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Effect of climate variability on crop income and indigenous adaptation strategies of households

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Abstract

Purpose – This study aims to examine the effect of climate variability on smallholders' crop income and the determinants of indigenous adaptation strategies in three districts (Mieso, Goba-koricha and Doba) of West Hararghe Zone of Ethiopia. These three districts are located in high-moisture-stress areas because of crop season rainfall variability.

Design/methodology/approach – Primary data collected from 400 sample households were used for identifying factors that affect households' crop income. The study used ordinary least square (OLS) regression to examine the effect of climate variability. Given this, binary logit model was used to assess smallholders' adaptation behavior. Finally, the study used multinomial logistic regression to identify determinants of smallholders' indigenous adaptation strategies.

Findings – The OLS regression result shows that variability in rainfall during the cropping season has a significant and negative effect, and cropland and livestock level have a positive effect on farmers' crop income. The multinomial logistic regression result reveals that households adopt hybrid crops (maize and sorghum) and dry-sowing adaptation strategies if there is shortage during the cropping season. Variability in rainfall at the time of sowing and the growing are main factors in the area's crop production. Cropland increment has positive and significant effect on employing each adaptation strategy. The probability of adopting techniques such as water harvesting, hybrid seeds and dry sowing significantly reduces if a household has a large livestock.

Originality/value – The three districts are remote and accessibility is difficult without due support from institutions. Thus, this study was conducted on the basis of the primary data collected by the researchers after securing grant from Swedish International Development Agency (SIDA).

Keywords Household, Adaptation, Determinants, Climate variability, Crop income

Paper type Research paper

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1. Introduction

Climate change and variability are becoming a strong threat for food security in the twenty-first century, particularly for the agriculture-dependent sub-Saharan African countries (Eva, 2009). Global warming is projected to have a significant impact on factors affecting agriculture, including temperature, carbon dioxide emission and precipitation. Identifying the agricultural effect of climate change might help to properly anticipate and adapt to the problem and maximize smallholders' productivity (Fraser, 2008). Because most African countries lack the capacity of adapting to this problem, minor changes can spark a significant effect on the agriculture capability of the nations. While climate change has global impacts on agriculture, regional variations are significant depending on the geographic location. For most developing countries, these differences underscore the difficulty of proposing the general strategies required for adopting new agricultural technologies so that the problem can be dealt with (David, 1993). Changing the consistency and intensity of rainfall is one of the most widely spread and potentially devastating impacts of climate change in East Africa. Precipitation variation ultimately affects moisture availability that may result in a reduction in agricultural production and shortages in potentially widespread food supply (Michael, 2006).

Both insufficient rainfall and its erratic distribution are the main reasons that reduce crop production and thus income (Mertz *et al.*, 2010). Variability in crop production and animal husbandry owing to climate variability will directly result in smallholders' income variation. For Ethiopian smallholders, crop production is the area that is mostly susceptible to climatic variation.

Few countries in Africa are trying to conserve resources and integrate climate change adaptation strategies into their management plans (Hansen *et al.*, 2003). Some smallholders' plant drought-resistant crops to adapt moisture stress (Patt *et al.*, 2005). Almost all households in Ethiopia, Mali and Yemen use adaptation strategies including improved seeds and changed planting dates, to make yields less susceptible to climate variability. There is a remarkable difference among countries and between households in the type of adaptation strategies implemented. In Ethiopia, wealthier households participate mainly in adopting communal strategies, such as soil erosion, communal irrigation or reforestation, communal water harvesting and rangeland management, for which external help is necessary (Arjan *et al.*, 2011). Few households chose non-farm income sources, but the problem here is that rural areas lack auspicious environment to sustain those activities. This indicates that smallholders' climate variability adaptation strategies in Ethiopia are affected by different factors. Thus, the general objective of this study was to examine the effect of variability in climate on crop income. Given this, the study assessed factors that determine indigenous adaptation strategies of smallholder farmers in West Hararghe Zone, Ethiopia.

2. Methodology

2.1 Description of the study area

Western Hararghe is one of the 17 zones of Oromiya National Regional State. The Zone is bordered in the South by the Shebelle River, which separates it from Bale Zone, in the Southwest by Arsi, in the east by East Hararghe, in the Northwest by Afar and in the North by Somali Regional State. This Zone has good potential for coffee production of about 8,364 tons of coffee, accounting for about 7.3 per cent of the region-level production and 3.7 per cent of the national-level production in 2012 (CSA, 2013). This Zone had a total population of 1,871,706 with 15,065 km^2 area coverage, resulting in a population density of 124.23 persons/km^2 (CSA, 2007). There are about 395,127 households, with an average size of 4.74 persons per household and 380,019 housing units. More than 92 per cent of the zone has faced frequent bouts of malaria, as it was frequently drought-ridden (World Bank, 2004). Empirical studies showed that the eastern zones of the Oromiya Regional State (West and East Hararghe) are prone to chronic food insecurity problems (François, 2003). Non-remunerative international prices and outbreak of diseases together with high moisture stress made coffee production a less attractive business for households of the area.

