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Farm-level Determinants of Farmers' Adaptation Decisions to Climate Variability and Change in Didessa Basin, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author CD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BS managed the analyses of the study. Author BA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Ethiopia has been identified as one of the sub-Saharan African countries, expected to suffer the most from negative impacts of climate change and variability due to its high reliance on climate variations. This study examines the determinants of farmers' adaptation decisions and constraints to long-term changes in climate variability and change using data collected through semi-structured questionnaires, focused group discussions and field observations from a survey on 450 farm-households in three agro-ecological zones located in Didessa sub-basin. Descriptive and inferential statistics were used to analyze the data. Farmers noticed a decrease in precipitation and an increase in temperature over the past 20 years. In response, it was found that the common adaptation options include: planting, Soil and water conservation, improved technology, use of different crop varieties, and a combination of strategies. However, the remedial actions to the changes are less. The main barriers to successful adaptation cited by farmers were Shortage of land (21.78%), lack of credit/ money (19.11%), lack of information (13.56%), and shortage of farm

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inputs (17.56%) and other institutional and cultural beliefs. A multinomial logistic regression model was used to examine the factors influencing farmers' decision to adapt to changing climatic conditions including socio-economic, demographic; farm characteristics, institutional and climatic variables. We conclude that concerned bodies need to create empowering environment which can promote adaptation options and support constraints farmers face in taking up adaptation to climate change. Also, the government needs to create access to socio-economic and institutional variables appropriate to reach small scale farmers, with limited resources to confront climate change and enhance the livelihood of the households in the study area.

Keywords: Perceptions; logit; agro-ecological-zone; Ethiopia.

1. INTRODUCTION

Climate change is widely recognized as one of the prime challenges facing Africa, and the continent is often cited as the hardest hit by potential transformations [1]. IPCC predicted that there will be an increase in temperatures between 0.3°C and 0.7°C over the next two decades and an increase of 0.3–4.8°C by the end of the 21st century depending upon emission scenarios [2,3]. The changes manifested in the form of increase in temperatures, frequency of cold days, cold nights, and decrease in overall coolness, while frequency of hot days, increased hot nights, heat waves drought, floods and different crop and animal pests all increases [3] and have been impacting the entire world’s life and livelihoods with different impact varies from country to country.

Sub Saharan Africa, for instance, will become drier and changes in rainfall patterns are expected to result in loss of crop yield (Niang et al. [4] Kotir [5] by at least 10–20% by 2050 [6], crop yield will drop by 20-50% in West Africa by 2050 due to less predictable and increased variation in rainfall [7]. In Ethiopia, under moderate global warming cereal production is expected to decline (10-12%) due to climate change [8]. To combat the adverse effect, farmers need to undertake appropriate investments in response. Adaptation seems to be the most efficient, friendly policy option [9] undertaken by farmers themselves or by governments implementing agencies. To these end, attempts have been made to analyze how farmers adapt to climate change and its determinants to adaptation options [10,11,12,13]. Most research found that socioeconomic and demographic and institutional factors are determinants for climate change adaptation among crop farmers.

The study was conducted in Didessa sub-basin because it is an area with few remnant forests cover, naturally endowed with beautiful landscapes and soils with good agricultural potential than another part of Blue Nile sub-basins [14]. This abundantly rich landscape has been continuously exploited for centuries and its present condition is very alarming. This is due to a number of factors which include: high reliance on agriculture as it is the predominant occupation, population pressure (resettlement and migration), the prevalence of serious land degradation and deforestation, declining agricultural productivity, socio-economic challenges, climate variability and changes (eg. drought in other parts of the country), government policy on property right and institutional factors (Teferazelalem, [15]. The main objective of the study is to explore determinants of farmers’ adaptation decisions to climate variability and change and its barriers in the Didessa sub-basin, Ethiopia employing a bottom-up (participatory) approach.

2. METHODOLOGY

2.1 Study Area and Data Source

Topographically, Didessa sub-basin has an area of 27,000 km^2 and located 35°22’ and 36°46’ East longitude and between 7°52’30” and 9°54’0”North latitude in the southern part of Blue Nile basin (Abay). The altitude in the sub-basin ranges approximately, between 630 to 3130 m.a.s.l excluding mountains of greater than 3500 masl [16]. It is divided into three agro-ecological zones, namely, 7% highland, 45.8% midland and 47.2% lowland (USGS, 2016). The highlands in the southern parts of the basin with an altitude greater than 2100-3127 m.a.s.l. The lowlands have lower altitude less than 1100 m.a.s.l in the northern parts of the sub-basin. Mean annual rainfall and mean max temperatures were 1586 mm, 30°C and 11.45°C respectively. The study was conducted on 450 mixed crop and livestock farmers collected between Aprils through to June 2015 production year. Study site selection was based on different aspects of the agricultural activity in the sub-basin including the agro-ecological zone, climate variables, soil and terrain and farming system and livelihoods and vulnerability levels. Focus group discussion (FGD), field observations were also performed.

