve
Participation in off-farm activities	OffarmActv	Dummy	Yes = 1 and 0 = No	+ve/-ve
Total annual income	TAnuIncom	Continues	Measured in Ethiopian birr	+ve
Access to extension services	EXT	Dummy	Yes = 1 and No = 0	+ve
Training on beekeeping	Traing	Dummy	Yes = 1 and No = 0	+ve
Access to credit	Credit	Dummy	User = 1 and otherwise = 0	+ve
Distance to Keble Agriculture office of respondents' residential	DistKAO	Continues	Measured in kilometers	-ve
Distance to Woreda Agriculture office of respondents' residential	DisWorO	Continues	Measured in kilometers	-ve

Source: author's calculations.

Demographic and Socio-economic Characteristics of the respondents. As Table 7 depicted, out of 268 respondents only 171 (63.81%) are adopters of a modern bee hive and the remains 97 (36.19 %) are non-adopters. The survey result, as depicted in Table 2 above shows that among the total respondents 95.5 % of the respondents are male headed and 4.5 % are female-headed households. Among the total sample, households 2.9 % of the female-headed and 60.8% male-headed households were adopters but the chi-square value is insignificant. The result of chi-square test (χ2-test) showed positive association between level of education and adoption of modern beehive which is significant at less than 1% level of significance. As chi-square test (χ2-test) shows access to extension service and provision of training on modern bee beehive technology, involvement in off-farm activities,

access to credit service and involvement in formal institution have a positive and significant association between probability of adoption of modern bee hive at less than less than 1%, at 1%, 2% and at less than 5% level of significance respectively.

Table 2

Demographic and socioeconomics characteristics of respondents (Categorical and Nominal variables)

Indicator		Adopters	Non Adopters	Total	$\chi 2$	Asymp. sig
Sex of respondents	Female	8	4	12 (4.5)	0.045	0.833NS
	Male	163	93	171(95.5)		
	Total	171	97	268(100)		
Level of education of the respondents	Illiterate	71	67	138(51.5)	18.809	0.000***
	Literate	100	30	130(48.5)		
	Total	171	97	268(100)		
Are you a member of community organizations?	Yes	164	92	256(95.5)	0.163	0.686NS
	No	7	5	12(4.5)		
	Total	171	97	268(100)		
Do you participate in formal institutions?	Yes	116	54	170(63.4)	3.949	0.047**
	No	55	43	98(36.6)		
	Total	170	98	2689100)		
Have you got extension services about modern beehive technology?	Yes	121	30	151(56.3)	39.922	0.000***
	No	50	67	117(43.7)		
	Total	171	97	268(100)		
Have you ever participated in modern beehive technology training?	Yes	125	24	149(55.6)	58.626	0.000***
	No	46	73	119(44.4)		
	Total	171	97	268(100)		
Have you ever used credit for beekeeping?	Yes	29	4	33(87.7)	9.444	0.002***
	No	142	93	235(12.3)		
	Total	171	97	268(100)		
Do you participate in off-farm activities?	Yes	101	37	138(48.5)	10.844	0.001***
	No	70	60	130(51.5)		
	Total	171	97			
Do you supplement feed for bee colony?	Yes	60	0	60(22.4)	43.853	0.000***
	No	111	97	208(77.6)		
	Total	171	0	268(100)		
Do you give water for bee's colony?	Yes	39	23	62(23.1)	0.028	0.866NS
	No	132	74	206(76.9)		
	Total	171	97	268(100)		
Did you plant bee forage?	Yes	68	0	68(25.4)	51.688	0.000***
	No	103	97	200(74.6)		
	Total	171	97	268(100)		
Do you change combs of modern frame hive?	Yes	89	0	89(33.2)	75.587	0.000***
	No	82	97	179(66.8)		
	Total	171	97	268(100)		

Note. *** and ** shows the level of significance at less than 1 % and 5%; The numbers in brackets are standard errors of mean and the bracket indicates the percentage of the respondents of the parameters. And also NS is NonSignificant.

Source: author's calculations.

