Perception of effect of climate change and adaptation strategies of beekeepers of Welmera district, Ethiopia

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Abstract— *This study identifies factors affecting smallholder beekeepers' decisions to choose strategies to adapt to climate change in Welmera District, Oromia regional state, Ethiopia. Accordingly, quantitative data analysis and a multinomial logit model was used to identify perception of effects of climate change and adaptation strategies, and factors influencing beekeepers' choice of adaptation strategies to climate change, respectively. Results signified that skip honey harvesting, additional feeding, bee hive shade and improved bee forage planting are the dominant adaptation strategies that smallholder beekeepers used to limit the negative impact of climate change. The result from the multinomial logit analysis showed that age, education, family size, farm size, income, perception of effects of climate change, membership to beekeeping group, and access to beekeeping extension contact were significance factors influencing adaptation strategies of beekeepers. This would be a catalyst in developing and implementing appropriate as well as viable adaptation strategies in beekeeping practices context.*

Keywords— Adaptation strategies, beekeepers, climate change, MNL, Welmera.

I. INTRODUCTION

Climate change affects agriculture (higher temperature, reduced rainfall, etc.) [1].With a relatively low capacity to absorb the shocks of such events, Ethiopia's economy is at risk of losing out on the gains that the country has made through its impressive economic growth in recent years [2].

Plant-pollinator interactions are important for food production, and maintaining biodiversity ([3], [4]). Honeybees are the most effective pollinators of flowering plants [5].

Beekeeping is a long standing practice in Ethiopia and it accounts for 1.3% of agricultural GDP [6].

Climate change is reported to influence honeybees through its effects on their resource bases [7]. This impact of climate change on honey yields is poorly understood; this lack of understanding of the effects of climate change on honey yields is prevalent in developing regions [8].

Climate change adaptation is crucial [9] in response to damage due to climate change. Because of the huge contribution of honey production to beekeeper farmers' economy and its high susceptibility to climate change, it is important to study beekeepers' adaptation strategies to overcome the anticipated adverse impacts of climate change.

Various studies on adaptation strategies to climate change and determinants of farmer's adaption decision in Ethiopia ([10], [11]) have significant limitations. It emphasizes crop production and disregards the adaptation measures to climate change on beekeeping activity and its links with crop production. This oversight may underestimate the factors affecting beekeepers with regard to climate change. Next, most of the studies are conducted in lowland and rift valley areas of Ethiopian and overlook highland area. However, climate change expected to have an influence on both moisture-sufficient highlands and the drought-prone areas. Once more, none of the works focused beekeeping related climate change in the study area. Therefore, the study focused on i) to examine beekeepers' perception of effects of climate change on honey production ii) to identify beekeepers' adaptation strategies in response to climate change, and assess the factors influencing beekeepers' choice of climate change adaptation strategies.

II. METHODOLOGY

2.1 Description of the study area

The study was conducted in Welmera district of Oromia Special Zone, Ethiopia. The district is 29 km away in West of Addis Ababa at 9002N latitude and 38034E and altitude ranges from 2000-3380 meter above sea level. It has annual rainfall and temperature ranging from 334-1350mm and 0.1C°-27C° respectively, and with mean annual rainfall of 1067mm and mean temperature of 18 C°. Crop-livestock mixed farming system characterizes agriculture in the district. The district is potential in honey production.

2.2 Sampling method and data collection method

Study population for the study was farmer beekeepers own any types of hive of the study area. The district was selected purposively. Primary data was collected on 164 smallholder beekeeper household heads using probability proportional sampling techniques to the size of the population in the selected seven kebeles, andfocus group discussants. The sampling size for the households' survey was determined using the rule $N \geq 50 + 8m$ [12] in order to assure that the econometric model could be estimated with sufficient degrees of freedom, where N = sample size, and m = number of explanatory variables.