2.2 Empirical Model

The decision of whether or not to use any adaptation option fall under the general framework of the random utility model. Considering a rational farmer who seeks to maximize the present value at the expected benefit of production over a specified time horizon, must choose among a set of ‘j ‘adaptation options where the order of the choices does not matter. The farmer i^{th} decided to use j adaptation option if the perceived utility from the choice of j is greater than the utility derived from other option (say k). Hence, the probability that choice j is given as:

$$Uij(\beta', Xi + ej) > Uik(\beta' Xi + eK), K \neq j \ (1)$$

Where, U_{ij} and U_{ik} are perceived utility by farmers i of adaptation option j and k, respectively. X_i is a vector of explanatory variables that influence the choice of adaptation option B_j and B_k are parameters to be estimated e_j and e_k are error term. Under the revealed performance assumption that farmers practice an adaptation option that generates net benefit and does not practice an adaptation option otherwise, the study relates the observed discrete choice of practice to the unobserved (latent) continuous net benefit variable as Yij = 1 if Uij > 0 and Yij = 0 if UIJ < 0. In this formulation, Y is a dichotomous dependent variable taking the value 1 when the farmers choose an adaptation option in question and 0 other wise.

Accordingly, the probability that the farmers i will choose adaptation option j among a set of adaptation option could be defined as

$$P\left(Y = \frac{1}{X}\right) \quad = P(Uij > Uik/x) \qquad (2)$$

$$= P\left(\beta' kxi + ej - \beta' kxi - ek > 0/X\right)$$

$$= P((\beta' j - \beta')Xi + ej - ek > 0/X)$$

$$= P\left(\beta' xj + e' > 0/X\right) = F(\beta * Xi)$$

Where e* is a random disturbance term, B* is a vector of unknown parameters that influencing adaptation and F (B*Xi) is a cumulative disturbance of e*evaluated at B*Xi. To this end, the discrete choice model called multinomial Logistic model (hereafter MNL) were selected to identify the factors that determine farmers’ decision to employ adaptation methods to climate change or not in the study area. MNL model is the most appropriate econometric mod-el to apply to the evaluation of qualitative dependent variables that have dichotomous groups (i.e. ‘adapted’ and ‘not adapted’) while the independent variables could be categorical, continuous and dummy [17] and the model is materialized when the dependent variable has more than two outcomes (i.e multiple adaptation response to climate change) [18]. The MNL model is widely employed in climate change adaptation practice of smallholder farmers in Africa [19,20,21], Sofoluwe et al. [22]; Hassan and Nhemachena, [23,10,24,25] and also in agricultural technology adoption studies [26].

To describe the MNL model, let y denote a random variable taking on the values {1, 2, . . ., J} for J, a positive integer, and let x denote a set of conditioning variables. In this case, y denotes adaptation options or categories and x contains different households, institutional and environmental attributes. The question is how cetirus paribus changes in the elements of x affect the response probabilities (P(y = j/x), j = 0, 1, 2. . . J. Thus, as explained by Wooldrdge, Jeffer M [18], the probability, that a farmhouse holds i with characteristics of x choose adaptation option j is specified as

$$Pi = E\left(Y = \frac{1}{Xi}\right) = \frac{1}{1 + e^{-(\beta 0 + \beta j Xi)}} \qquad (3)$$

For easy explosion (substituting (β_0 +$\beta_j$$x_i$) by zi

$$pi = \frac{1}{1 + e^{-zi}} = \frac{e^{-zi}}{1 + e^{-zi}} \qquad (4)$$

Where Pi =E(Y=1) is the probability that the farm household practice adaptation strategies (dependent variable), z_i is a set of the explanatory variable of i^{th} farm household β_0 and β_j are the parameter to be estimated

If Pi, is the probability of adapting, as stated in equation 4 the probability of not practising adaptation is expressed as

$$1 - pi = \frac{1}{1 + e^{-zi}} \qquad (5)$$

From this, it is customary to write the logistic model in the odd ratio in favour of adaptation:

$$\frac{\Pr\left(y=\frac{1}{x}\right)}{[1-pr\left(y=\frac{1}{x}\right)]}=\frac{e^{-zi}/1+e1+e^{-zi}}{1/1+e^{-zi}}=e^{-zi} \quad (6)$$