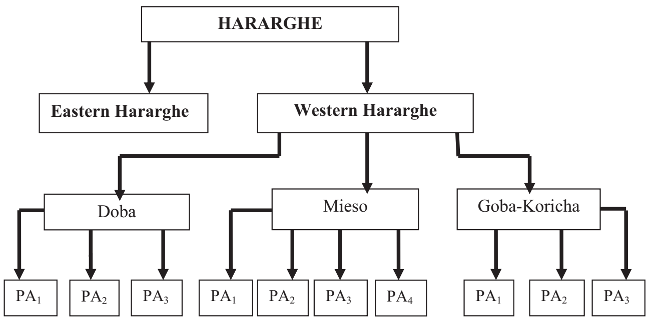
This study was conducted in three districts of the West Hararghe Zone (Mieso, Goba-koricha and Doba) on the crop production sub-sector only. The three districts were selected purposively because they are highly dependent on crop production on the one hand and are suffering from climate variability, on the other hand.

2.2 Method of sampling and data collection

The study used both primary and secondary data to achieve the predefined objectives. Secondary data were collected from published and unpublished works of different governmental and non-governmental institutions. A multi-stage sampling technique was used to determine sample households and collect the data: first, sample districts that had severe moisture stress were selected purposively. Second, sample villages from these districts were selected randomly and the sampled households were finally selected using systematic sampling. A considerable sample size was used to make the sample more representative. The primary data were collected from farm households using questionnaire, which were distributed and collected by enumerators who know the culture and language of the research area. In addition, the study also conducted focus group discussions with the farming society to extract common problems shared by the society of the study area at large (Figure 1).

2.3 Method of data analysis

2.3.1 Ordinary least squares regression. Ordinary least squares (OLS) regression is a generalized linear modeling technique that is used to model a single response variable that has been recorded at an interval scale. The technique may be applied to either single or multiple explanatory- and categorical-type variables that have been properly coded (Hutcheson, 2011). Here in this research, the dependent variable was crop income collected



Source: Own formulation, 2015

Figure 1.
The sample frame

by each sample household. Crop production inputs, crop price, natural factors and others may affect crop income of households.

$$Y = F(K, H, P, S, \ldots D) \tag{1}$$

where: Y is the crop income of households expressed in terms of birr, the local currency; K is the working capital budgeted for the crop production; H is human labor employed in the crop production sub-sector; P is the price of each crop depending on the nearest local market; S represents the climate-related shocks including rainfall inconsistencies D represents the demography-related variables like education, sex and age of the household head. The aforementioned mathematical expression would be transferred to a logarithmic functional form as follows:

$$\ln Y = \alpha + \beta_1 \ln K + \beta_2 \ln H + \beta_3 \ln P + \beta_4 \ln S + \mu_i \tag{2}$$

The unknown parameters in equation (2) will show the interaction of each explanatory variable with the dependent variable.

2.3.2 The logit regression. The model assumes that the data are case-specific; that is, each independent variable has a single value for each case and the dependent variable cannot be perfectly predicted from the independent variables for any case. As with other types of regression, there is no need for independent variables to be statistically independent from each other. The binary logit model for identifying determinants of adaptation behavior was specified as follows:

$$P(X) = \frac{\exp(\alpha + \beta X)}{1 + \exp(\alpha + \beta X)} \tag{3}$$

Where β is the coefficient of the covariates considered in the regression, and α refers to the value of the constant term.

The log of odds ratio, which is a linear function of parameter estimates, is:

$$\log\left(\frac{P_i}{1 - P_i}\right) = \alpha + \beta_j X_i \tag{4}$$

2.3.3 Multinomial logistic regression. This study addressed the responsiveness of households for climate variability by implementing the multinomial logistic regression model. This model can predict the probabilities of the different possible outcomes of a categorically distributed dependent variable, given a set of independent variables. The model can be implemented when the dependent variable in question is nominal (a set of categories which cannot be ordered in any meaningful way) and consists of more than two categories. The multinomial logit model assumes that the data are case-specific; that is, each independent variable has a fixed value for each case, and the dependent variable cannot be perfectly predicted from the independent variables for any case.

$$\Pr(y_i = j) = \frac{\exp(X_i \beta_j)}{1 + \sum_{j=1}^{J} \exp(X_i \beta_j)} \tag{5}$$

and

$$\Pr(y_i = 0) = \frac{1}{1 + \sum_{j=1}^{J} \exp(X_i \beta_j)}, \tag{6}$$

where: y_i is the observed outcome for the i^{th} individual and X_i is a vector of explanatory variables.

