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Vulnerability of Smallholder Farmers to Climate Change in the Central Rift Valley of Ethiopia: A Gender Disaggregated Approach

Yitayal Abebe[1] and Adam Bekele[1]
[1]*EIAR, Melkasa Research Center, P.O. Box: 436, Adama, Ethiopia annum*

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Abstract

In Ethiopia agriculture is the dominant sector and a large majority of the population make their living out of it. It is dominated by smallholder production under rain-fed system.Climate change is projected to be a major threat for the sector resulting in variability in smallholder farmers' productivity and income. The impact of climate change is expected to vary greatly among regions, sectors and social groups and communities. It is also expected to vary between gender groups. Therefore, this study will try to address gender differentiated vulnerabilities to climate change in the Central Rift Valley of Ethiopia where moisture stress is relevant. Field data was collected from 290 randomly selected farm households in the representative districts of Adama and Adamitulu-Jidokombolcha. We adopted Vulnerability as expected poverty (VEP)approach was where an individual's vulnerability is the prospect of a smallholder household considering poor and non-poor scenarios. Results of the analysis indicated that men and women headed households vary interms of their vulnerability to climate change infavor of the latter. It was also found out that the two gender categories vary in terms of the different socio-economic characteristics to face the threat of climate change. Therefore, emphasis is required to reduce vulnerability through gender disaggregated interventions and policy makers need ensure that development policies include gender oriented adaptation options to create resilience to the impacts of climate change.

Introduction

Agriculture is the mainstay of the Ethiopian economy. Yet the sector is dominated by small-scale rain-fed mixed crop-and-livestock production with very low productivity. The rain-fed nature of agriculture underlines the importance of the amount and temporal distribution of rainfall and its significant influence on crop yields and food supply and famine in the country (Cheung *et al.*, 2008).

Smallholder farm households in Sub-Saharan Africa experience many shocks that results to a wide variability in their agricultural production. This often causes them to be vulnerable to food insecurity and poor livelihood.The major risk factor for the vast majority of farmers practicing dry-land farming is the unreliability of the rainfall and the high frequency of drought. Ethiopia one of the most vulnerable to climate change with least capacity to respond to vulnerability in Africa (Stige *et al.*, 2006) i.e. it is highly sensitive to modest changes in climate and the ability to adapt is severely constrained (McCarthy *et al.*, 2001).

The expected impact of climate change varies greatly among regions, sectors and social groups and communities due to the fact that resources are distributed unevenly. It is also recognized that even within regions impacts, adaptive capacity and vulnerability will vary (IPCC 2001).This variation is also expected to exist between men and women headed smallholder households. Women headed smallholder farm households in sub-Saharan Africa are found to be the poorest and more food insecure (Byela, *et al*., 2015). As a result, they are expected to be highly vulnerable with changes in climatic conditions. Considering the vulnerability to climate change between the different social groups is essential to tackle the differential effect of climate change (Bohle *et al.,* 1994). Studies in the past have covered region and country level vulnerabilities to climate change (Deressa 2009; Dercon *et al*., 2005) and the differences in reference to men and women has not been studied and well documented to generate appropriate policy action.

Therefore, this study will try to fill these gaps by analyzing vulnerability of smallholder farm households due to climate change considering the gender of the household head.

Methodology

The study area

The study was conducted in the Central Rift Valley (CRV) area of Ethiopia. The altitude of the region ranges from 1600 masl in the central lowlands to about 3000 masl in the highlands. It covers a total area of about 10,274km^2, with population of about2 million people (Getnet, 2014). The region receives an average annual rainfall of about 855 mm and the average minimum and maximum temperature are 14.6 % and 30.1% respectively. The dominant livelihood strategy for the majority of the population in the CRV is mixed crop and livestock farming. Cereals and pulses(wheat, barley, maize, beans and teff) are the dominant crops in the study areas. Fruits, vegetables and sugar cane are also important cash crops in these areas. The CRV has been facing climate extremes of flood and drought, land degradation and population pressure. Therefore, the potential impacts of climate change and vulnerability are expected to be high.

Data and sampling

The study mainly used primary data that were collected from sample farm households in the CRV during 2013/2014 season. A multistage sampling technique was applied to select sample households for this study. In the first stage, two districts, namely Adama and ATJK were selected from the CRV. Then, 3 kebeles were selected from each district randomly. Finally, a sample of 290 farm households were included in the survey using random sampling and probability proportional to size technique. As a result, 142 of sample farm households were female headed and the remaining 148 were male headed.