The survey result revealed that the household's average age was 48 years while the mean age for adopters and non-adopters were 46.86 and 50.02 respectively with a

significant mean difference at 10% level of significance. The household average tropical livestock unit was 5.125 TLU with 5.697 TLU and 4.1168 TLU for adopters and non-adopters respectively and the mean difference was significant at 5% level of significance. The T-test also shows that the average total income of farm households was 29320.4179 birr. The mean total annual income for adopters and non-adopters is 32977.43 birrs, 22873.52 birr respectively and the mean difference between adopters and non-adopters was significant at Less than 1% level of significance (Table 3).

Table 3

Demographic and socioeconomics characteristics of continuous explanatory variables

Variables	Mean			t-value	Sign.
	Adopters	Non-adopters	Combined		
Age of the respondents	46.88	50.02	48(.81)	-1.87	(.063)*
Number of family labor of the household in man equivalent	2.86	2.99	2.9(.07)	-.93	(.355)
Total amount of farm land in hectare	.89	.77	.84(.03)	1.96	(.051)**
Number of livestock owning of the household in TLU	5.73	4.12	5.15(.19)	4.06	(.000)***
Number of traditional hive you keep	7.22	4.25	6.14(.52)	2.81	(.005)***
How far is the kebelle agricultural office?	3.02	4.19	3.44(.19)	-2.94	(.004)***
How far is the woreda agricultural office?	16.97	16.78	16.9(.55)	.17	(.867)
Total annual income of the household	31924.8	22873.52	28648.77 (696.2)	6.75	(.000)***
Amount of honey yield harvested per colony from frame hive	13.55	-	-	-	-
Amount of honey yield harvested per colony from transitional hive	11.26	-	-	-	-
Amount of honey yield harvested per colony from traditional hive	4.45	4.24	4.36(.18)	.593	(.554)

Note. ***, **, and * show the level of significance at 1, 5 and 10 % respectively; the numbers in brackets are a mean standard error.

Source: author's calculations.

Honey yield productivity

In table 4 depicted that the honey yield productivity of frame hive was by far better than the traditional beehives in the areas. The minimum and maximum yield value of the frame hive was 8.5 k.g and 26 k.g per hive. Therefore, average honey yield per hive from frame hive in the 2013 and 2014 production years was 14.3 k.g and 13.5 k.g respectively. On the contrary, the average honey yield per hive from the traditional hive in the 2013 and 2014 production year was 4.9 k.g and 4.4 k.g respectively.

Major Constraints of beekeeping in the study Area. As depicted below in table 5, 44% of respondents ranked pests and predators as the first major constraints of beekeeping, 20.5% of respondents ranked drought as the second major constraints of beekeeping which results shortage of bee forages and leads to the bee colony to

abscond and also 13.4% of respondents ranked lack of bee equipment (like modern bee hive, waxstumper, honey extractor, queen excluder) and accessories (like smoker, cloth, bee veil, brush) as the third major constraints of beekeeping sector which hinder the farm households to implement appropriate improved bee hive management practices(like internal inspection of hive, adding and reducing supper, even to harvest the honey) on time.

Table 4

Two years data on honey yield productivity per each type of hive

Type of beehive with production year	Minimum	Maximum	Mean	Std. Dev.
Amount of harvested yield in kg per frame hive in 2013	8.5	26.0	14.3	3.5
Amount of harvested yield in kg per frame hive in 2014	8.0	21.0	13.5	3.3
Amount of harvested yield in kg per transitional hive in 2013	7.0	18.0	11.1	4.0
Amount of harvested yield in kg per transitional hive in 2014	7.5	19.0	11.3	3.5
Amount of harvested yield in kg per traditional hive in 2013	0.0	15.0	4.9	2.5
Amount of harvested yield in kg per traditional hive in 2014	0.0	15.0	4.4	2.7

Source: author's calculations.

The fourth, fifth, sixth and seventh major constraints were the application of herbicide for crop, beekeeping skill, shortage of bee forage and financial constraints respectively.

Table 5

Major constraints of beekeeping in the study area

Indicator	Frequency	Percent
pests and predators	118	44.0
shortage of bee forage	9	3.4
lack of extension support	6	2.2
Drought	55	20.5
indiscriminate chemical application	22	8.2
lack of bee equipment	36	13.4
beekeeping skill	11	4.1
poor technology compatibility	1	.4
tough management package	3	1.1
financial problem	7	2.6
Total	268	100.0

Source: author's calculations.