Consequently, it is easy to see the odd ratio is

$$\ln\left(\frac{pi}{1-pi}\right)=zi=\beta 0+\beta jxi \quad (7)$$

For this study, unbiased and consistent parameter estimates of the MNL model in Eq. (3), however, work under the assumption of the independent irrelevant alternatives (IIA) to hold (Wooldridge, [18]. More specifically, the IIA assumption requires that the probability of using a certain adaptation method by a given household needs to be independent of the probability of choosing another adaptation method (i.e., $\frac{Pj}{Pk}$) is independent of the remaining probabilities and homoscedastic of the basic model in Equation (3). The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable, but estimates do not represent either the actual magnitude of change nor probabilities [19,20,21]. The marginal probabilities measure the expected change in probability of a particular choice being made concerning a unit change in an independent variable from the mean. Differentiating Equation (8) concerning the explanatory variables provides marginal effects of the explanatory variables given as:

$$=\frac{\partial pj}{\partial xk}=pj(Bjk-\sum_{j=1}^{j-1}pjBjk) \quad (8)$$

Following the procedures, variance inflation factor (VIF) and contingency coefficient (CC) were employed to detect multi co-linearity which is the common econometric problem of the cross-sectional data analysis (Wooldridge[18]. Breusch-Pagan test was conducted to assess the presence of Heteroscedasticity (*unequal spread,* or *variance)* in the model.

2.3 Choice of MNL Model Variables

The dependent variable in the empirical estimation is the choice of an adaptation option from the set of adaptation measures. Based on literature review, and field observations, the adaptation practices identified included (1) Planting trees indicates an aggregate choice (agroforestry, establishing the protected area and Planting along the contour). (2) Crop variety representing an aggregate of choice undertaken for the sake of climate risk diffusion (includes crop rotation, intercropping, use of improved seeds). (3) Soil and water conservation (plowing along the contour, stone and soil bunds, fallowing, use of compost) (4) Improved technology (use of chemical fertilizer, draining vertisol, water harvesting) (5) a combination of strategies (planting tree, SWC, improved technology, crop variety) and (6) No adaptation as a reference control. The adaptation was considered as the dependent dummy variable. To determine the dummy, a value of '1' was assigned to those households that had adopted at least one of the adaptation options and '0' for those that had not adopted. The identified adaptation options compared well with options found in the literature Bryan et al. [11] and [6,10]. The choices of the explanatory variables were based on data availability and literature. The explanatory variables are some of the factors that affect the use of adaptation options to climate variability at the farm level. Although there might be many factors affecting farmers' use of adaptation options, the study identified twenty independent variables to be most appropriate in explaining the use of adaptation options at the farm level. In the empirical model, each explanatory variable included testing the impacts and variation from one adaptation to another.

3. RESULTS AND DISCUSSION

3.1 Farmers Perceived Long Term Climate Variables

Notwithstanding the agro-ecological zones, farmers were asked about their perception of climate change (pattern of temperature and rainfall) and their adaptation strategies in the past 20 years. About 82% of highland, 92% of midland and 83.33% of lowland farmers' explained perceived increases in temperature and 81% of Dega, 54.5% of Woyina-dega and 73.33% of kola observed the decreases in rainfalls. The annual temperature for the basin has shown increasing trends for the last three decades (1986–2015) with mean annual temperature during the study period was 19.84°C. The average annual temperature trend line (minimum, maximum and mean) has exhibited a positive slope indicating that the average temperature has increased by 1.40°C in the past 30 years compared to the national level average annual temperature (1.3°C) [8]. Temperature rose with an average rate of 0.181°C in the last decade indicating that the basin was warming slowly and temperatures were rising during the 10 years in the basin compared to the national level increase (0.23–0.25°C per decade) over the past 55 years [27,25] and 0.5°C to 2°C increase for the last three decades in Northern shoa (Asamirew T and Dirba K., [28].

Similarly, rainfall trends in the study area have been decreasing over several decades with high variability in terms of amount and distribution during the study periods. Scientific evidence showed that the average annual rainfall is 1675.17mm in the sub-basin (Table 1). The findings conceded that within many studies in Ethiopia and all of Africa where rainfall varies between 23.5 mm-146.16 mm in Northern and South Western Ethiopia (Asamirew T. and Dirba K., [28], in South Africa [24] Sahel region of Arica [29] and Tanzania for the last 35 seasons [30].

Farmers who claimed to have observed changes in climate over the past 20 years were asked if they had responded to the climate change through adaptation options. Almost about 89% indicated that they have adopted at least one major adaptation option identified through the survey (Table 2). There were 10 types of adaptation measures identified in the study area. However, it was categorized under a set of choice included in the MNL model which includes: planting trees, crop variety, soil and water conservation, improved technology, multiple adaptations and no adaptation (Table 2). In the study area, most farmers practice multiple adaptations strategy, while few of them employ SWC techniques.