A pretested structured questionnaire was used to collect primary data at household level. The questionnaire contained information on a variety of topics including on household demographic characteristics, resource endowments, production, income, agricultural services etc.

Analytical framework (vulnerability framework)

Vulnerability can be defined in different ways from different perspective. According to IPCC (2001) vulnerability to climate change is defined as "the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained (McCarthy *et al.,* 2001).

Vulnerability also varies within the region due to difference in adaptive capacity Vulnerability is influenced by a variety of social factors such as provision of services and access to alternative livelihoods. Hence poorer communities and groups will have difficulty adapting to climate change (Eriksen *et al*., 2008; Handmer *et al*. 1999; Bohle *et al*. 1994). They have less capacity to recover after such events due to lack of assets to engage in alternative economic activities or help arrest decline in the availability of resources. Hence assessing smallholder farmers' vulnerability to climate change has significant value in the design and implementation of social and economic policies (Handmer *et al.*, 1999).

There are three principal approaches that have been widely used to assess vulnerability levels of different social groups', namely, vulnerability as expected poverty (VEP), vulnerability as expected utility (VEU) and vulnerability as uninsured exposure to risk (VER) (Hoddinott and Quisumbing 2003). While VEP and VUP measure the ex-ante probability of a household's loss of welfare attributed to shocks against a minimum level, VER measures ex post welfare loss due to shocks.

Following Christiaensen and Subbarao (2004), we adopted vulnerability as expected poverty(VEP) approach where a household's vulnerability is the probability of that household becoming poor in the future if currently not poor, or the prospect of continuing to be poor if currently poor. Vulnerability as expected poverty is often operationalized by analyzing a monetary welfare indicator of poverty, such as income or consumption by setting a poverty line and aggregating the poverty data. Accordingly, in this study vulnerability is defined as expected poverty as a result of climate shock, while income is used as a proxy for poverty. Therefore, vulnerability can be defined in terms of the probability that a climate shock will move household income below a given minimum level i.e. income poverty line (Chaudhuri *et al*. 2002).

This study focuses on income poverty as proxy parameter to analyze vulnerability to climate change. The current scenario can be measured directly from household mean income, and the future is estimated based on the current status projected to the future conditional on some characteristics.

This study utilizes cross-section data in estimating the mean income and probability of household vulnerability or being income poor and restrictions in terms of relevant farm and non-farm internal and external factors. We adopted the methodology followed by Chaudhuri (2000) i.e. income per capita data and the official poverty line for measuring and analyzing vulnerability.

Therefore, the vulnerability level V of household $i$at time $t$denoted by V_{it} can be defined in terms of probability as $V_{it} = \Pr(I_{i,t+1} \leq Z)$, where Pr=probability, $I_{i,}$ is household's expected per capita income level, $_{t+1}$=time, Z=poverty line for the household.

Estimation of the next period (t+1) requires that we build and run a model of the determinants of income such that

$$lnY_i = X_i\beta + \varepsilon_i \qquad (1)$$

where, Y_i is the per capita income of household i, **X** denotes, farmer related and external factors that are assumed to influence per capita income (see Table 1), $\beta$is parameter to be estimated and $\varepsilon_i$is the disturbance term, where, E[ε_i/X]=0 and var[ε_i/X_i] = $\sigma^2_{\varepsilon,i} = X_i\theta$

Thus, a household's per capita income is regressed on household characteristics and shocks in order to obtain the estimated coefficients to be used for estimating the current state and for further prediction of the household's future poverty. A Households with high predicted poverty is considered vulnerable.

A three-stage feasible generalized least squares (FGLS) was followed (Amemiya, 1977) to correct for non-spherical errors and estimate the influence of the hypothesized covariates on per capita income and the variance as proxy indicators of vulnerability.

The first step entails estimation of residuals from equation 1 using OLS (Ordinary Least Squares) procedure.

The second step involves;
estimation of the square of the residuals on the hypothesized covariates,

$$\hat{e}^2_{OLS,i} = X_i\theta + \eta_i \qquad (2),$$

And making predictions from the second step to transform the equation as

$$\frac{\hat{e}^2_{OLS,i}}{X_i\hat{\theta}_{LS}} = \frac{X_i\theta}{X_i\hat{\theta}_{LS}} + \frac{\eta_i}{X_i\hat{\theta}_{LS}} \qquad (3)$$

and estimating the transformed equation using OLS to obtain FGLS coefficients ($\hat{\theta}_{FGLS}$).