3. Data analysis and discussion

3.1 Demographic characteristics of sampled households

Table I showed that the majority of the sampled households had a large family size, ranging from four to eight persons per household, and with an average family size of 6.03. In the study area, 75 per cent of the households had a family size of five to eight persons, which indicated that the majority had a large family size, and the Doba district had the largest family size compared with other districts. This large family size attributed to a relatively high dependency ratio, seen in the households of Goba-koricha.

Most household heads in the study area were under 50 years of age, which had a higher economic effect, especially for the crop production sub-sector that demands more labor. Most (86 per cent) of the sample household heads were at their economically active age (Table I), which may be very useful for efficient production and management of the crop production. Because the sub-sector is in need of active labor, having a younger household head would be a crucial input in performing better. More than half of the household heads were illiterate and did not have even basic education. These circumstances may create difficulty in expanding new technologies, as uneducated people are reluctant to adopt new technologies.

3.2 Landholding and farming system of households

Agriculture in the study area is purely practiced by an ox plough using traditional wooden materials because the area is one of the most densely populated regions of the country and here each household owns a very small plot of land, although they have a large family size to manage.

Table II showed that the majority of the sample households had no surplus draught power, given the other natural and uncontrolled factors that encumber crop production;

Table I. Family size and dependency ratio of sample households

Family size	Percent	District	Family size	Dependency ratio
≤2	1.5	Doba	6.5	1.72
2-4	20	Mieso	5.9	1.65
4-6	34.4	Goba-koricha	5.9	1.72
6-8	40.4	Average	6.03	1.69
8-10	3.4			

Source: Own computation, 2015

Table II. Cropland and livestock ownership of households

Land (ha)	Household (%)	Pair of oxen	Households (%)
Below 1	47.81	Below 1	40.0
1.1-2	36.57	1-2	51.6
2.1-3	12.82	2-3	7.5
Above 3	2.81	Above 3	0.9
Total	100	Total	100

Source: Own computation, 2015

draught power shortage was also the other bottleneck. Some households tried to generate income from renting oxen power; hence, those who did not have draught power could not take advantage of this benefit.

Average landholding in the study area was about 1.34 ha, ranging from a minimum landholding of 0.13 ha to a maximum of 5.50 ha. A significant proportion of sample households (about 48 per cent) had landholding of less than 1 ha, which was very small for the application of modern technologies and extensive farming system to collect potential gains from such applications. This low landholding forced farmers of the study area to practice intensification and inter-cropping as their main strategies for maintaining welfare. They had very low and fragmented plots of land as compared with the national-level landholding. In the West Hararghe Zone, the average landholding was 0.9 ha, in which around 66 per cent of the population owned less than 1 ha (CSA, 2007). Because the Mieso District is agro-pastoral, it had relatively larger livestock and a pair of oxen as compared to the other sampled districts.

Cereal crops took the predominant area of land (78.17 per cent) in the crop production of the country in 2013 (CSA, 2013). Similarly, these crops had the largest share in the quantity of grain crops produced in the study area. Farmers in the study area allocated most of their land for sorghum production, which is the main source of food and is also better drought-resistant. This crop takes the fourth largest share (15.58 per cent) of the national grain crop production. Maize takes the second largest share in land allocation of the sample districts because it is the main source of food and is somewhat adaptive to the climatic conditions of the area. The two cereals are major food crops both in terms of the area cultivated and volume of production. Farm households in these districts produced sorghum and maize in larger volume compared to other crops.

Most households allocated a small fraction of land to produce other cereals and the stimulant crop *K'ht*. It is a cash crop; households did not produce in plenty owing to land shortage and climate condition of the area. Farmers were highly dependent on few cereal crops because of their climate adaptability, in which there was a new variety of those crops that was drought-resistant and short-seasoned. Farmers of the Doba district also produce haricot bean and other vegetables because of relatively better moisture availability. They mainly produce haricot bean and some other cereals through intercropping with sorghum and maize. Households tried to cope with the land shortage problem through intercropping, which is a common practice adopted by most smallholders of the zone. Besides intercropping, farmers have a habit of producing more than once within one production season. This means farmers first cultivate short-seasoned crops and then they cover the land with other type of crops to use the available moisture and land (Table III).