About 19.78% of farmers in the study area adopted planting trees as an adaptation strategy. A survey in the Nile Basin of Ethiopia [12,10] found that planting trees is the most common adaptation strategy. Planting trees has diverse ecological and economic benefits, which bring about adaptation to climate change. However, the responses of farmers to climate change can also be driven by their understanding of the causes of climate change. Switching to crop varieties less sensitive to climatic stress is one of the preferred strategies of farmers in the study area. Accordingly, 15.78% of the study area farmers used crop variety as an adaptation strategy. This adaptation strategy has been

Table1. Traditional climatic zones and their physical characteristics in Didessa

AEZ	Altitude	Area (%)	item	AMRF(mm)	ARF (mm)	MaxT(°c)	MinT(°c)
Dega	2300-3200	7	Mean	163.06	1956.69	21.41	11.47
			Stddev		69.59	2.03	0.52
			CV (%)		63	9	5
WoyinaDega	1500-2300	45.8	Mean	130.49	1565.88	28.35	12.12
			Stddev		56.87	1.48	0.89
			CV (%)		61.4	5	7
Kola	500-1,500	47.2	Mean	125.25	1502.94	29.6	16.07
			Stddev		64.8	2.87	1.13
			CV (%)		104	10	7
Didessa	500-3200	100	Mean	139.59	1675.17	26.45	13.22

Source: Calculated based on NMA, 2015

Table 2.Distributions of Farmers Adaptation strategies in the Didessa basin.

Adaption strategy	Dega	Woyina-dega.	Kola	Didessa	Per cent
Planting tree	14	39	36	89	19.78
Soil and water conservation	8	11	28	47	10.44
Improved technology	27	21	10	58	12.89
Crop Variety	21	26	24	71	15.78
Multiple adaptations	19	85	31	135	30
No Adaptation	11	18	21	50	11.11
Total	100	200	150	450	100

Source: Survey result, 2015

supported by policymakers were an emphasis was placed on crop varieties that tolerate environmental stresses, including drought [31,25]. Such crops include short-season varieties of staple crops, improved maize and sorghum.

The study found that farmers were applying SWC techniques for various reasons, including adaptation to environmental change. Accordingly, 10.44% of the study area practices soil water conservation as an adaptation strategy although the practice was less compared to the other adaptation strategies. SWC is important for alleviating water shortages, worsening soil conditions, and other negative effects of climate variability and change [32]. Despite improved technology is preferred as an adaptation option. Only 12.89% of the total cultivated area in the Didessa sub-basin is currently utilizing improved technology. However, introducing improved technology into rain-fed cropping systems and small land size is critical to future agricultural production and predicted to be a profitable investment on both small and large scales. Improved technology increases yields and returns on investments. It also allows farmers flexibility in crop species and varieties and length or number of growing seasons. Employing multiple adaptation strategies in the study area was higher than the other strategies. Hence, it was practised by about 30% of the surveyed farm households. But such an adaptation strategy was constrained by financial, shortage of labour and farm size.

3.2 Determinants of Adaptation to Climate Variability and Change

The MNL model was run taking no adaptation as a base category against other groups to be compared with. The MNL adaptation model was run and showed some significant levels for the parameter estimates. The likelihood ratio statistics as indicated by chi-square of 996.74 with 5 degrees of freedom at p-value < 0.0000, pseudo R^2 (0.6451) and log-likelihoods of -274.26 implying the model has strong explanatory power. The results of the MNL model present the estimated marginal effects in Table 3. To see the probability of a particular choice of adaptation for a unit change in the independent variables, the regression coefficients, average marginal effect and their significance levels were used [19,20,21].

Farm and Households Characteristics: Age: In this analysis age may not be viewed as an indicator to capture farming know-how although age is interrelated with the ability to cope with climate risks [9,25] MNL results showed that age of the household is found to be significant at 5% and negatively correlated to both planting trees and SWC methods. A unit increases in the age of the household decrease the probability of adapting planting trees and implementing SWC (Table 3). The implication is the likelihood of them taking up climate adaptation measures was higher among younger farmers. This is because, young farmers are energetic, innovative and not hesitate to take risks and as such are ready to employ climate adaptation technologies. The result in agreement with Shiferaw and Holden [33] which indicated a negative relationship between age and adoption of SWC practices in Ethiopia, and use of improved varieties [34] and is consistent with what Franklin et al. [35] observed in the relationship between age and changing crop varieties in climate adaptation in Northern Gahanna. On the other hand, improved technology significantly and positively correlated with age of the farming households. As the age of the households' increases, the likelihood for the adoption of improved technology as climate adaptation significantly increases by 5%. This finding well-matched with what Gebrehiwot and Anne [25] investigations in the highlands of Ethiopia where a unit increase in the age of the household heads increased the probability of employing different adaptation methods to the climate changes. These result similar to Nhemachena & Hassan [36] finding in Southern Africa regions.

Farm Experience: Experienced farm households will increase the probability of taking up an adaptation option. Experienced farmers have an increased likelihood of choosing tree planting and SWC in the study area. A one-unitincrease in experience (regardless of age) results in a significant increase of 10% for the possibility of adopting tree planting and SWC techniques as an adaptation strategy by 0.23% and 0.18% respectively. Experience in farming increases the probability of practising and promoting different adaptation measures to climate variability. Studies in Ethiopia and South Africa confirmed that, highly experienced farmers are more likely to have information and knowledge about change during climate a climatic situation than the other less experienced farmers and can easily employ climate adaptation measures [37,11,36]. The probability of adoption of improved technology, crop variety and use of multiple adaptations decreases with farming experience (Table 3). The FGDs revealed that farmers with the greatest farming experience are in the older brackets. As a result, the likelihood of employing adaptation strategies to climate change decreases as farmers get older and older in the study area. This finding is confirmed by previous studies which showed older farmers are lacking in interest and incentive to adapt to climate change [38, 33,34].