The focus group discussions for this study were held with separate groups of elders in both Dega and Woynadega agro-ecology comprising 5–10 individuals per group. The sessions were moderated by the researcher using a checklist including climate change impact in the area, and what factors influenced beekeepers' adaptation decisions. Secondary data which support primary data were collected from different sources like research articles, internet and concerned offices.

2.3 Methods of data analysis

The qualitative analysis used interpretation by narrating the response of the respondents and focus group discussants. The quantitative data analysis used descriptive statistics to summarize beekeepers' perceived effects of climate change on honey production and existing adaptation strategies to climate change effects, and Multinomial logit model (MNL) used to determine factors affecting beekeepers' adaptation decision using STATA version 13.

2.4 Econometric data analysis

Either multinomial logit or multinomial probit regression model used when there is a dependent variable with more than two alternatives (i.e. unordered qualitative or polytomous variables). Both of them estimate the effect of explanatory variables on dependent variable involving multiple choices with unordered response categories [13].

In this study a MNL was employed as it's easy to compute and also MNL analysis exhibits a superior ability to predict adaptation strategies and picking up the differences between adaptation strategies to climate change employed by households. This model makes it possible to analyze factors influencing beekeepers' choices of climate change adaptation strategies in the context of multiple choices.

Following Green [13] the MNL model for a multiple choice problem is specified as follows:

$$pij = \frac{e^{Xi\beta I}}{\sum_{j=1}^{j=5} e^{xi\beta j}}; j = 1 \ldots\ldots 5 \quad (1)$$

Where pij = is the probability of beekeeper's choice of adaptation strategies from category j), Xi= is predictors of response probabilities; e is the natural base of logarithms; and βj is the parameters to be estimated by maximum likelihood estimator (MLE).The estimated equations provide a set of probabilities for the j + 1 choice for a decision maker with Xi characteristics. For identification of the model, we need to conveniently normalize by assuming β=0 [13]. Therefore, the probabilities are given by:

$$Prob.\left(yi = \frac{j}{xi}\right) = pij = \frac{e^{xi\beta j}}{\sum_{j=2}^{j=j} e^{xi\beta j}}, for\ j > 1 \quad (2)$$

$$Prob.\left(yi = \frac{j}{xi}\right) = pi1 = \frac{1}{1+\frac{e^{xi\beta j}}{\sum_{j=2}^{j=j} e^{xi\beta j}}} \quad (3)$$

The marginal effects (δij) of the characteristics on the probabilities are specified as

$$\delta ij = \frac{\partial ij}{\partial x1} \rho ij[\beta j - \sum_{j=0}^{j} \rho ij\beta j] = \rho ij[\beta j - \beta^{-}] \quad (4)$$

Before running the model, the problem of multicollinearity among the continuous and dummy variables was detected. The variance inflation factor (VIF) was used for continuous predictor variable in the study. A VIF value greater than 10 is used as a signal for existence of severe multicollinearity [14]. For dummy variables if the values of contingency coefficient (CC) is greater than 0.75, the variable is said to be collinear. No multicollinearity occurred at all.

2.5 The summary of statistics for explanatory variables

Based on the review of adaptation literatures, 13 possible explanatory variables were considered in this study and examined for their effect in beekeeper's adoption decision of an adaptation strategy to climate change (Table 1).

III. RESULTS AND DISCUSSION

3.1 Beekeepers' perception of effect of climate change on honey production

Respondents were asked to indicate their response whether or not climate change had a negative effect on their honey production. The majority (70.12%) perceived climate affects their honey production negatively whereas 29.88% were not (Table 2). Table 2 further shows that, 22.56% and 21.34% of the respondents from Dega agro ecological zone had perceive effects of change in climate and taken adaptation measures to climate change respectively, while the remaining 19.51% and 20.73% did not. In the same way 47.56% and 46.34% the respondents from Woynadega agro ecological zone had already perceived effects of climate change and taken adaptation measures to climate change, respectively. However, as compared to the beekeepers between Dega and woynadega agro-ecological zones, the respondents who perceived and take adaptation measures from Woynadega agro-ecological zone are relatively higher. This is may be due to the fact that the intensity of climate related problems gets higher and higher as one goes from Dega to woynadega. Therefore, this proportion could also be an indicator of where the climate related problems is a little bit more sever. However, there are about 10.37% and 11.59% of the respondents did not yet perceive and taken adaptation measures to climate change from woynadega agro-ecological zone as compare to dega agro-ecological zone.