In the last step, since $X_i\hat{\theta}_{FGLS}$ is a consistent estimate of variance, $\sigma^2_{e,i}$, the estimates of the standard deviation $\hat{\sigma}_{e,i} = \sqrt{X_i\hat{\theta}_{FGLS}}$, is used to transform the original income equation (eq. 1) as

$$\frac{lnY_i}{\sqrt{X_i\hat{\theta}_{FGLS}}} = \left[\frac{X_i}{\sqrt{X_i\hat{\theta}_{FGLS}}}\right]\beta + \frac{e_i}{\sqrt{X_i\hat{\theta}_{FGLS}}} \quad (4)$$

and equation (4) is estimated by OLS to obtain $\hat{\beta}_{FGLS}$.

Thus using the estimates $\hat{\beta}$ and $\hat{\theta}$the expected log income (equation 5) and its variance (equation 6) are estimated as

$$E\left[ln\hat{Y}_i X_i\right] = X_i\hat{\beta}_{FGLS} \quad (5)$$

$$\text{and, } V\left[ln\hat{Y}_i|X_i\right] = \sigma^2_{e,i} = X_i\hat{\theta}_{FGLS} \quad (6)$$

Assuming that income per capita is log normally distributed, the probability level of the household's vulnerability can be estimated using the following relationship:

$$\hat{v}_i = \Pr\left(ln\hat{Y}_i < lnZ_i\,|X_i\right) = \Phi\left[\frac{lnZ_i - X_i\hat{\beta}_{FGLS}}{\sqrt{X_i\hat{\theta}_{FGLS}}}\right] \quad (7)$$

Where, $\hat{v}_i$=pr=probability level of individual household i under consideration, Φ =cumulative distribution function

The choice of the vulnerability threshold involves generating a sample that is classified into two groups, that is those that are vulnerable and those that are not vulnerable to food insecurity. It entails establishing a vulnerability threshold, such that a household is said to be vulnerable if its vulnerability probability is greater or equal to V. According to Chaudhuri *et al*. (2002) the choice of vulnerability threshold is quite arbitrary and the mean vulnerability level is considered as one of the cut-off points for vulnerability measurement. Thus, anyone whose vulnerability level lies above this threshold faces a risk of poverty that is greater than the average risk in the population and hence can legitimately be included among the vulnerable and not otherwise.

Results and Discussion

Socioeconomic profile respondents

Table 1, depicts that 48% of the households belong to Adama district (51.1% of the sample are women) and the remaining to ATJK district (48.6% of the sample are women). On average the respondents are about 40 years old with low level of education (2 years of schooling) and large family size (average of 5.58 members per household).

A household has 1.44 hectares of land and 3.42livestock (tropical livestock unit/TLU). About 89% of the respondents reported to have access to agricultural extension program while the rest (11%) did not. Eighty-one per cent of the total households apply fertilizers to their fields and the remaining 19% (which make 44% of those who perceived high input price) do not apply fertilizer. On average the farmers travel long distances (50 minutes) to reach the main market coupled with poor roads and the traditional means of transport, rendered them hard time getting there. With regard to external shocks about 65% reported that they perceived an extended dry-spell and 26% flood during the cropping seasons. About 21% of the respondents are below the food poverty line of 2200kcal.Among the farmers, 28% practice land renting-in and 53% participate in off-farm activities and48% use farm credit to enhance their livelihood. Also, they are involved on average in 1 (1.35) social organizations.

Table 1. Socioeconomic profile respondent's (N=281)

Variable	Mean	S. D.	Min	Max
Sex of household head (Male=1, Female=0)	0.50	0.50	0	1
Age of household head in years	39.76	12.85	18	80
Level of education of household head in years	2.25	2.99	0	10
Family size of the household	5.58	2.41	1	13
Own land size in hectare	1.44	0.91	0	4.25
Tropical livestock unit	3.42	3.51	0	17.5
Malnutrition status (Yes=1, No=0)	0.21	0.56	0	1.67
Expectation of inputs price (High=1, low=0)	0.44	0.50	0	1
Distance to main market in minutes of walking	50.18	24.53	10	90
Use of fertilizer (Yes=1, No=0)	0.81	0.39	0	1
Indicator of land renting (Yes=1, No=0)	0.28	0.45	0	1
Participation in social groups	1.35	0.78	0	4
Off-farm activity (Yes=1, No=0)	0.53	0.50	0	1
Credit availability (Yes=1, No=0)	0.48	0.50	0	1
Access to extension services (Yes=1, No=0)	0.89	0.31	0	1
Occurrence of flood (High=1, Low=o)	0.26	0.44	0	1
Dry-spell occurrence (High=1, Low=o)	0.65	0.48	0	1
Location (Adama=1, ATJK=0)	0.48	0.50	0	1

Source: Survey data

Climate change awareness, information sources and adaptation

About 98% of the respondents were aware that climate is changing. About half were aware relatively long time ago whereas the remaining half became aware only recently. More than 38% of the respondents believe the cause of climate change is human activity while 22.3% attribute it to natural occurrence.