Family Size: The influence of family size viewed from two angles (labour endowment and source of off-farm employment) [39]. The study hypothesized that larger family sizes are associated with a higher labour endowment, which would enable them to adapt to climate risks. In the study area, an increase in household size will increase the likelihood of adopting tree planting (agroforestry, establishing the protected area and planting along the contour) as adaptation measures to climatic risk significantly by 10%. The employment of SWC (such as ploughing along the contour, stone and soil bunds, fallowing, and use of compost) had a positive effect though the increase was not significant. This implies that larger families would enable a household to accomplish various adaptation options and various agricultural tasks, especially during seasons. This result is in agreement with [12].

The coefficient of family size is negative and significant at 10% with the probability of choosing improved technology as an adaptation strategy. This is because improved technologies such as the use of chemical fertilizer, draining vertisol, water harvesting demands high financial requirement which might be difficult for farm households with large family size and relying on mainly agricultural (no off-farm and non-farm) activities. Larger family sizes could increase the use of cheap climate adaptation methods. This finding is consistent with Apata et al.[40, 34].

Educational Level: The hypothesis is that the household head level of education increases the probability of employing different adaptation options. As a result, a unit increase in adult education increases the probability of choosing multiple adaptations by 27.9% and significant at 1% and crop varieties by 0.32% in the study area. Adult education decreases the use of SWC and improved technology as adaptation measures which become significant at 1% and 5% respectively. As education level goes from adult to primary level SWC decreased by 20.27% and significant at 1% and increase crop variety by 20.12% and significant at 1%. Moreover improved technology and crop variety increased by 12.34% and 28.59% and statistically significant at 5% and 1% respectively as farmers scaled their education to secondary level and above.The rationale behind the positive relationship between education and climate adaption measures are because educated farmers have more knowledge of climate change and more aware of various techniques and management practices to adapt to the effect of climate change. The study conducted in Ethiopia, Zimbabwe, India and South Africa found that high level of farmer's education and experience increases the probability of embracing adaptation options [10,25,41,36].

On-Farm Income: The study result revealed that farm households income had a significantly positive impact in adopting improved technologies and multiple adaptation strategies of ($p < 0.01$ and $p < 0.05$) respectively. For one unit increase in farm income (measured in ETB) the probabilities of choosing improved technology and multiple adaptation strategies increased by 0.0014% and 0.016% which had positive impacts as taking up planting trees as adaptation measures. This is similar to the findings of Simane et al. [42]. Franklin et al. [35] indicated that higher incomes positively increase adaption to climate change. Therefore, farmers with high farm-based incomes can adapt more to climate change (E.g. improved technologies), affordable climate change adaptation technologies should be designed and made available for farmers to adopt.

Off-Farm Income (Measured in ETB): Increasing off-farm income did not increase the probability of choosing adaptation measures to the changing climate in the study area and only had positive coefficient with planting trees and crop varieties. This is probably because the possibility of shifting to or practising off-farm and nonfarm activities are not in place due to cultural bound and existing opportunities. Contrary to the findings evidence in sub-SSA showed that [24,10,22,26,34] smallholder farmers' access to non-farming income sources increased the likelihood further investments into adaptation options.

Tropical livestock unit (TLU): Ownership of livestock is one of the basic capitals and an important component of the farming system in the study basin. In the study areas, livestock was a source of cash and served as a shock absorber

Table 3. Results of the marginal effects from the multinomial logitadaptation Model, n = 450