They perceived effects of climate change in beekeeping in terms of declining availability of bee forages; diminish honey yields; occurrence of bee colony absconding; and high temperature in the area. In this study, the weighted average index (WAI) was used to rank the effects of change in climate on honey production. Respondents were asked to score the effects of climate change based on a 0-2 Likert scale (i.e. in terms of 'high', 'moderate' and 'low'). Beekeepers generally perceive effects of climate change in terms of high, moderate and low. As per the past experiences, the rate of shortage of honey bee forages due to climate effect was ranked first by respondents (WAI=1.93) (Table 3). According to the interviewed beekeepers, this problem is directly related with deforestation of forest coverage from time to time for expansion of agricultural lands and various purposes which cause shortage of bee forage. When bee forage is exhausted, honeybee colonies suspended the capacity to rear brood; often provoking rapid population decline and resulted colonies absconding that may cause honey lose [15]. Moreover, slight diminish in honey yield due to adverse effects of climate change were ranked second (WAI=1.7). This may be happen due to simply a shortage of nectar-producing flowers because honeybee forage determines the amount of honey yield obtained provided that other factors are suitable for honey production. Honey bee colony absconding and high temperature were ranked third and fourth, respectively (WAI=0.93 and WAI=0.86) during study year. Bee colony loses can affect directly honey production and income of beekeeper. Among many, lack of food is major cause of bee colony absconding [16]. If the beehive temperature becomes too high then foragers will be busy collecting water, to reduce the nest temperature, rather than nectar or pollen. This will in turn affect honey production negatively. Group discussants also associated the impact of climate change with reductions in honey production and considered such reductions as a salient risk posed to their beekeeping activity.

TABLE 1
EXPLANATORY VARIABLES INCLUDED IN THE ANALYSIS

Variable	Description	Expected sign
Agro-ecology	Dummy takes the value of 1 if Woynadega and 0 otherwise	+
Sex	Dummy takes the value of 1 if male and 0 otherwise	+
Age	Continuous	+
Education	Dummy takes the value of 1 if literate and 0 otherwise	+
Family size	Continuous	+
Farm size in hectares	Continuous	±
Livestock	Continuous	+
Total income	Continuous	±
Perception	Dummy takes the value of 1 if perceived and 0 otherwise	+
Number of bee colony	Continuous	+
Membership	Dummy takes the value of 1 if a member and 0 otherwise	+
Extension contact	Dummy takes the value 1 if have access and 0 otherwise	+
Credit	Dummy takes the value 1 if have access and 0 otherwise	+

TABLE 2
PERCEPTION OF EFFECT OF CLIMATE CHANGE AND ADAPTATION STRATEGY ACROSS AGRO-ECOLOGY

Agro-ecology	Perception of effects of climate change (%)		Adaptation by per cent	
	Yes	No	Yes	No
Dega	22.56	19.51	21.34	20.73
Woynadega	47.56	10.37	46.34	11.59
Total	70.12	29.88	67.68	32.32

TABLE 3
RANK EFFECT OF CLIMATE CHANGE BY BEEKEEPERS

Variables	Ranking of occurrence			WAI	Rank
	High (2)	Moderate (1)	Low (0)		
Lack of bee forage	107	8	0	1.93	1
Reduced honey yield	77	35	3	1.7	2
Colony absconding	21	65	29	0.93	3
High temperature	18	63	34	0.86	4