As shown in table 6 among different pests and predators which highly affect the bee colony 32.1% of the farm households ranked ants as the first common pests, in the same manner, 30.6% and 29.5% of respondents ranked wax moth and birds as the second and the third common pests and predators respectively. And the remaining 5.2%, 1.5% and 1.1% of respondents ranked spider, lizard and honey badger as fourth, fifth and sixth common pests and predators respectively in the study area.

Table 6

The major pests and predators of beekeeping in the study area in rank

Indicator	Frequency	Percent
Ant	86	32.1
wax moth	82	30.6
honey badger (megoza)	3	1.1
Birds	79	29.5
Spider	14	5.2
Lizard	4	1.5
Total	268	100.0

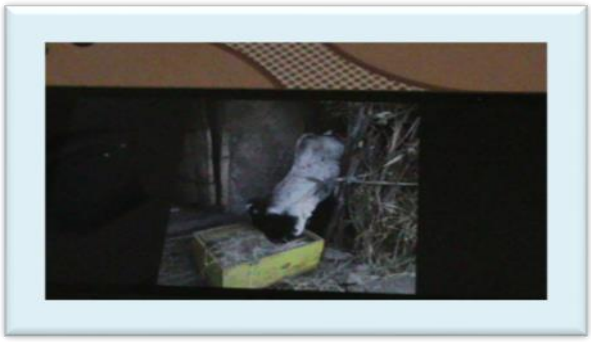
Source: author's calculations.

Fig. 2. The effect of wax moth

Modern bee hive technology practices Reasons for discontinuing of modern beehive. In the Table 7 showed that among all adopters 35 (20.5 %) were discontinued modern bee hive production due to different problems. 40 % of the respondents were to absence tough hive management and 40 % due to pest occurrence beyond their controlling mechanism specifically wax moth even though the attempted to manage.

Absconding of bee colonies

Modern beehive used as an animal feeding setting



Modern beehive used as a material for construction

Poor management practices

Table 7

The distribution of modern beehive and reasons for discontinuing of modern bee hive

Indicator		Frequency	Percent
Do you use modern beehives?	No	97	36.2
	Yes	171	63.8
	Total	268	100.0
Did you discontinue frame hive production?	No	136	79.5
	Yes	35	20.5
	Total	171	100
If yes, why do you discontinue frame hive production+?	Tough hive management	1	2.9
	pest occurrence (typically wax moth)	14	40.0
	Lack of inputs (wax, reconstructing material, smoker etc)	1	2.9
	Lack of skills (wax casting, honey harvesting, honey extracting, etc)	1	2.9
	Pest occurrence and lack of inputs	4	11.4
	Absconding	12	34.3
	Drought	2	5.7
	Total	35	100.0
If you discontinued frame hive, for what purpose the equipment use it?	Putting for clothes as a box	9	25.7
	For using as sitting chair	2	5.7
	For used as fuelwood	1	2.9
	For using as a coffee pot sitting	3	8.6
	Simply stored in the house	20	57.1
	Total	35	100.0

Source: author's calculations.

Proportion of modern beehive. The average proportion of modern beehive was 0.46 and 0.23 for adopters and the whole sample respectively with a maximum of 13 beehives, While, the average number of modern beehives was 2.87 and 1.49 hives for adopters and entire sample, respectively with a maximum of 13 modern beehives. Moreover, the total sample beekeepers have their own total number of beehives was 2000 (444 modern and 1556 traditional) hives with bee colony and 755 (255 modern and 500 traditional) hives without bee colony due to bee colony absconding and pests and predators attack. The average number of beehives with bee colonies for the total sample beekeepers was around 8 (6 traditional and 2 modern) with a minimum of 1 and maximum of 81 beehives.

Colony Management Practices. According to the survey result, external inspection is applied and known than internal inspection unless it is for honey harvesting time. The sample respondents indicated that they remove all combs destroying a colony for traditional hives even they could not change the old combs for modern hives due to lack of supply of wax and it is costly as well lack of awareness. 33.2% of the entire respondents changed the old comb of the colony, while, the remains 66.8% did not change the old comb. The result of $\chi 2$ –test showed significant and positive association between the comb change practice and the

probability of decision to adopt modern beehive which is significant at less than 1% level of significance. This indicates that the beekeepers that change the old and waste combs have good beekeeping practice than the beekeepers that did not change the old comb.