Variables	Planting Tree		SWC		Improved Tech		Crop Variety		Multiple Strategy		No adaptation	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Agro-eco. _midland	0.171	0.000***	-0.3390	0.757	-0.0227	0.535	-0.091	0.93	0.2438	0.000***	0.037	0.319
Agro-eco. _lowland	0.4963	0.000***	-0.4753	0.664	0.0299	0.729	-0.0963	0.928	-0.0158	0.526	0.061	0.100
Age	-0.0019	0.016**	-0.0014	0.043**	0.0015	0.046**	0.00062	0.425	-0.00084	0.412	0.002	**0.002*****
Family size	0.01012	0.083 *	0.0113	0.121	-0.01037	0.064*	0.00479	0.537	0.0048	0.563	-0.02	**0.004*****
Education _adult	-0.0439	0.161	-0.1097	0.003***	-0.083	0.016**	0.0032	0.912	0.2796	0.000***	-0.045	0.230
Education _primary	0.022	0.481	-0.2027	0.000***	0.0400	0.289	0.20124	0.000***	-0.0392	0.355	-0.0213	0.601
Education _second	0.032	0.433	-0.2290	0.000***	0.1234	0.035**	0.2859	0.000***	-0.12014	0.014**	-0.0922	**0.054***
Farm size	0.1032	0.000***	-0.0082	0.454	-0.0264	0.010***	-0.03084	0.038**	-0.0275	0.090*	-0.010	0.422
Farm Experience	0.0023	0.097*	0.0018	0.084*	-0.00039	0.757	-0.0007	0.594	-0.0013	0.460	-0.0017	0.142
Income _off farm	5.11e-06	0.771	-2.51e-06	0.880	-8.44e-06	0.683	0.000021	0.255	-0.000353	0.255	-2.57e-06	0.881
Income _ on farm	4.25e-06	0.320	-0.000025	0.006**	0.000014	0.000***	-0.000011	0.274	0.000162	0.019**	1.21e-06	0..875
TLU	-0.0172	0.000 ***	0.01309	0.119	0.0049	0.170	0.01775	0.018**	-0.02259	0.002***	0.0040	0.542
Extension cont.	-0.0132	0.332	-0.2838	0.067*	0.0217	0.092*	0.0486	0.006***	0.0957	0.000***	-0.12457	**0.000*****
Access to training	0.0133	0.559	-0.2731	0.237	-0.0175	0.44	0.00038	0.989	0.0266	0.407	0.00455	0.848
Access to credit	0.04425	0.088*	0.0071	0.773	0.0295	0.213	0.0133	0.633	0.622	0.074*	-0.03209	0. 244
Access to clim. Info	-0.048	0.038 **	0.0400	0.057*	0.0122	0.559	-0.0298	0.242	-0.00626	0.846	0.0318	0.186
Dist. from market	-0.00097	0.672	0.0053	0.030**	0.0016	0.489	0.00155	0.571	0.00075	0.831	-0.00825	**0.007*****
Access to irrigation	0.0779	0.015**	-0.10091	0.085*	-0.0321	0.384	0.0738	0.113	-0.0073	0.165	0.0548	0.233
Temperature	-0.0427	0.000***	0.06007	0.001***	-0.01687	0.004***	0.0057	0.684	0.0035	0.721	-00026	0.808
Rainfall	0.00035	0.390	-0.00034	0.000***	0.0010	0.000***	-0.000066	0.295	0.000357	0.000***	-0.00084	**0.090***

*Significance code: *** significant at 1%, ** significant at 5%, and * significant at 10%*

Dependent Variable: Adaptation strategies; Number of observations = 450; LR Chi square (100) = -1149.70; Pseudo R_ square = 0.645; Log Likelihood = -274.26; Prob. > Chi square = 0.0000; Base category: engagement in No adaptation

Source: Survey result, 2015

against climatic risks. The marginal effect from the model indicated that an increase in ownership of livestock by one unit decreased the probability of farmer's preference to employ planting trees and adoption of multiple strategies as an adaptation strategy by 1.72% and 2.2% significantly at 1%. This is might be due to the expansion of grazing land at the expense of cropland and small land size. On the other hand, livestock ownership was positively related to adaptation methods such as SWC, improved technologies and crop varieties. Deressa et al. [10] found ownership of livestock to be positively related but not significant to most of the adaptation options employed in the study area. Recently, Gebrehiwot and Anne, [25] also found that a unit increase in the number of livestock resulted in a 4.5% increase in the probability of using different crop varieties to adapt to climate change.

3.4 Farm Characteristics

Farm Size (in this study refers cultivable land): An increase in farm size will increase the likelihoods of employing tree planting as an adaptation option by 10.32% and is significant at 1% and the MNL model showed a significant decrease at 1%, 5% and 10% in improved technology, crop variety and use of multiple adaptation option respectively. According to FGD the negative relationship could be related to investment in adaptation options (i.e. irrigation facilities, improved seeds and use of fertilizer, water harvesting and draining vertisoil) where it is expensive for large farms. Hence, the probability of adopting those strategies is higher with smaller farm sizes. Similar studies also indicated that the positive association between farm size and undertaking tree planting as an adaptation strategy [19]. Deressa et al. [12] found that choices of particular adaptation options could be determined by plot specific and farm characteristics.

3.5 Institutional Factors

Access to Training: Participation in climate variability and change-related training programs is found to be increasing tree planting, crop varieties and use of multiple adaptations positively by 1.3% and 0.03% and 2.6% respectively even though not significantly. However, access to training decreased SWC and improved technology by 27.31% and 1.7%. This result is consistent with Belaineh et al. [43] where participation in climate variability and change-related training programs is found to be negatively and significantly associated with crop diversification and SWC at 5% level.