Farmers have several information sources about climate change. However, the major sources of information for 86.6% of farmers was found to be their own observation of trends in climate variables. The informal media and communities around them such as village meetings, and personal relationships account for 46.2% and 13.1 % respectively. The formal media, radio and Bureau of Agriculture (BoA) extension provide information to 29.7% and 29. 3% of the households which may imply the need for improving the role of formal sources in creating awareness and to enable farmers to cope better to the shocks

Perceived occurrence of climate extremes in the last 10 years in CRV

Assessment of farmers' perception on the occurrence of climate shocks in the last 10 years indicated that most (over 69%) of the farmers' experienced seasonal drought, variability of onset of rainfall (68.6%), early cessation of rainfall (68.3%) and long dry spells(66%). Also, flood and high temperature were important to about 30% of the farmers.

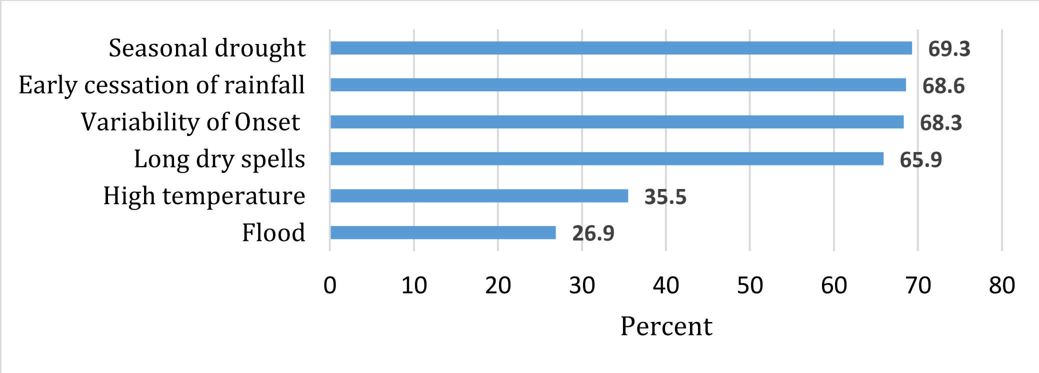

Fig 1. Perceived occurrence of climate change

The shocks have been encountered differently in Adama and Adamitulu-Jidokombolcha (ATJK) districts (Table 2). Seasonal drought, variability of onset of rainfall, and flood have been perceived by Adama district households more often than by households in ATJK district significantly at 1%. The two districts were similar in terms of their exposure to the other climate extremes.

Table 2. Number of times extreme climate condition occurred in the past 10 years

Climate extremes	All Sample (n=290)		ATJK district (n=150)		Adama district(n=140)		t
	Mean	STD	Mean	SD	Mean	SD	
Seasonal drought	1.61	1.36	1.37	1.36	1.87	1.31	3.18***
Long dry spells	1.69	1.53	1.57	1.47	1.81	1.58	1.31
Onset Variability	1.87	1.65	1.54	1.49	2.23	1.75	3.62***
Early cessation of rainfall	1.75	1.48	1.63	1.39	1.89	1.56	1.5
Flood	0.71	1.56	0.17	0.94	1.29	1.86	6.54***
High temperature	1.21	1.78	1.22	1.84	1.2	1.72	-0.1

Source: Own survey, 2014.
*Note: ***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively*

Coping strategies used to deal with major climate extremes

Analysis of the coping strategies used to deal with the major climate extremes showed farmers use different strategies for different shocks (Table 3.). While planting of early maturing varieties was the main mechanism of coping for long dry spell (54.5%), variability of onset of rainfall (51%) and early cessation of rainfall (36.9%) selling of livestock (28.9%)was found to be the more preferred strategy in the case of seasonal drought.