Land allocated	Sorghum	Maize	Other cereals	'khat'
0-0.5	55.63	86.25	95.94	98.75
0.56-1	28.75	10.63	4.06	1.25
1.1-1.5	8.75	0.94	0.00	0.00
1.56-2	5.31	1.88	0.00	0.00
2.1-2.5	1.25	0.31	0.00	0.00
2.56-3	0.31	0.00	0.00	0.00
Total	100	100	100	100

Source: Own computation, 2015

Table III. Households' (%) cropland allocation for each crop

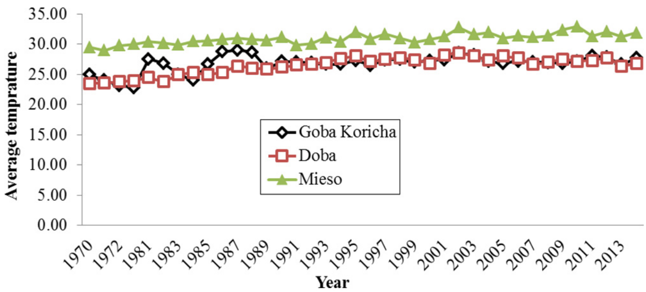
Farmers are highly dependent on the oxen plough, of which the majority of them possessed less than a pair. There are households that do not possess even a single ox, but based on their culture households who do not have ox would borrow for few days to plough their cropland and provide crop residue in exchange. Even though the area has this culture, more than half of the households responded that they have draught power shortage.

3.3 Climate variability and farmers' crop income

3.3.1 Crop season temperature and rainfall in the sample districts. Mieso District had the highest average temperature, in all the years considered, than the other two districts. The overall temperature condition of the study areas showed that there was a continuous increment over time, especially after early 1990s (Figure 2).

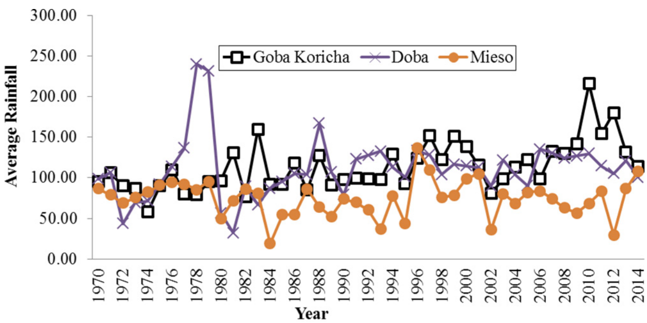
Although it became consistent recently, the rainfall variability in the Doba District was very high in previous years compared with other districts, especially in the 1980s. Recently, there was observed a drastic reduction in rainfall during the crop season of Goba-koricha and Doba districts. In the past three decades, greater variation has been observed regarding rainfall in the sampled three districts. In general, rainfall during the crop season of the Mieso district was lower than that of the other districts, and the circumstances were relatively similar in the other two districts (Figure 3).

Rainfall during the crop season of the Mieso district was consistent in 2013 and 2014 production years, which resulted in better productivity and higher food crop availability.



Source: Ethiopian National Meteorology Agency, 2014

Figure 2.
Average crop season temperature in the three districts



Source: Ethiopian National Meteorology Agency, 2014

Figure 3.
Average crop season rainfall in the three districts

This contributed to reduce food insecurity problem. Doba district had a higher food insecurity problem because it received the lowest rainfall compared with the other two districts.

3.3.2 Weather condition and crop yield. Most studies revealed that climate change is likely to reduce agricultural productivity, production stability and household income in some areas that already have high levels of food insecurity (Greg *et al.*, 2011). Households of the study area, on average, lost about 8.06 quintals of crop because of insufficient rainfall during the cropping season in the previous production year. An increase in summer temperature had a negative effect on productivity, and it caused an average loss of 8 quintals for 86.88 per cent of the sample respondents. This result was consistent with the findings of Mariara and Karanja (2006) in Kenya and that of Eid *et al.* (2006) in Egypt. In connection to this, maize was the most sensitive crop as compared with other crops cultivated in the study area. Sample households viewed that sorghum had better resistance to weather condition of the area than maize. Respondents also replied that they had a habit of sowing sorghum on dry soil even under conditions of late-onset rain. They did this because of the drought-resistance nature of sorghum and because the seeds are small enough to wait safely in the soil without being damaged until the rain arrives.