Access to Extension: The study assumed that the frequency of contact with extension service agents is expected to influence the likelihood of adopting different adaptation option positively. The marginal value of the model indicates that the likelihood of choosing improved technology, crop variety and use of multiple adaptation strategies as adaptation option increased positively with level of significance at 10%, 1% and 1% respectively and a negative correlation existed within SWC with its level significance at 10% in the study area. The influence extension services have on adoption is varies. Empirical studies on the adoption of SWC measures found that extension services were not a significant factor (Pender et al. 2004). However, it comes into view that extension workers service in the study area emphasized on improved technology, crop varieties and multiple strategies. These imply that farmers who have access to extension services are more likely to be aware of climatic conditions and knowledge in various farm management practices in response to climate change. Similar studies confirm this [25,24,36].

Distance from Market: The probability of employing different adaptation option increases with an increase in access to markets. This is because access to the market serves as a platform for farmers to exchange information. An increase by one km to markets increases the probability of farmer practising SWC as adaptation strategy by 0.53% and 5% level of significance. This result implies that farmers who access markets are likely to be introduced with diverse inputs or technologies such as stone banding, terracing soil band, trenching and other related technologies. Notwithstanding the significance, proximity to markets has positive impacts on improved technology, crop varieties and multiple adaptation strategies despite its significance.

Access to Credit: Access to cheap credit increases farmers' financial capacity to meet their farm-level transactional costs and various adaptation options. Accordingly, the result showed that one-unit increase access to credit increases the likelihoods that farmers will take up adopting tree planting and multiple adaptations as a strategy by 4.4% and 62.2% with a significant level of ($p < 0.1$). The implication is access to credit improves farmers' adaptive capacity to practice planting trees and utilizing multiple adaptations. Of course, access to credit has positive impacts on all adaptation options. In line with the findings, Bryan et al. [11] found that farmers with access to credit were 11% more likely to adapt to climate change in South Africa and 6% more likely to adopt climate change in Ethiopia. Similar evidence also substantiates the result [24,10,26,34, 22].

Access to Climate Information: Smallholder farmers require different types of climate information (early warning signals, weather forecasts, pest attacks, input management, cultivation practices, pest and disease management) during each stage of the agricultural production process in order to adapt to climate variability and change [6,9]. The results showed that the probability of adopting SWC as an adaptation measure has risen with increased access to information by 4% and significant at 10%and decrease planting a tree by 4.8% with the level of significance 5%. Improved technology also had a positive influence on climate information. This implies that farmers with access to timely weather information are more likely to adapt to climatic change. Similar findings have been reported in Ethiopia, Nepal and South Africa [10] found that in East Africa, adoption of improved varieties and increased fertilizer use is related to weather information.

Access to Irrigation: The results from MNL showed that the likelihood of using irrigation increases with the planting trees which is a major adaptation strategy and decreases SWC. access to irrigation influence farmers to employee planting trees as the major adaptation option are 7.7% and decrease SWC by 10.09% and is significant at 10% in the study area. Also, there is a positive relationship between accesses to irrigation and crop variety as an adaptation option.

3.6 Climatic Factors

Agro-Ecological Zone: Local climate and agro-ecological setting of farmers are expected to influence decisions on whether to adopt or not. Farmers' living in different agro-ecological settings used different adaptation measures in response to climate variability. The MNL result showed that farmers living Kola and Woyina-Dega are more likely to employ planting tree ($p< 0.01$) relative to the base category (Degaagro ecology). Hence, rural households, living in lowland can increase the probability of using tree planting as an adaptation strategy by 49.63% followed by Woyina-Dega (17.1%).Living in Woyina-Degaagroecology positively correlated and significantly increase multiple adaptation strategies by 31.29% compared with those households' living in the *Dega and Kola* respectively ($p<0.01$). A similar report by Kurukulasuriya and Mendelsohn, [32], Deressa et al. [10], Gutu et al. [44], Belaineh et al. [43], Simane et al. [42] showed that farmers living in regions with relatively lowland and temperate zone had an increased likelihood of adapting tree planting as adaptive measures. This attributed to the difference in soil, climate and other natural resources as well as experiences to climate-related stress.

Temperature: Areas with a high annual mean temperature between 1986 and 2015 were more likely to adapt to climate change through different adaptation practices. An increase in temperature by one degree celsius higher above the mean increased the probability of using SWC (6%, $P< 0.01$)to preserve moisture content and decrease tree planting but improved technology by 4.2% ($P< 0.01$) and by 1.67% ($P< 0.01$). Positive correlations with crop variety and multiple strategies explained by the model. Hence, in response to an increase in temperature farmers tend to change agricultural practices that suit the changes. For instance, farmers tend to use crop varieties that resist drought, diversify or vary planting dates so that crops are not grown during the periods of high warmth [45,36,46], Increasing temperatures were found to be positively and significantly correlated with the choice of SWC at $p < 10\%$ in Ethiopia and Farmers in Burkina Faso respectively.