Supplementary feeding practices. Regarding supplementary feeding, almost all non-adopters and adopters not gave supplementary feed to the colony at dearth period, however, 60 (22.4 %) of adopters gave supplementary feeding like malt powder, sugar, shiro and honey and also water at dearth period throughout the year which explained in Table 2, it is a positive association between supplementary feeding and adoption of modern beehive. Thus, it leads the colony to become active and the colony not attacked by different pests and predators easily. According to farm household knowledge, the dearth period for the colony is that of February till June fourth week in case there is no Belg season.

According to the survey result, 52.4, 18.93, 5.83 and 22.82 % of the activities which are internal and external cleaning and hygiene, honey harvesting, giving water and supplementary feeding were undertaken by a spouse, husband, children and one of them available at the time respectively (Fig. 3).

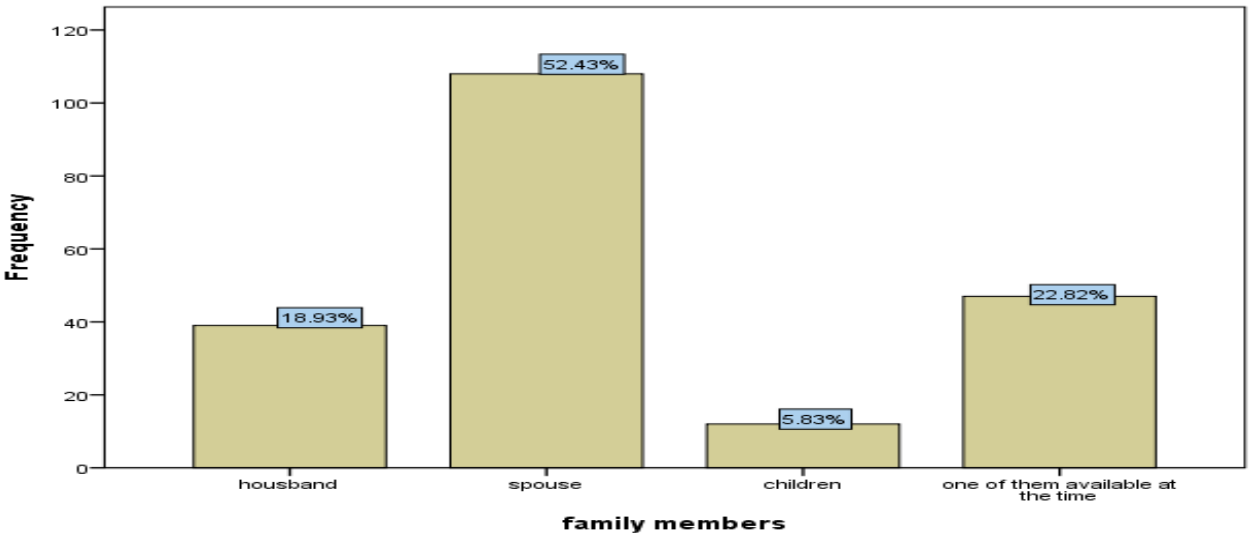


Fig. 3. The responsibility of family members who follow up / inspection and hygiene, honey harvesting, give water & supplementary feeding, to the bee colony

Source: built by the author.

Shading /apiary barn/ construction practices. As shown in the table above based on the survey result among the total respondents 75.7% of the respondents construct apiary barn and the remaining 24.3% did not construct apiary barn. Among those who construct apiary barn 65% construct the barn in a separate manner and 35% in a non-separate manner. Among the total respondents, 67.5% of the farm households set the direction of the apiary barn east to west which is enables the bee colony to get sunlight in the morning. 7.1% Set the direction of the apiary site west to east and the reason why they select/set this direction the sample respondents respond

that to protect from the wind and 10.4% of the respondents set some number of the bee colony in east-west direction and some other bee colony in north-south direction and their justification why they set this direction was to protect the bee colony to fight each other.

