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Smallholder Farmers' Adaptation to Climate Change and Determinants of their Adaptation Choices in Hobicha, Southern Ethiopia

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Abstract

Different evidences indicate that climate of the earth was changed and continuously changing. Thus, this study investigates the adaptation strategies of smallholder farmers and its factors that influence the choice of farmers' in Hobicha woreda, Wolaita zone, Southern Ethiopia. The data was collected from 137 sample households using a survey questionnaire and was analyzed using both descriptive statistics and econometric methods. The multivariate probit model was used to examine the adaptation strategies and the determinant factors that influence farmers' choice of the adaptation strategies respectively. The adaptation strategies considered in the MVPM model analysis were crop selection (49.6%), cropping calendar (61.3%), crop diversification (57.7%), soil and water conservation practices (45.3%) and irrigation (8.8%). In addition, the MVPM analysis showed that gender, age, educational status, farm size, Soil fertility, distance from the market center, agroecology, access to climate information and access to credit of the households are significant factors influencing the smallholder farmers' adaptation strategies. Therefore, strengthening the farmers' adaptive capacity to climate change is important policy implication.

Keywords: Climate change, Adaptation strategies, Multivariate Probit Model and Hobicha Woreda

Introduction

Agriculture constitutes the backbone of least developing countries 'economies and is a major contributor to the gross domestic product (GDP). Most of poor people particularly smallholder farmers in least developing countries live in rural areas, where they depend, directly or indirectly, on agriculture for the livelihood. Ethiopia is one of the least developing counties in which agriculture is the main source of the country's economy and smallholder farmers are the drivers of many economies in Ethiopia even though their potential is often not brought forward. They are farmers owning small-based plots of land less than 0.9 hectares per farm household on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labor [1]. According to [2] the share of agriculture to Ethiopian economy during the Fiscal Year 2017/18 was 34.9 percent. The sector contributed 16.5 percent to GDP growth. This was due to a high increase in crop production of smallholder farmers which increased by 4.7 percent as compared to previous year performance. The rising of agricultural production of smallholder farmers at the national level leads to improve overall economic growth and development. This indicates that the sector is expected to have a base and primary determinant for the growth and transformation plan of the country. However, the issue of climate change stands at the side of smallholder farming agriculture. The reason is clear and straightforward. In addition to socioeconomic challenges, such as endemic poverty, conflicts, limited access to capital and global markets; the change in climate is probably the most complex and challenging environmental problem facing the world today.

To minimize the impact of climate change on smallholder farmers', adaptation strategy is vital instrument. The past studies argued that one way of reducing the vulnerability and severity of climate change impacts is through adaptation. Without adaptation, climate change is generally detrimental to the agriculture; but with adaptation, vulnerability can largely be reduced [3-6]. Accordingly, most study have been done in Ethiopia by different authors such as [7-9] and others focusing the Nile Basin as a case study repeatedly by changing its methodology for the need of identifying the dominant agro ecological based adaptation strategies of smallholder farmers to the changing climate. However, there is no strong evidence for aggregating their findings across the country. In addition, the study did not examine effective agro ecological based adaptation strategies and the determinant factors that influence farmers' choice of the adaptation strategies in response to climate change sufficiently by using multivariate probit model. As a result, there is mismatch between the responses which is taken by smallholder farmers to reduce the adverse effect of climate change on crop production and the rate at which climate is changing in the study area. Hence, this study investigates the adaptation strategies of smallholder farmers and its factors that influence farmers' choice in Hobicha woreda.