Precipitation: A one-millimetre decrease in average annual rainfall significantly increase the likelihoods of SWC by 0.034% at ($p < 0.01$), whereas, adoption of improved technology and multiple adaption strategies increased positively with an increase in rainfall by one millimetre ($p < 0.01$). The implication of this is that as precipitation decreases the probability of farmers efficiently utilizing water resources for crop production and SWC to preserve water and reduce evaporation increases [45,36,46].

3.7 The barrier of Successful Adaptation Measures

Adaptation to climate change is costly. The results of farmers' perceived constraints to implement promising adaptation measure

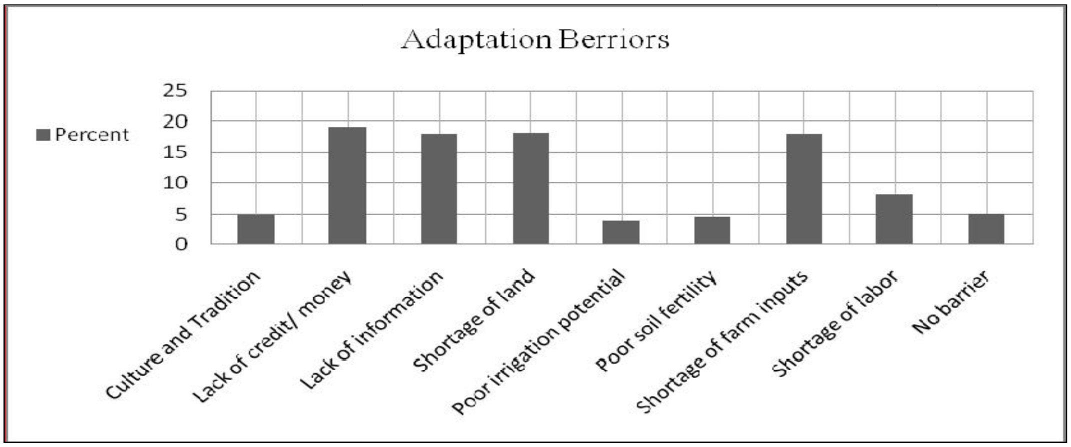

Fig. 1. Barriers to implementing promising adaptation measures
Source: Survey result, 2015

identified by farm households are shown in Fig. 1. The study asked farmers about their constraints for implementing promising adaptation measures in response to perceived climate change. They were asked ‘‘what were the main constraints/difficulties in changing your adaptation ways?" Farmers in the study area gave many reasons for in effective adaptation measures which associated with socioeconomic variables and inadequate government support of agricultural activities. The result found that major barriers identified by farmers were shortages of land (21.78%), lack of credit/ money (19.11%), lack of information (13.56%), shortage of farm inputs (17.56%) and others important barriers to adaptation such as shortage of labor (8.22%), poor soil fertility (5.33%), culture and tradition (4.89%) and poor irrigation potential (4.44%).

Shortages of land have been associated with high population pressure. High population pressures force farmers to intensively farm over a small plot of land and make them unable to prevent further damage by making it impractical to do things such as planting trees which competes for agricultural land. Lack of money hinders farmers from getting the necessary resources and technologies which is required to assist and adapt to climate change (Deressa T. 2010). Lack of information on climate adaptation could be attributed to the fact that researches on climate change and adaptation options have not been strengthened in the study area. The result of FGD also confirmed that unpredictability of weather, coupled with high farm input prices like an improved seed, improved breed of animals and irrigation technologies. Also, the FGD revealed that lack of agricultural credit and government support limits the farmer's ability to obtain the necessary resource required to employ adaptation options.

Lack of access to timely weather information hinders farmers' ability to adapt to climate change. The result of the study mirrored a study conducted in South Africa and Ethiopia were in South Africa (36%) lack of access to credit/money and in Ethiopia shortage of land (27%) identified by farmers as a serious constraint to adaptation (9). In addition, Empirical facts identified access to climate information [10,19] Deressa T. [47] shortages of land Bryan et al. [11] and the socio-economic position of the household and lack of capital to invest in improved technology for small farm size [46] Deressa et al. [10], Sofoluwe et al. [22] are some among the determinants.

4. CONCLUSION

This paper examines the farm-level analysis of determinants of adaptation options along with barriers in the Didessa sub-basin. It is noted that most of the farmers noticed an increase in temperature while precipitation declined. In response, farmers employed Planting tree, SWC, crop variety and improved technology and a combination of other strategies. Of course, variations prevailed due to difference in household characteristics, socio-economic, institutional and other climatic variables. Besides, shortage of land, lack of credit/ money, lack of information, shortage of farm inputs, shortage of labour, poor soil fertility, culture and tradition and poor irrigation potential are the major barriers to adaptation. Therefore, we conclude that concerned bodies need to create enabling environment that promotes adaptation options which support constraints the farmers face in taking up adequate adaptation to climate change by strengthening and increasing access to socio-economic and institutional service appropriate to reach farmers with affordable and locally available adaptation options to confront climate change and enhance their livelihoods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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