Table 8

Shading construction, direction of apiary barn, reasons to set the direction and not constructing apiary shade

Indicator		Frequency	Percent
Do you have apiary barn (bed, floor, shade) for bee hives?	No	65	24.3
	Yes	203	75.7
	Total	268	100.0
If yes, from which material did you prepare the shade?	Grass, stone, and wood	191	94.1
	Iron sheet	12	5.9
	Total	203	100.0
If yes, how the apiary barn prepared?	Non-separated	71	35.0
	Separated	132	65.0
	Total	203	100.0
If yes, the direction of apiary barn?	East to west	181	67.5
	West to east	19	7.1
	North to south	38	14.2
	South to north	2	.7
	West to east and south to north	28	10.4
	Total	268	100.0
Why you make the direction of apiary barn the above one?	To protect from the wind	29	10.8
	Suitable for collecting nectar	42	15.7
	To water source direction	3	1.1
	Cultural influence	28	10.4
	To get morning sunlight earlier	125	46.6
	Decrease the conflict with each other	17	6.3
	All except cultural influence	9	3.4
	Protect from sunlight	15	5.6
	Total	268	100.0
If no, why did not construct apiary barn?	Cost of construction	14	21.5
	Ignorance	34	52.3
	Perception problem	17	26.2
	Total	65	100.0

Source: author's calculations.

Honey marketing. In the Table 9 revealed that 91.4 % of the respondents produce honey primarily for market and the remains 8.6 % are for their home consumption. The average price of crude honey in the local market was 95 birrs/kg, 75 birrs/kg, 150 birrs/kg, 65 birrs/kg and 100 birr/kg-in Sekota, Asketema, Ziquala, Bugna and Lalibela respectively at honey harvesting time. The sample households put up for sale on average 38.34 kg crude honey and had revenue of 2921.9 birrs per

household in 2015 production year.

Shading construction practices in the study area

Table 9

Percentage of honey to sold into the market

Indicator		Frequency	Percent
Do you sell honey in the 2015 year?	No	23	8.6
	Yes	245	91.4
	Total	268	100.0

Source: author's calculations.

Table 10

Income gained from honey sold and amount of honey sold in 2015

Indicator	N	Minimum	Maximum	Sum	Mean	Std. Dev.
Total volume of honey sold in kg for from the three hives in the 2015	217	.0	360.0	8320.0	38.341	50.3176
Total income gained in birr for honey sold from the three hives in 2015	218	.00	19400.00	636969.00	2921.8761	3510.79193

Source: author's calculations.

Honeybee flora plantation practices. According to [1], over 80 plant species for honey bee flora were investigated in Wag-Lasta area. However, the sample households were not applied honeybee flora plantation practices due to the perception problem, awareness and lack of availability of honey bee flora seedling. The natural bee forage is seasonal and hence, feed shortage occurs in some months of a year, especially, in dearth period (January – June). The distribution of bee forages in the study areas is declining over time due to deforestation and expansion of cultivated lands and soil degradation.

Comparative Advantages of modern beehive over traditional beehive. High honey yield and better quality, ease of inspection and, ease of product harvesting are the major relative advantages of modern beehive over traditional beehive identified by the majority of beekeepers with a group discussion if and only if all modern beehive technology packages should be fulfilled. On the other hand, the high cost of the hive and other equipment and accessories, high skill requirement, the need of improved bee equipment and accessories, vulnerable to pests and predators as well as

sunlight and demands additional labor force are the key relative disadvantages of the modern beehive as distinguished via the majority respondents with group discussion. On the other hand, the traditional beehive has different drawbacks. Those are; low honey yield and least better quality, difficult to internal inspection and harvesting honey, short lifespan (it breaks by rain). However, the traditional beehive has an advantage as a source of colony multiplication and low cost of a hive. During Focus Group Discussion, there is an unknown or hidden problem on modern beehive adoption because the group members believed that modern beehive (frame hive) is not suitable to bee colony, but, I do not understand the case. The bee colonies stay in this hive at least one or two years after then abscond due to unknown reason. According to group discussion and personal observation, there are different opportunities to disseminate and upgrade the beekeeping sector in the study area. Those are; diversified very qualified honeybee flora, environmental friendless of the sector and attention given by the government to beekeeping sector (wag-himra zone characterized by apiculture and small ruminants).