Materials and Methods

The study was conducted in the Hobicha woreda, which is one of the 22 woredas located in Wolaita Zone. The woreda is located between 06^{0}42'11''N to 06^{0}49'20''N latitude and 37^{0}45'56.4''E to 38^{0}05'16E'' longitudes. According to [10], the administrative center of Hobicha woreda, Bada town, is located at a distance of 18km away to the direction of North from Abela Abaya, 22 km away to the direction of South from Damot woyde, 27 km away to the direction of Northwest from Sidama zone (specially Loka Abaya woreda), 18Km away to the direction of Southeast from Sodo Zuria woreda, 21 Km South east from Humbo woreda [10]. The study applied mixed research design which includes both quantitative and qualitative approach. The data related to the type of adaptation strategies used by smallholder farmers' in response to climate change and variability and the factors that influence farmers' choice of adaptation strategies to climate change in the study area was obtained from both primary and secondary sources. The primary data was obtained from the smallholder farmers through questionnaire, personal interview and FGD which ensure the consistency and accuracy of the primary data obtained through questioners. Secondary data were collected from published and unpublished agriculture official sources, books, journals and research reports. Hobicha woreda was selected purposely and two sample *Kebeles* (Hobicha Borkoshe from midland and Ello Erasho from lowland) were selected randomly based on agro-ecology. Out of the total HHs in sample *kebeles*, 137 samples were selected, in order to make representative samples by using Kothari, 2004 formula.

Methods of data analysis

Both descriptive and inferential statistics method was employed to analyze the data collected from the sample households. The qualitative data obtained through key informant interviews, focus group discussion and the reports of woreda offices were compiled, organized, summarized and analyzed using qualitative techniques.

Multivariate Probit Regression Model Specification

Smallholder farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate change impact than adopting a single strategy. Because a single equation statistical model on climate change adaptation strategies does not modify the likelihood of his/her adopting another adaptation strategies. In this study the dependent variables for adaptation strategies written as

$$Y_{ij} = \begin{cases} 1 = soil\ and\ water\ conservation \\ 2 = crop\ selection \\ 3 = crop\ diversification \\ 4 = coping\ calender \\ 5 = irrigation \end{cases}$$

Where j = is adaptation strategies that selected by i^{th} Smallholder farmers in the study area.

Sallholder farmers are using multiple strategies simultaneously for climate change adaptation. The proposed methodology would derive insight on the smallholder farmer's socio-economic factors that lead to their implementation of different adaptation options. This implies that farmers irrespective of their age, sex, education, etc used specific type of climate change adaptation options. However, the choices among the adaptation strategies are not mutually exclusive as farmers are using more than one adaptation strategies at the same time and therefore the random error components of the adaptation choice may be correlated. So that using a multivariate probit model, which allows for the possible at the same time correlation in the choice to access the five different adaptation strategies simultaneously. Mathematically the model can be specified as follows

$$Y_{ij} = \begin{cases} 1 & if \quad Y_{ij} > 0 \\ 0 & otherwise \end{cases} \quad (1)$$

Where, i = farmer ID number, Y_{i1}= 1, if farmer use crop selection (0 otherwise), Y_{i2}= 1, if farmer use cropping calendar (0 otherwise), Y_{i3}=1, if farmer use crop diversification (0 otherwise), Y_{i4} = 1, if farmer use Soil and water conservation (0 otherwise) and Y_{i5} = 1, if farmer use irrigation(0 otherwise).

The Multivariate Probit (MNP) model was written as follows.

$$Y_{ij} = X^T{}_{ij}\beta_j + \varepsilon_i \quad (2)$$

Where Y_{ij} (j =1... 5) represent the five different adaptation option (strategies) faced by the ith, x_i is a $1\times k$ vector of observed variables that affect the adaptation choice decision of farmer β_j is a $k\times 1$ vector of unknown parameters (to be estimated), and ε_i is the unobserved error term. Assuming the error terms (across i = 1 ... m alternatives) are multivariate and are normally distributed with mean vector equal to zero, the unknown parameters in Equation (2) are estimated using simulated maximum likelihood.