3.2 Beekeeping adaptation strategies to climate change

In this survey, beekeepers were asked what adaptation strategies they have typically used in order to adapt to the negative impact of climate variability and changes in honey production. As a result, adaptation strategies used by beekeepers were jump honey harvesting (21.95%), additional feeding (20.73%), bee hive-shading (17.07%), and bee forage planting (7.93%) in a declining proportion (Table 4). In general, 67.68% of beekeepers in the district had actually adapted to climate change compared to 32.32 % who do not adopt any of adaptation strategy. Jump honey harvesting, additional feeding and bee hive shade are indigenous practices while using improved bee forage is introduced development intervention to increase honey production.

The use of jump harvesting of honey as an adaptation strategies to climate change effects is to save honey to perpetuate strong colonies for next honey flow season as only strong colony survive compared to weak colony which is more vulnerable to any shocks of climate variability and change. According to beekeepers opinion taking honey during lack of sufficient pollen and nectar would dramatically weaken bee colony and expose bee colony to threats (absconding, starvation, and pest attack).

In the same way, interviewed beekeepers supplement their bee colony with additional feeds in the absence of bee forage as adaptation strategy to climate change. Similar studies also reported that about 90.7% of the beekeepers seem aware of supplying additional feeding for their bee colonies [17]. Some of interviewed beekeepers were preferred shade for beehive to reduce direct sun light radiation effect on bee activities. Also some beekeepers who perceived declining state of indigenous bee forages in their area started use of improved bee forage using micro-irrigation.

TABLE 4
ADAPTATION STRATEGIES BY BEEKEEPERS

Adaptation strategies	Per cent
Additional feeding	20.73
Bee forage planting	7.93
Beehive shade	17.07
Skip harvest	21.95
Not adapted	32.32
Total	100

3.3 Determinants of beekeepers' choice of adaptation strategies

Farmers' adoption behavior, especially in low-income countries, is influenced by a complex set of socio-economic, demographic, institutional and biophysical factors ([18], [19]). Statistically influential determinants are factors on which efforts should be exerted to enhance farm-level beekeeping adaptations to climate change and variability in the study area.

The result of MNL model showed how factors that influence beekeepers' choice of adaptation strategies in the study area. Table 5 represented the results of parameter estimates of MNL regression model with some significant levels of the parameters estimates. The likelihood ratio statistics as indicated by ch2 statistics (LR chi-square (52) = 2241.05 are highly significant $P < 0.0000$), suggesting the model has a strong explanatory power.

As indicated earlier, the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable: Estimates do not represent actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed (Table 6). In all cases the estimated coefficients should be compared with the base category of no adaptation.

3.3.1 Age of the respondent

A one year increase in age of the household head, the likelihood of beekeepers' using planting of honey bee forage, jump honey harvesting and bee hive shade as adaptation strategy increases by 56.2%, 89.1% and 69.9% at 1%, 1% and 1% significance level respectively, holding other variable constant (Table 6). This means that the likelihood of taking up climate adoption strategies was higher among older beekeepers. Because as the age of the household head increases, the person is expected to acquire more experience in climate conditions and that helps take action to combat climate change.

3.3.2 Education of the respondent

As the household heads get access to education, the likelihood of using adaptation strategy additional feeding and bee hive shade increases by 29.8% and 74.5% at 5% and 1% level of significance respectively, holding the value of other variables constant (Table 6). This hints that the educated households are more sensitive for managing their bee colony by providing supplementary feeding, and reduce hot to reduce problems of effects of change in climate.

3.3.3 Family size of the respondent

MNL models show a one unit increase in the family size, the likelihood of beekeepers use improved bee forage as adaptation strategies increase by 23.3% at a significance level of 1% keeping other variables constant (Table 6).