Farmers Perception on modern beehive technology. Farmers strongly agreed in Modern beehive technology gives high-quality honey yield, the modern beehive technology improves honey yield production and productivity, modern hive beekeeping is profitable as compared to the traditional hive and the technology was easy to understand and implement which accounts 51.5, 43.9, 21.6 and 13.5 percent respectively. On the other hand, 20.5, 29.2, and 21.1 % farmers were strongly disagreed, disagree and not decided on modern beehive technology is not vulnerable to different bee diseases respectively. The reason behind that the farmers were not distinguished the vulnerable beehive types among the three beehive types due to lack of technical skills. As the $\chi 2$ result shown in table 9, the observed frequencies across categories depart significantly from the expected homogeneous distribution. However, farmer's participation in modern beehive technology utilization is as such, not high as expected. This is due to the thinking that farmer's commitment, skill in modern beehive technology packages, dependency by the aid of NGOs, lack of individual extension services and follow-up of the experts and supply of all necessary equipment and accessories declined year to year. As revealed in table 9, the mean score of each Likert item is less than 3.5 score except Likert item 1.1 and 3.2. This indicates that the level of adoption of modern beehive technology of beekeepers was minimal. The possible reasons for minimum adoption of modern beehive are as indicated in Table 9, technology complexity, the absence of sufficient training, deficiency of extension support and services and lack of beekeeping equipment & accessories in the right time and as well its price is expensive (Table 11).

Econometric models Results. Based on the log-likelihood values of the two models estimated, the LR-test results suggest the rejection of the Tobit model. That is, the test statistic Γ = exceeds the critical value of the $\chi 2$ distribution (Table 11).

Estimates of the parameters of the variables expected to have an effect on the decision to adopt and intensity use of modern beehive technology were displayed in Table 12. A total of 17 explanatory variables were incorporated into the double

hurdle model among those variables 9 variables significantly influence the probability of adoption decision and 6 variables statistically to affect the intensity use of modern beehive. Heteroskedasticity problem was corrected by the use of command *robust* in Stata (version 12).

Table 11

Farmers perception on modern beehive technology

Likert items	Strongly disagree		Disagree		Not decided		Agree		Strongly agree		Mean Score	χ^2-test
	N	%	N	%	N	%	N	%	N	%		
1. Concerning technology compatibility												
1.1. Modern hive beekeeping is profitable as compared to traditional hive.	33	19.3	46	26.9	1	0.6	54	31.6	37	21.6	3.1	48.035 (0.000)
1.2. Management of modern hive is not difficult as compared to traditional hive.	35	20.5	53	31	-	-	83	48.5	-	-	2.8	20.632 (0.000)
1.3. Modern beehive technology does not need expensive equipments and accessories.	111	64.9	58	33.9	1	0.6	-	-	1	0.6	1.4	195.947 (0.000)
1.4. Modern beehive technology gives high quality honey yield.	5	2.9	-	-	2	1.2	76	44.4	88	51.5	4.4	145.936 (0.000)
1.5. Modern beehive technology is not vulnerable to different bee diseases.	35	20.5	50	29.2	36	21.1	50	29.2	-	-	2.6	4.930 (0.177) NS
1.6. Modern beehive technology is not vulnerable to different bee pest.	-	-	39	22.8	112	65.5	20	11.7	-	-	2.9	82.772 000)
1.7. Modern beehive technology is not labor intensive.	33	19.3	76	44.4	15	8.8	47	27.5	-	-	2.4	46.520 (0.000)
2. Concerning training provided												
2.1. The training provided was practical and theoretical concerning improved management package of modern beehive technology.	21	12.3	31	18.1	-	-	109	63.7	10	5.8	3.3	142.053 (0.000)
2.2. The training improves your modern bee keeping management skill and knowledge.	61	35.7	44	25.7	13	7.6	53	31	-	-	2.3	30.988 (0.000)
3. Concerning the extension services												
3.1. The follow up of experts help you apply improved management package were good.	55	32.4	66	38.8	6	3.5	41	24.1	2	1.2	2.2	97.706 (0.000)
3.2. The modern beehive technology improves honey yield production and productivity.	-	-	10	5.8	-	-	86	50.3	75	43.9	4.3	59.193 (0.000)
3.3. The modern beehive technology gives high wax yield production and productivity.	9	5.3	152	88.9	6	3.5	4	2.3	-	-	2.0	372.556 (0.000)
3.4. The technology was easy to understand and implement.	15	8.8	40	23.4	3	1.8	90	52.6	23	13.5	3.4	134.936 (0.000)
3.5. The absconding rate of modern beehive is low as compare to traditional beehive.	38	22.2	112	65.5	3	1.8	18	10.5	-	-	2.0	163.994 (0.000)
4. **Concerning the sustainability of the technology usage**												
4.1. You will adopt the technology in the future.	26	15.2	35	20.5	54	31.6	54	31.6	2	1.2	2.8	55.228 (0.000)
4.2. You will tell to your neighbors' and other farmers about the merit of the technology.	30	17.5	77	45	43	25.1	21	12.3	-	-	2.3	42.310 (0.000)