Results and Discussion

Investigating adaptation strategies used by smallholder farmers

Out of the total sample households surveyed, 72.3 % of the respondents were male headed and 27.7% of the respondents and were female headed. The survey results revealed that both male and female headed households were adopting climate change adaptation strategies to reduce its impact. As indicated in survey

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data the maximum age of the household heads was 82 years and the minimum experience being 24 years with the average age of 48 years. The study result revealed that age is an important factor and significantly affecting farmer's adoption of climate change adaptation strategies. The survey result also indicates that the farm size of the sampled households ranges from 0.25 to 0.9 hectares with an average size of 0.55 hectares. In addition, 63.5% of the respondents had access to information on the issue of climate change and its effect, whereas 36.5% reported the opposite. The farmers were also asked whether they have perceived changes in the rainfall and temperature or not in their locality area. As indicated in the graph below shows about 17.52% and 80.29% of the respondents perceived that there is an increment in the level of rainfall and temperature in their local area while about 82.48% and 19.71% of the respondents had perceived a reduction in the level of the rainfall and temperature respectively.

In line with this, the smallholder farmers in the study area are more likely to adopt a number of adaptation strategies to reduce the adverse effect of climate induced risks and constrains than adopting a single strategy in the study area. The climate change adaptation strategies for smallholder farmers in the study area were selected by asking sample households the actions they take to reduce the adverse effect of climate change on crop production. The survey result indicates that, farmers have adopted different adaptation strategies like crop selection, cropping calendar, crop diversification, soil and water conservation practice and irrigation. Their responses were indicated in Table 1.

Table 1: Type of adaptation strategies used by smallholder farmers' against climate change in the study area.

Farmer decision	Adaptation Methods									
	Crop selection		Cropping calendar		Crop diversification		Soil and water conservation		Irrigation	
	No	%	No	%	No	%	No	%	No	%
Used	68	49.6	84	61.3	79	57.7	62	45.3	12	8.8
Not used	69	50.4	53	38.7	58	42.3	75	54.7	125	91.2
Total	137	100	137	100	137	100	137	100	137	100

Note: Farmer were used multiple adaptation strategy.

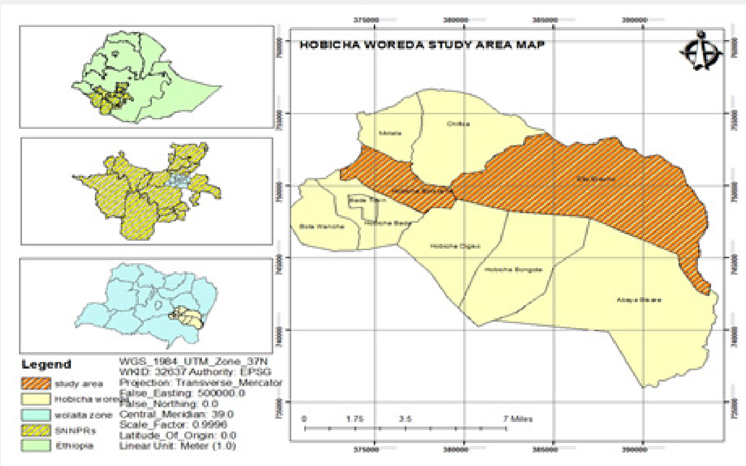

Figure 1: Location map of the study area.

Adjusting cropping calendar: in the above table, about 61.31% of the sampled households were used adjusting cropping calendar as an adaptation strategy to reduce the adverse effects of climate change on crop production in the study area. This strategy is the most frequently used by respondent farmers in the study area because farmers easily adopt this strategy if they have information about changes in climate. This is in line with [5], where farmers in Central Africa (Cameroon, Equatorial Guinea and Central African Republic) noted that adjusting cropping calendar as adaptation strategy towards the changing climate.

Crop diversification (varieties): about 57.66**%** of the respondents were used crop diversifications as the second most dominant adaptation strategy to adapt the adverse effect of climate change on crop production systems. Farmers reported to recover, multiply and use a different variety of crops (like Maize, sorghum, teff, haricot bean and barley varieties), which are supposed to have drought resistant and early maturing variety. The study also revealed that farmers diversify crop types as a way of spreading risks on the farm. This is in line with the finding of [12-14] where they found crop diversification is a major adaptation strategy to reduce the adverse effects of climate change.