TABLE 5
PARAMETER ESTIMATES OF MNL CLIMATE ADAPTATION MODEL

Variable	Additional feeding	bee forage	Skip harvesting	Bee hive shade
	Coef. P-value	Coef. P-value	Coef. P-value	Coef. P-value
Agroecology	1.733 0.190	1.085 0.526	1.603 0.236	1.396 0.284
Sex	0.0467*** 0.007	1.334 0.488	2.145 0.177	0.446 0.758
Age	0.188 0.415	0.545 0.335	0.340 0.151	0.228 0.102
Education	1.571 0.407	1.384 0.494	0.322 0.139	1.425 0.452
Family	0.412 0.313	0.035 0.155	0.179** 0.036	0.129 0.755
Farm size	0 .785** 0.016	-0.596** 0.023	0.148 0.115	-2.655 0.773
Livestock	0.934** 0.024	-0.1141** 0.011	0.004 0.706	0.6548 0.107
Totincome	-0.0004** 0.011	-0.002** 0.022	0.560 0.193	0.037** 0.010
Perception	0.331*** 0.001	0.019*** 0.003	0.145** 0.012	0.0002* 0.081
Colony	0.269 0.684	0.563*** 0.001	0.674* 0.087	0.156 0.745
Membership	0.729** 0.032	2.481 0.130	0.416** 0.010	0.5098* 0.065
Extension	0.835** 0.021	0.2528** 0.016	0.445** 0.032	2.267* 0.067
Credit	1.4011 0.105	0.374 0.118	2.452 0.192	0.642 0.122
Cons	-3.798** 0.015	6.689** 0.031	9.550 0.302	-3.29** 0.030
Base category	No adaptation			
Number of observation	164			
LR chi2(52)	2241.05			
Log likelihood	-138.37809			
Prob> chi2	0.0000			
Pseudo R-Square	0.4474			

Notes: *, **, *** = significant at 10%, 5%, and 1% probability level, respectively

TABLE 6
MARGINAL EFFECTS FROM THE MNL CLIMATE ADAPTATION MODEL

Variables	Additional feeding	Forage planting	Skip harvesting	Beehive shade
	Coef. P-value	Coef. P-value	Coef P-value.	Coef. P-value
Sex	1.141 0.102	0. 048 0.107	0 .337 0.481	0.337 0.600
Age	0.113 0.519	0.562*** 0.006	0.891*** 0.000	0.699*** 0.000
Education	0.298** 0.01	0.0032 0.731	1.446 0.171	0.745*** 0.000
Family	0.939 0.303	0.233*** 0.003	0.194 0.757	0.208 0.349
Farm size	0.217 0.306	0.127** 0.02	0.569 0.486	0.776*** 0.000
Livestock	1.343 0.435	0.259 0.845	1.215 0.225	0.123 0.485
Totincome	0.935** 0.023	-0.040*** 0.002	0.657 0.565	0.000 0.720
Perception	0.267*** 0.001	0.217 0.610	0.287** 0.038	0.578*** 0.005
Colony	1.603 0.262	0.286 0.108	0.985 0.161	0.411 0.405
Membership	0.646*** 0.000	0.000 0.72	0.953*** 0.000	0.467*** 0.001
Extension	0.021*** 0.007	0.149** 0.014	0.012 0.916	0.179*** 0.009
Credit	0.999 0.486	0.092 0.817	0.012 0.916	0.259 0.845
Agroecology	0.017 0.835	1.603 0.262	0 .149 0.345	0.007 0.923

Notes: *, **, *** = significant at 10%, 5%, and 1% probability level, respectively

3.3.4 Farm size of the respondent

A one hectare increases in the farm size, the likelihood of the beekeepers use honeybee forages plantation and bee hive shade adaptation strategy increases by 12.7% and 77.6% at 5% and 1% level of significance respectively, holding other variables constant (Table 6). This indicates that the bigger the size of the farm, the greater the proportion of land allocated for bee forages.