Farmers developed a tradition of adopting new crops that had never been grown before and had good drought resistance with better yield on the existing water stress as an adaptation strategy. Rainfall oscillation, mainly shortage, which happened every five years had a devastating effect on crop yield. Table IV shows that sorghum was more productive as compared to other crops produced in the area. The two dominant crops of the area were more productive if one compares the national productivity with the study area. The national productivity of maize in 2012 and 2013 was 1,220 kg/ha and 1,379 kg/ha, respectively whereas that of sorghum was 2,054 kg/ha and 2,106 kg/ha for the 2012 and 2013, respectively. The yield of the two crops in 2013 was 2,688 kg/ha and 2,309 kg/ha for maize and sorghum, respectively, in the West Hararghe Zone (CSA, 2014). Sorghum yield in Doba district (2,550 kg/ha) was better than that in the other districts and even better than that at the zonal level (2,309 kg/ha). The average sorghum yield in Goba-koricha was also higher than that of Mieso. Besides growing the dominant crops of sorghum and maize, few farmers in the study area also produced wheat, wherein the yield of this cereal was better in Goba-koricha than in the other sampled districts.

Table IV showed that households of Doba faced extreme production losses (1,480 kg/ha) because of the previous year's rainfall shortage, which was the main reason for the reduction in yield as compared with the other two districts. Regarding the recorded production loss and information gained from group discussions, the previous year's weather condition was not favorable for crop production in Doba. All of the sampled households in the district faced production loss, although there was a difference in the amount of loss per hectare per household. Given this, only 78.35 per cent of the households in Mieso faced production loss,

Districts	Sorghum	Maize	Other Cereals	Total production loss*
Doba	2552	1650	600	1480
Mieso	2430	1770	1180	580
Goba-koricha	2470	1460	1280	1003
Overall	2460	1638	1130	806

Source: Own computation, 2015; * The loss was due to previous year's rainfall shortage

Table IV. Crop yield (kg/ha) and loss in the study area which was not higher than the households of Doba. Farmers in the study area used both organic and inorganic fertilizers to increase crop productivity given the ongoing moisture stress. Organic fertilizer applications like compost and animal dung were common practice in each district. Farmers in Mieso district had a habit of practicing shifting cultivation to maintain soil fertility, as their landholding was relatively better.

3.3.3 Determinants of crop income. Household-level agricultural panel data would have been ideal for addressing inter-temporal effects, but such data sets are rare in developing countries. On the other hand, if sufficient variation is observed in the cross-sectional data, especially variation within what climate variability is likely to bring about, then it is reasonable to use such data to understand effects of the problem. However, instead of using farmland value, which is not available in most developing countries, it would be better to rely on net revenue per hectare as the dependent variable (Pradeep and Mohamed, 2006). Our specification was entirely driven from the Ricardian technique of determining farm net revenues. These empirical research studies used OLS estimation technique to identify determinants of net revenues per hectare using time-series data that include temperature and rainfall. The research included previous year's crop season rainfall condition as a dummy variable, which is one critical input to determine households' current year crop income.

Majority of the Ethiopian population is dependent on agriculture for its consumption and source of income. Thus, if any problem that harms farmers' agriculture occurs, then households may lose a lot of income and their food availability will considerably reduce. The crop production sub-sector of the country is the most susceptible for climate variability owing to its direct interaction and nature dependency. Based on the regression result, the model was strong enough to encompass the variations in the dependent variable. Cropland and livestock units had a positive and significant effect on households' crop income in the study area. A larger livestock unit implies possession of enough draught power, which is a critical input for plowing, harvesting and threshing activities, which significantly affects the crop income. Likewise, farmer's educational attainment had a positive and significant effect on household's crop income in the study area (Table V).

Previous year rainfall amount had a significant effect on households' crop income based the regression result. This implies that if rainfall reduces successively because of climate variability, smallholder households will not be able to produce even for their own subsistence. This result was consistent with the findings of Mano and Nhemachena (2006). Those authors concluded that if the temperature increases by 2.5°C and 5°C, the net farm revenue will decrease by approximately US$0.3bn and US$0.8bn, respectively based on the sensitivity analysis of alternative climatic scenarios.

Table V. Determinants of households' crop income

Variables	Coefficient	SE	*Z*
Ln Dependency ratio	−0.0727	0.3789	−0.19
Education level	0.1303	0.0705	1.85**
Ln Farm experience	−0.3055	0.3664	−0.83
Ln TLU	0.5568	0.2658	2.09**
Ln cropland	0.9253	0.3155	2.93***
Rainfall inconsistency	−1.3099	0.4976	−2.63***
Constant	5.9133	1.3760	4.30***

Sources: Model result, 2015; *** and ** represent 1 and 5% significance levels, respectively

3.4 Determinants of indigenous adaptation strategies

Although many of the farmers in the study area were not qualified enough to use modern technologies for sensing and understanding the extent and degree of climate change, they had better perception about the ongoing climate variability based on their traditional knowledge. They have argued that there is successive rainfall reduction and temperature increment in their surroundings. With time, climate variability has become more severe, and they are unable to produce some crops that were dominantly produced previously. Some farmers remembered that there was bimodal rainfall within the area and they had produced twice a year, but now they faced subsequent rainfall shortage even in the main rainy season to produce hybrid sorghum and maize that have better drought resistance.