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Figure 2: Crop diversification in Hobicha Woreda (Photo by the Author, 2020).

Soil and water conservation: considering the magnitude of the moisture stress in the woreda, soil and water conservation techniques has got special attention by farmers to reduce the adverse effects of climate change and serve to increase on-farm yields. About 45.25% of sampled household prefer and used soil and water conservation practice. This is in agreement with the findings of [15,16] they found that soil and water conservation measures as adaptation strategy to reduce the adverse effects of climate change. However, its adoption level is low as compared with the other strategies because farmers with small farm and labor size could not easily adopt soil and water conservation measures as adaptation strategy.

Irrigation: In the study area 8.8% of the respondent farmers used irrigation as an adaptation strategy to respond to the adverse effect of climate change. It provides large comparative advantage to those farmers to produce different horticultural crops such as tomato, onion, pepper, head cabbage, carrot, potatoes, sweet and potato to cope up the impact that climate change imposes on their livelihood. In general, the descriptive analysis result revealed that sampled households of the study area respond to change in climate stresses by using mutually inclusive adaptation strategies such as crop selection, cropping calendar, crop diversification, soil and water conservation measures and irrigation by giving priority as climate change major adaptation strategies. Similarly, members of focus group discussion (FGD) in two Kebeles confirmed that farmers adopt different kinds of adaptation strategies to reduce the negative consequences of climate change so as to improve their livelihood.

Determinant factors that influence farmers' choice of the adaptation strategies

This section discusses the results from the multivariate probit model. The likelihood ratio test (chi2 (10) = − 302.81, Wald ($\chi 2$ (70)) test = 123.76 and P = 0.000 of the independence of the error terms of the different adaptation equations in table 3. Thus, this study adopts the alternative hypothesis of the mutual interdependence among the multiple adaptation strategies. According to mvprobit model output in the table 3, the results of the correlation coefficients of the error terms are significant for any pairs of equations indicating that they are correlated. The results on correlation coefficients of the error terms indicate that there is complementarily (positive correlation) and substitutability (negative correlation) between different adaptation strategies

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being used by smallholder farmers. The results support the assumption of interdependence between the different adaptation strategies, which may be due to complementarily in the different adaptation strategies and from omitted household-specific, and other factors that affect uptake of all the adaptation strategies.

The simulated maximum likelihood estimation results suggested that there was positive and significant interdependence between household decisions to use of soil and water conservation and using crop selection, and using crop diversification, coping calendar and irrigation. It also suggested that there was negative and significant interdependence between household decisions to use of soil and water conservation and crop selection, using crop selection and crop diversification, using soil and water conservation and coping calendar, and using irrigation and crop diversification. The result of multivariate Probit (mvprobit)model shows that the likelihood of households to adopt crop selection, coping calendar, crop diversification, soil and water conservation and irrigation were 49.6%, 61.31%, 57.7%, 45.3% and 8.8%, respectively. The result also shows that the joint probability of using all adaptation strategies was 5.0918% and the joint probability of failure to adopt all of the adaptation strategies was only 0.02%. The model results suggest that different household, socio-economic and farm characteristics are significant in determining the households' decisions to choose climate change adaptation strategy. Therefore, the results of the multivariate Probit (mvprobit) model indicated that gender of household head, age of household head, agro-ecology, education status of household head, access to credit, access to climate information, farm land size of household, distance from market center and soil fertility are significantly affect the smallholder farmers' choice of climate change adaptation strategies in the study area. The result therefore supports the use of multivariate probit model. The significant factors are presented in the table 2 as follows:

Table 2: Factors that influence farmers' choice of adaptation strategies.