Source: author's calculations.

The multicollinearity problem was checked by using VIF (Variable Inflation Factor) for continuous and dummy variables and there is no series problem which is the mean VIF value is 10.33.

Table 12

Test of double-hurdle model versus Tobit model

Indicator	Tobit, 0≤Y≤1	Probit, D	Truncated Regression, (Y>0)
LOG-L	-139.837	-97.804	33.998
Number of observation (N)	268	268	136
Double-hurdle versus Tobit test statistic: $\Gamma = 152.062 > \chi^2 0.01,17 = 33.409$			

Source: author's calculations.

Number of traditional beehives possessed. The econometric model result shows a number of traditional beehives the beekeepers possessed was positively influence the probability of adoption decision of modern beehive and negatively affect the intensity use of modern beehive at 1 % significant level. The reason might be those beekeepers who own a large number of traditional beehive are reluctant to use a large number of modern beehive rather they tried to demonstrate a small amount of modern beehive to compare the honey yield advantage between modern beehive and tradition beehive (Table 13).

Access to credit service. Access to credit had a positive effect in both hurdles at 10% and 5% significant level respectively. As the credit service provision of the beekeeper's change, the intensity use of modern beehive increased by 20.7 % modern beehive. The reason behind this result is credit service minimize the financial constraints of beekeepers which enable they obtain modern beehive (Table 13).

Distance of beekeepers residence from woreda agriculture office. The distance of beekeepers residence from woreda agriculture office was a negatively significant influence on the intensity use of modern beehive at 1 % significant level. The distance of the farmers' residence from the woreda agriculture office far by one kilometer, the intensity use of modern beehive decreased by 0.91 kilometers. The implication of this result is that farmers who are far from woreda agriculture office did not easily access the modern beehive (Table 13).

Training Access. Access to training had positively influenced the probability of adoption decision of modern beehive at 1 % significant level, turned out to be negatively significant in the intensity use of modern beehive at 5 % significant level, which is an unexpected sign. The justification behind this might be the training was given for those beekeepers own a large number of traditional beehives and also might be farmers who are participating in training only focus for per diem they get during training rather than using modern beehive (Table 13).

Age of the respondents. As regards the age of the beekeepers, it can be observed that age has a parabolic effect on the level of modern beehive adoption with turning point of 47 years, though; it is insignificant in the probability of adoption decision. However, age is negatively significant in the intensity use of modern beehive at 5 % significant level. This indicates that farmers aged above 47 years are most likely to have a lower level of modern beehive due to the expectation of risk

aversion behavior of aged farmers for fear of absconding, tedious management, and other unexpected events. It is undecided for those farmers to increase the number of the modern beehive as the age of the beekeepers increase beyond the turning point.

Off-farm activity participation. Involvement in off-farm activities other than beekeeping passes significant in first hurdles and positively affected the probability of adoption decision at 1% significant level, but it affected the intensity use of modern beehive negatively. The reason behind this is farmers participated in other off-farm activities earn additional income and acquire improved technologies. As a result, more probably decide to adopt modern beehive. Nevertheless, this might not be true for the intensity of use of modern beehive (Table 13).

Annual income and livestock holding, as well as Extension service and education status of the sample beekeepers, were statistically significant in the first hurdle; however, they were insignificant in the second hurdle unexpectedly. Thus, all are significant mean difference and association between adopters and non-adopters with t-test and $\chi 2$ – test respectively (Table 13).