About four-fifth (85.3 per cent) of sample households replied that the problem of climate variability, which can be explained by moisture stress, is easy to perceive. Deressa (2006) also concludes that decreasing precipitation appeared to be more damaging than increasing temperature. Table VI shows that water shortage is a critical problem in crop production of households in the study area. Shortage of cropland was the second cause affecting crop production of the study area. Given their culture sensing climate variability via moisture stress households of the area also perceived the direction of rainfall variation.

Table VI shows that early cessation of rainfall was the most frequent type of rainfall variability in the study area. Nearly 81 per cent of the households faced the problem of early rainfall cessation, even before the crops' grain-filling stage. Regarding the view of respondents in the study area, rain mostly ceased during the flowering stage of crops, resulting in significant production losses. Erratic distribution and insufficient amount of cropping season rainfall were also core bottlenecks of the crop production in the area. Although the main agricultural problem of the area is related to natural factors such as successive moisture stress and other unexpected windfall-type factors, there are also other bottlenecks such as shortages in the cropland area.

More than half of the households responded that factors related to climate variability are the main problems that triggered poor performance of agriculture. Interviews with household heads indicated that they frequently faced complete crop loss owing to moisture stress, especially if the problem happened at either the flowering or fruit formation stage of the crops. In such situations, households tried to supplement with irrigation from harvested water or the crop would be used as livestock feed.

Climate change adaptation is a two-step process. First, the household must perceive that the climate is changing. Next, they should respond to such changes through appropriate adaptation strategies. It is assumed that economic agents, including smallholder farmers, use adaptation methods only when they perceived that utility or net benefit from using such a method is significantly greater than without it (Maddison, 2006; Nhemachena and Hassan, 2008 and Deressa *et al.*, 2008). Smallholders adopt different mechanisms to cope with climate

Direction of rainfall variation	Frequency (%)	Common problems	Frequency (%)
Late start	7.6	Land shortage	26.7
Early cease	19.7	Water shortage	63.5
Insufficient amount	11.4	Over flood	5.1
High temperature	0.6	Low land productivity	4.8
Combination of all	60.7	Total	100.0
Total	100.0		

Source: Own computation, 2015

Table VI. Common direction of rainfall variation and crop production problems variability depending on their economic capacity. In connection with the ongoing climate variability that results in a late start and early cessation of rain, farmers adopted hybrid sorghum and maize, especially newly innovated sorghum varieties that have better drought resistance. About three-fourth (75 per cent) of the sampled farmers replied that they adopt mixed cropping strategies to mitigate the problem of crop failure. They hope that if one of the crops failed, the other one will substitute the failure and farmers will not totally be in loss.

The main reason behind the adaptation of different crop mixes was rainfall variability. They had responded that they frequently change their crop mix to cope with the rainfall variability, although the new crop mixes (66.3 per cent of sample households) do not fully mitigate the problem. If rains are delayed, then farmers of the area sow crops, especially sorghum in the dry land and wait until rain comes. At the same time, they construct terraces and collect rain water to supplement their crop when there is early cessation in the rainfall during the cropping season. Households of the area plough their land in a horizontal counter line way, and they build horizontally lined and parallel blocks from stone and mud to reduce water runoff. Thus, the land would remain moisturized for long periods and the plants use the water efficiently.

Households' ability to take advantage of climate change mitigation and adaptation technologies is also linked to their education level, cultural practices, skills acquired and access to financial assets (Greg *et al.*, 2011). There are different constraints that hinder farmers to apply different adaptation mechanisms to reduce the negative effect of climate variability. Some of the constraints were cropland area shortage, low income, poor agricultural practices, low awareness, limited source of income, absence of off-farm and non-farm activities. The study area had no access to non-farm and off-farm employment, which may be sourced either from missing markets or entry barriers. Moreover, many of the household heads and their spouses lack a visionary outlook to identify the possible off-farm opportunities that may be managed with low education level. Being poor and not having buffered stock of money was another bottleneck for the absence of diversified sources of income and easy adaptation to the problem of climate variability (Table VII).