3.3.5 Total income

MNL result reveals that as one percent increases in income the likelihood of giving additional feeding as adaptation strategy increased by 93.5 % at 5% of significance level. However, a one percent increases in income of beekeeper reduces the likelihood of use improved bee forage planting adaptation strategy by 4.0% at significance level of 1% (Table 6). This is because beekeepers, perhaps, invest their income on other livelihoods activity than buying either honey bee forage seeds or seedlings in the study area. This is probably purchase of improved bee forages seeds and/or seedling is unfamiliar to the study area. Most beekeepers consider beekeeping as secondary activity.

3.3.6 Perception of climate change effect

Beekeepers who notice effect of climate changes are likely to increase taking up additional feeding, jump honey harvesting and bee hive shade adaptation strategy by 26.7%, 28.7% and 57.8% at a significance level of 1%, 5% and1%, respectively, compared to beekeepers who did not notice effect of climate change, holding other variables constant.

3.3.7 Member of beekeeper group

The result reveals being a membership to the beekeeper group would increase the likelihood of use additional feeding adaptation strategy by 64.6% at 1% level of significant. Moreover, as compared to the beekeepers who have no access to social network, the likelihood of use skip honey harvesting and bee hive shade adaption strategies to climate change increase by 95.3% and 46.7% at 1% and 1% level of significant, respectively (Table 6). During qualitative assessment, focus group discussants also largely cited social networks as an imperative medium of climate information exchange.

3.3.8 Beekeeping extension

Being getting the extension contact is likely to increase the probability of the beekeeper using additional feeding, improved bee forage planting and bee hive shade as adaptation strategies by 2.1%, 14.9% and 17.9 %, at a significant level of 1%, 5% and 1% respectively, higher than those households' who do not have access extension services (Table 6).

IV. CONCLUSION AND RECOMMENDATION

The study used cross-sectional data collected on 164 sample households in the production year 2018/2019, and applied descriptive and econometric approaches to analyze the data.

The majority of respondents in the study area perceived effects of climate change on honey production and they have taken at least one adaptation measure in response to effects of climate change.

The result from the MNL analysis shows that age, education, family size, farm size, total income, perception, member of beekeeping group, and access to beekeeping extension contact of the household heads have a significant influence on beekeepers' choice of climate change adaptation strategies in the study area.

Being a member of beekeeping group would increase the probability of beekeeper to share beekeeping information related to impact of climate change to adjust their beekeeping to adverse effects of climate change. Hence, concerned bodies either at district level, zonal or higher level should encourage beekeepers to participate in beekeeping organization.

It is important that, extension providers should intensify the provision of beekeeping extension services by insuring increased interaction between smallholder beekeepers and extension agents to complement indigenous knowledge from fellow beekeepers.

Increasing promotion of agroforestry and beekeeper's access to improved bee forages provision along with develop micro-irrigation to enhance their adaptive capacity and long-term resilience to adverse impacts of climate change and variability is very important.

Amidst changing climate and dwindling water availability, the introduction and dissemination of less water consuming bee forage varieties, drought tolerant, shorter cycle, and higher bloom and with good nectar and pollen in the area is important.

REDD^{++} has a potential has to support various adaptation activities in the developing countries. In so doing, country will be able to address underlying drivers of deforestation and forest degradation while supporting communities to adapt.

As a policy issue to support adaptation, the need for the government to enhance collaboration with a spectrum of stakeholders such as civil society and the private sector in ensuring that smallholder beekeepers have access to appropriate information, and training on beekeeping activity related climate change adaptation strategies is very necessary.

ACKNOWLEDGEMENTS

I would like to thank Prof. Fikadu Beyene and Dr. Tesfaye Lemma for their un-reserved effort, insightful and constructive comments for making my paper valuable. I am also highly grateful to the Oromia agricultural research institute for logistic support to conduct this research and I also thank my sample respondents for their valuable cooperation during data collection in responding to all questions with patience and gave the necessary information for this research work.

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