Table 13

Maximum likelihood estimation of a double-hurdle model of adoption decision and intensity use of modern beehive technology

Variables	Probit model result			Truncated regression result			
	Coefficients	Robust Std. Err.	P – value	Marginal Effect	Coefficients	Robust Std. Err.	P – value
Sex	-.282058	.3886472	0.468	.1470069	.1470069	.117739	0.212
Age	-.0003844	.0515471	0.994	.043803	.043803	.0196082	0.025
Age2	-.0002374	.0005094	0.641	-.0004633	-.0004633	.000209	0.027
FamLabor	.205767	.0903976	0.023	-.0205384	-.0205384	.0265964	0.440
Educ	.4676153	.2371266	0.049	.0178647	.0178647	.0536641	0.739
TFland	.1797264	.2597785	0.489	-.0439899	-.0439899	.0509018	0.387
LivstockHold	.0983316	.0384715	0.011	-.0077746	-.0077746	.0080526	0.334
Suppfeed	.1664784	.2383377	0.485	-.0423402	-.0423402	.053151	0.426
NoTdH2007	.0533955	.0195905	0.006	-.0366384	-.0366384	.0066278	0.000
HLKFrHive				-.0060097	-.0060097	.0073341	0.413
DistKAO	-.042388	.0339281	0.212	-.003469	-.003469	.0083313	0.677
DisWorO	-.0066131	.012012	0.582	-.0090828	-.0090828	.0031311	0.004
EXT	.7044103	.2113232	0.001	.0597975	.0597975	.0612544	0.329
Traing	1.011333	.2071388	0.000	-.1385142	-.1385142	.071543	0.053
Credit	.7118622	.4300433	0.098	.2069757	.2069757	.0820266	0.012
OffarmActv	.6424252	.2318289	0.006	-.0479963	-.0479963	.0587648	0.414
TAnuIncom	.0000419	.0000116	0.000	3.05e-06	3.05e-06	2.87e-06	0.287
Cons	-2.78572	1.361036	0.041		-.1578401	.4570117	0.730
sigma					.2475725	.0158073	0.000

Number of obs. = 268
Log- L = -97.804359
Wald chi2 (16) = 112.82
Prob. > chi2 = 0.0000
Pseudo R2 = 0.4424
Correctly predicted = 70.8%P = predicted value

Number of obs = 136
Log- L = 33.998286
Wald chi2 (17) = 101.48
Prob. > chi2 = 0.0000
Limit: lower = 0, upper = +inf
correctly predicted = 36.2%P

Conclusions. Even though the government of Ethiopia gives great attention to the beekeeping sub-sector to promote modern beekeeping technologies, but the probability of adoption and intensity use of modern beehive technology is found to be minimal. Pests and predators, drought and lack of bee equipment and accessories are ranked as the first, second and third major constraints of beekeepers respectively. From the survey result, the Tobit model clearly shows that age, number of livestock owned, educational level, number of local hives beekeepers possessed, training provided, total annual income of beekeepers, credit service, distance to Kebele agricultural office, extension service, and participation in off-farm income sources are the main determinants factors of probability of adoption and intensity use of modern beehive in the study area.

Based on the conclusions the following recommendations are drawn:

✓ Beekeeping equipment and accessories have to be supplied /accessible/ to the farmers and great attention have to be given which can increase productivity and take appropriate management practices of modern beehive which can positively affect beekeepers' capacity probability of adoption and intensity use of modern bee hive.

✓ Provision of credit service which enables the farmers to solve their financial constraints. This is that credit services to beekeepers to widen the financial basis of poor beekeepers. Beekeepers can use the loan to buy modern beehives and access to modern beehives equipment and accessories like the honey extractor, wax stumper, queen excluder, smokers, brush, gloves, bee veil, and others.

✓ Adequate training have to be provided for farm households both practically and theoretically oriented bases, as well as training, have to be given by giving attention to the wise way (timely application) of using different chemicals specifically herbicides to minimize the death of honey bees.

✓ Agricultural extension services have to be provided for farm households including those farmers who are far from development agent offices.

✓ Pest and predators especially wax moth and bird appropriate prevention and controlling methods have to be further studied by biological researchers. And also appropriate coping mechanisms for beekeeping during the occurrence of drought have to be further studied by biological researchers.

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