Households adopted different methods of reducing the negative effect of climate variability on their crop production. Adoption behavior and their capacity were hampered by different socioeconomic and natural factors. Deressa *et al.* (2008) indicated that there is a negative correlation between age and adoption of improved soil conservation practices. The same logic holds true here in this research. Households that receive better crop income and possessed relatively larger cropland areas would have better probability of adopting different mechanisms to reduce the effect of climate variability. Because the adaptation of new techniques may have risks, it may need a reserve to insure from the occurrence of risks

Table VII. Determinants of households' adoption behavior

Variables	Coefficient	SE	*t*-value
Dependency ratio	−0.1463	0.1608	−0.91
Education	0.0052	0.0588	0.09
TLU	−0.0820	0.0333	−2.46**
Total cropland	0.6730	0.2761	2.44**
agehhh^2	−0.0023	0.0014	−1.66*
Food security	0.4111	0.3286	1.25
Crop income	0.0012	0.0006	1.97*
Constant	1.2675	0.5475	2.32

Sources: Model result, 2015; ** and * indicates 5 and 10% levels of significance, respectively connected to adoption. Cropland had a significant and positive relationship with farmers' adaptation behavior. Possessing relatively larger livestock reduced households' adoption behavior because of lower reliance on crop production that is more sensitive to climate variability (Table VIII).

Driving forces for the farmers to adopt one strategy in land-use choice are differences between the available crops for cultivation and the soil, climate and observable and unobservable characteristics of the farm (Leopoldo and Soto, 2005). Adaptation measures that farmers report may be profit-driven, rather than climate variability. Despite this missing link, Maddison (2006) and Nhemachena and Hassan (2008) assume that adaptation actions are driven by climatic factors, wherein Deressa *et al.* (2008) did the same. In the same logic, this study identified that smallholders adopt few strategies like water harvesting, using hybrid and drought-resistant crops, sowing short-seasoned crops and sowing on the dry soil to reduce the effect of climate variability. Ground water harvest technologies are well adopted as a means of managing moisture stress. Smallholders of the area collect rain water during the rainy season to supplement crops if rain ceased earlier.

Most scholars assumed that any change in the profitability of land will be immediately capitalized into land value. This implies that farmers can adapt to any changes in climate immediately and effortlessly. The belief is that farmers are keenly aware of changes in climate and they immediately select crops that are adaptable to the new climate conditions. This assumption effectively considers all constraints on the way farmers make their land-use decisions. Estimates produced under this model should be considered as a lower bound to the actual cost from climate variability, at least in the short run; there may be constraints that prevent the farmer from responding to climate variability with promptness.

This study considered five alternative levels such as no adaptation (0-level), using water harvesting techniques (1-level), adopting hybrid input crops (short-seasoned and drought-resistant) (2-level), applying afforestation programs (3-level) and dry sowing of the crop (4-level). The 0-level served as a base to simplify comparison among others. Because there was consideration of one alternative as the base, the model result represented for the rest four alternatives. Based on the value of χ^2, the model was strong enough and the covariates' explanatory power was very strong, which indicated that the variation in the dependent variable was strongly explained by the variations of independent variables included in the model.

Table IX showed that household's probability of adopting water harvesting technology increases on average with cropland area and vice versa, which means the probability of adopting water harvest technology increases when farmers have a larger landholding. Possession of large livestock would divert attention of households toward their livestock rather than the crop sub-sector and result in lower probability of adopting water harvesting technologies. Likewise, farming experience also decreased households' probability of adopting this technology in the study area. Household's tropical livestock unit (TLU) level

Variables	dy/dx	SE	*Z*	Average value X
Dependency	−0.0218	0.0238	−0.91	1.8719
TLU	−0.0122	0.0049	−2.52***	6.2313
Total cropland	0.1000	0.0398	2.51***	1.3413
Agehh^2	−0.0004	0.0002	−1.66	1615.76
Crop income	0.0002	0.0001	2.08**	2263.77

Sources: Model result, 2015; *** and ** indicates 1 and 5% levels of significance, respectively