Variables	Crop Selection		Cropping Calendar		Crop Diversification		Soil and Water Conservation		Irrigation	
	Coeff.	T	Coeff.	T	Coeff.	T	Coeff.	T	Coeff.	T
Gender	-.136** -0.277	0.49	.240 (.280)	0.86	.245** (.278)	0.88	.148 ** -0.071	2.06	.443 (.415)	1.07
Age	.006** -0.009	0.68	.023** (.010)	2.33	.004 ** -0.01	0.45	.006** (.0002)	2.06	-.016 (.016)	-1
Educ	.082** -0.088	1.92	-.048 (.088)	-0.54	-.110 (.08)	-1.24	.144** (.088)	1.69	.155 (.125)	1.23
Fsize	-0.344 -0.63	-0.55	-.835 (.642)	-1.3	.127** -0.637	0.2	.121 (.647)	0.19	3.470 (1.169)	2.97
Sfertility	0.025 -0.202	0.13	-.046 (.205)	-0.23	-.250 (.205)	-1.22	-.075 (.204)	-0.37	.0002*** (.001)	3.91
Dmarket	.005** -0.045	1.12	.0188 (.046)	0.4	.030 ** -0.048	0.63	.050** -0.047	1.06	.0670 (.122)	0.55
Agroecol	.240** 0.138	1.35	-0.168 0.127	1.12	0.352 0.264	1.03	.181** 0.231	2.54	.480*** 0.276	3.53
Aclinfor	0.198 -0.24	0.83	.315 (.232)	1.35	-.326 (.233)	-1.4	.525** -0.218	2.41	.143 (.427)	0.34

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Acredits	.125 ** -0.384	0.33	.444* (.385)	1.15	.416** (.135)	3.08	.389** (.386)	1.01	1.160** (2.045)	0.57
Constant	-1.331 (.919)	-1.45	.544 .(.912)	0.6	1.143 (.926)	1.23	.051 (.906)	0.06	-6.936*** (2.147)	-3.23

Figure 3: Soil and water conservation practice in Hobicha Woreda (Photo by the Author, 2020).

Figure 4: Irrigation in Hobicha Woreda (Photo by the Author, 2020).

Gender of the household head: The result of the mvprobit model indicates that the gender of household head is significantly and positively affects adaptation of crop diversification and soil and water conservation at 5% significance level to reduce the shocks of climate change. The positive coefficients for gender variable shows male household head increases the probability of using soil and water conservation and crop diversification as adaptation strategy to climate change. These indicate that male-headed households adapt more readily to climate change and implement high labor and capital-intensive adaptation strategy than female headed households. This result is in line with that of [17-19]; they found that male-headed household has a higher probability of using soil and water conservation and crop diversification than female headed households. However,

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gender of the household head is significantly and negatively affects adaptation of crop selection at 5% significance level. The negative coefficients for gender variable show that female-headed households are more likely to take up crop selection as climate change adaptation strategies. This finding is in contrast with the findings of [20] and [21], where gender is significantly affecting the adoption of adaptation strategies.

Age of household head: Age of the household head is a key variable affecting the use of crop selection, crop diversification, cropping calendar, soil and water conservation positively and significantly at 5% significance level. An increase in the age of a household head increases the use of crop selection, crop diversification, cropping calendar and soil and water conservation as an adaptation strategy to reduce the impact of climate change. This is because as the age of farmer increases, also the farming experience of the household head increases, the farmer is likely to acquire more experience in weather forecasting and that helps increase in likelihood of practicing adaptation strategies. Experienced farmers are more likely to have more information and knowledge on changes in climatic conditions than younger farmers. This result is in contrast with the result of [23] and found that age of the household is significantly and positively related to the adoption of crop selection, cropping calendar, crop diversification and soil and water conservation measures.

Educational status of household head: The mvprobit model result reveal that literate of farmers has positive and significant effect on the likelihood of using crop selection and soil and water conservation as an adaptation strategies at 5% significance level. The use of crop selection and soil and water conservation practices by farmers who were literate is likely to be greater than farmers who were illiterate. This suggests that being literate would improve access to information, capable to interpret the information, easily understand and examine the situation better than illiterate farmers. This result is in support of the findings of [7] found that the level of education influence farmers' choice of using crop selection and soil and water conservation as an adaptation method.