Table VIII. Marginal effect of variables on adoption behavior of household

Strategies	Variables	Coefficient	SE	Z
1. Water harvest	Dependency ratio	−0.0106	0.2182	−0.05
	Education	−0.0616	0.0766	−0.80
	TLU	−0.0849	0.0427	−1.99**
	Cropland	1.7214	0.4225	4.07***
	Farming experience	−0.0536	0.0223	−2.41**
	Crop income	0.0005	0.0009	0.61
	Water shortage	0.5490	1.0079	0.54
	Constant	−0.0301	1.3075	−0.02
2. Hybrid seeds	Dependency ratio	−0.1010	0.2020	−0.50
	Education	−0.2015	0.0732	−2.75***
	TLU	−0.0678	0.0327	−2.07**
	Cropland	1.6032	0.4052	3.96***
	Farming experience	−0.0746	0.0206	−3.62***
	Crop income	0.0010	0.0010	0.82
	Water shortage	2.0783	0.8929	2.33**
	Constant	0.0656	1.1589	0.06
3. Afforestation	Dependency ratio	0.1774	0.3549	0.50
	Education	−0.2303	0.1720	−1.34
	TLU	−0.1076	0.1027	−1.05
	Cropland	1.6541	0.6343	2.61***
	Farming experience	−0.0116	0.0364	−0.32
	Crop income	0.0002	0.0013	0.12
	Water shortage	−11.461	499.165	−0.02
	Constant	9.196	499.167	0.02
4. Dry sowing	Dependency ratio	0.2044	0.3384	0.60
	Education	−0.2006	0.1379	−1.45
	TLU	−0.1673	0.0814	−2.06**
	Cropland	2.0926	0.5041	4.15***
	Farming experience	−0.0543	0.0327	−1.66*
	Crop income	0.0011	0.0010	1.14
	Water shortage	2.8747	1.0483	2.74***
	Constant	−4.7352	1.7552	−2.70***

Sources: Model result, 2015; ***, ** and * indicate 1, 5 and 10% statistically significance levels, respectively

Table IX.
MNL Model result (0 = No adaptation is base outcome)

also had a negative effect on probability of adopting hybrid seeds of sorghum and maize. Because hybrid crops are part of new technologies, experienced households with the crop production may hesitate to adopt them even though the inputs are better in their productivity as compared to the local breeds. Besides being less experienced, older household heads may have buffer stocks to cope with the risk that may source from adopting new technologies.

Previous year's rainfall shortage and expectation of the current problem initiated households to adopt hybrid seeds of the two cereals to reduce the effect of the problem. In the same fashion, households may sow seeds on the dry soil and wait until the rain comes if rains are delayed. They have practiced this method especially for sorghum, as the seeds are small and are not easily exposed to insects in the soil. Households that had relatively larger TLU would not adopt hybrid sorghum and maize, which may be because of the lower biomass of those crops to collect better livestock feed. It is well known that hybrid crops can withstand moisture stress and short seasoned crops have a lower biomass, which will result in having lower aftermath as a source of feed for the livestock. Because of lower crop residue supplied from hybrid sorghum and maize, households could not adopt those crops, especially if they have larger livestock.

If a household has a relatively larger cropland area, the probability of adopting hybrid sorghum and maize as means of mitigating the negative effect of rainfall shortage, which was considered as one dimension of climate variability, would increase. Possessing a large cropland also increased households' adaptation of this method to reduce production losses triggered by delayed rainfall. Having a larger cropland area also motivated farmers to use afforestation programs that could be a long-lasting means of mitigating the effect of climate variability. Possession of a large cropland may be one precondition to apply the method by mainly those households that have enough experience in rainfall forecasting.

4. Conclusions and recommendations

This paper addressed how agricultural production and farmers' incomes are affected by on-going climate variability, and the adaptation strategies practiced by smallholder farmers in three drought-prone districts of West Hararghe, Oromia National Regional State of Ethiopia. Most sampled farmers perceived and understood the effect of climate variability, which is a critical bottleneck for crop production of the area. Rainfall inconsistencies are common problems of the study area, creating a serious threat to smallholder households. The problem is becoming extreme dangerous unless protective measures like water harvesting and other long-lasting measures are taken by different stakeholders.

Most of the sample households had better understanding about the ongoing climate variability and they were trying to adopt different mechanisms for mitigating the likelihood effect of the problem on crop production. They had indigenous knowledge of water harvesting technologies, which are important technological advancements to make farmers more efficient in using scarce and the critical agricultural input, water. Thus, there should be rigorous efforts to enhance the local skill of smallholders and to make those strategies more efficient.

Adaptation of off-farm and non-farm activities is one method of reducing the effect of climate variability through having a diversified source of income. Continuous training and awareness session should be conducted for smallholders of the area to increase their participation in alternative sources of income.

Because smallholders in the study area had a relatively large livestock, each adaptation method should take into account the sub-sector that is highly dependent on the crop production as a source of food. For instance, hybrid sorghum and maize that are currently adopted by households have better moisture stress resistance with a lower biomass, which would result in having lower aftermath as a source of the livestock thereby smallholders were reluctant to adopt those crops especially if they have larger livestock units. Thus, more attention should be given to livestock feed when new hybrid crops are introduced in the study area to be easily accepted by farmers, as livestock feed shortage is the most appreciable problem equivalent to households' food shortage.

5. Limitations of the study

This study was based on primary data collected from three districts considering sample smallholder households, which has the limitation of considering some parameters of climate variability like long run rainfall and temperature. In addition, the study has the limitation of generalizability, as it was conducted in few districts that could not represent the national-level smallholder households.

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