Farm size of the household: The result of the model indicates that farm size of the household has positive and significant effect on the likelihood of using crop diversification practices as adaptation strategies to reduce the negative effect of climate change at 5% significance level. This implies that large farm size increases the likelihood of using crop diversification to reduce climate change impact. This result is also in line with the findings of [23] and [24].

Soil fertility: The coefficient of soil fertility is positive and statistically influencing the choice of irrigation as an adaptation strategy at 1% significance level. The farmers with fertile soil have more probability of using irrigation as an adaptation strategy to climate change compared with the farmers with infertile soil because fertile soils are more productive than infertile soils.

Distance from the market center: The result of the model indicates that distance from the market center is positively and significantly related to use of crop selection, crop diversification and soil and water conservation practice as an adaptation strategies to reduce the impact of climate change at 5% significance level. Proximity to market is an important determinant of crop selection, crop diversification and soil and water conservation practices as adaptation strategy, most probably reason the market serves as a means of exchanging information with other farmers. Moreover, access to inputs and transportation will be high for households far from a given market. Hence being more far from market center decreases the use of crop varieties or planting different crops as an adaptation strategy, because better access to markets enables farmers to obtain information on climate change and other important inputs they may need. This result is consistent with the finding of [25] and [26].

Agroecology: The results of this analysis indicate that agroecology of the households is positively and significantly affect the adoption levels of crop selection, soil and water conservation at 5% and irrigation at 1% significance level as an adaptation strategies to reduce the adverse effect climate change on crop production. This implies that the households in the lowland agroecology have high probability of using crop selection, soil and water conservation and irrigation to reduce climate change impact. This is in consistent with [27] who compared the farmers between kola and woyna-dega agro ecological zones and found that the adaptation status of respondents in woyna-dega agro ecological zone are relatively lower than kola due to low intensity of climate related impacts in woyna-dega agro-ecological zones

Access to climate information: It has a significant and positive impact on soil and water conservation at 5% significance level. This is because the farmers having more information about climate change related information have greater probability of using soil and water conservation compared to farmers who have no access to climate related information. This is in line with [28] and [27] they found that access of information on climate, influences farmers' to choice soil and water conservation measure as an adaptation strategy.

Access to credit: The model result shows that access to credit for smallholder farmers has positive and significant effect on the likelihood of using crop selection, crop diversification, soil and water conservation and irrigation at 5% significance level and cropping calendar at 10% significance level as adaptation strategies. The farmers to introduce new technology, to buy modern crop, fertilizers and oxen, can use credit. Moreover, access to affordable credit facilities is likely to ease cash constraints and allow households to invest in production inputs for climate change adaptation. This is in consistent with the findings of [7,8,29] they found that access to credit increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to adopt.

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Conclusion

This study was intended to examine climate change adaptation strategies of smallholder farmers in Hobicha woreda, Wolaita zone, southern Ethiopia. The results revealed some information about smallholder farmers' adaptation strategies to climate change and the determinant factors that influence farmers' choice of the adaptation strategies. The result from multivariate probit regression model shows that farmers have adopted different strategies like crop selection, cropping calendar, crop diversification, soil and water conservation practice and irrigation to reduce the consequences of climate change so far and to manage future patterns in climate change. However, gender, age, educational status, farm size, soil fertility, distance from the market center, agro-ecology, access to climate information and access to credit of the households are considered as the major determinant factors that influence farmers' choice of the adaptation strategies of smallholder farmers in response to climate change in the study area. In addition, some of the sample respondents in this study area have not taken adaptation measures to climate change due to different barriers**.** Therefore, strengthening the farmers' adaptive capacity to climate change is important policy implication and any concerned bodies should take in to consideration identification of agro ecological based effective adaptation strategies of smallholder farmers and the determinant factors that influence farmers 'choice of the adaptation strategies in to their climate change adaptation strategy.

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