Table 3. Adopted climate extremes coping strategies (percent of farmers)

Coping strategies	Seasonal drought (n=201)	Long dry spells (n=191)	Variability of Onset (n=198)	Early cessation of rainfall (n=198)	Flood (n=78)	High temperature (n=187)
Early maturing verities	24.9	54.5	51.0	36.9	6.4	10.7
Off-farm work	22.4	0.5	2.5	9.6	6.4	13.6
selling of livestock	28.9	16.8	9.6	10.1	5.1	2.9
Migration	2.5	12.6	10.6	0.5	10.3	9.7
None	17.4	1.6	4.0	35.9	37.2	6.8
praying to God	0.5	14.1	22.2	6.1	12.8	56.3
Food aid	2.0			1.0	12.8	
Replanting	1.5				9.0	

Farmers also used other mechanisms such as Aid, replanting, migration to other places, praying to God and off-farm work to a relatively smaller degree to cope with different shocks. However, farmers also reported not taking action to the shocks particularly in the case of early cessation of rainfall (35.9%), flood (37.2%), and drought (17.4%), which may be due to lack of awareness or availability and affordability of coping mechanisms.

Vulnerability analysis based on expected poverty

Table 4 presents the results of the FGLS analysis. Data and hypothesized variables were subjected to appropriate diagnostic tests were made. However, no serious problem was found in the process. Both models (income and variance) are significant at 1%. Results of the analysis revealed that family size, malnutrition and occurrence of flood affect log household income negatively and significantly, while education level, ownership of land and livestock, renting of land, off-farm activity and the district the household resides contribute to it positively and significantly.

Table 4. Model estimates of income vulnerability of smallholder farmers

VARIABLE	*Income*		
	Coef.	Std. Err.	*t*
Sex	0.0207	0.0314	0.660
Age	0.0010	0.0012	0.870
Education	0.0116	0.0056	2.090
Family Size	-0.0434	0.0067	-6.510***
Land (ha)	0.0855	0.0191	4.470***
Livestock (TLU)	0.0216	0.0044	4.890***
Market distance	0.0017	0.0006	3.110***
Input price	0.0328	0.0297	1.100
Extension	0.0218	0.0452	0.480
Fertilizer use	0.0545	0.0359	1.520
Land rent-in	0.1492	0.0347	4.300***
Participation	-0.0234	0.0183	-1.280
Malnutrition	-0.1286	0.0270	-4.770***
Off-farm activity	0.0823	0.0284	2.900***
Credit	-0.0396	0.0299	-1.320
Flood	-0.0626	0.0355	-1.760*
Dry spell	-0.0341	0.0304	-1.120
District	0.1205	0.0339	3.550***
_Cons	0.3409	0.0865	3.940***
Number Of Obs		281	
F (18,262)		15.59	
Prob > F		0.000	
R-Squared		0.5171	
Adj R-Squared		0.484	
Root Mse		0.2127	

*, **, and *** indicate significance at 10%, 5%, and 1% level respectively

Vulnerability of households to poverty

Following the results of the FGLS procedures we estimated the probability of a household falling below a given level of income poverty line, and performed sensitivity analysis under five different minimum levels of income poverty lines.

Results of the analysis of vulnerability index estimate based on the FGLS revealed that the overall mean vulnerability was 0.33. Using the US$ 1.25 threshold (World Bank, 2008); female headed households (0.36) were significantly (P<1%) more vulnerable than their male (0.30) counterparts (Table 5.). The higher level of vulnerability of female heads could be due to fact that these heads mainly live alone due to loss of their husbands to death or divorce resulting in reduced (less)access to resources and additional burden in caring for the household (Byela *et al*., 2015; Chhinh and Poch, 2012). Also farmers in ATJK district were more vulnerable compared to those in Adama district. This may be due to the less access to other (off-farm) income generating employment opportunities available to farmers in ATJK than to farmers at Adama that benefit from the relatively cosmopolitan town and other agro-industrial activities.

Table 5. Vulnerability level of smallholder farmers at mean

Attributes		N	Mean	Std. Err.	Std. Dev.	t
Sex	Female	140	0.36	0.01	0.09	5.25***
	Male	141	0.30	0.01	0.10	
	Combined	281	0.33	0.01	0.10	
District	ATJK	146	0.36	0.01	0.10	7.50***
	Adama	135	0.29	0.01	0.09	
	Combined	281	0.33	0.01	0.10	

*** indicate significance at 1 level

Source: Survey data

Sensitivity of vulnerability changing poverty lines

Figure 2 revealed that household vulnerability to climate change and poverty are positively related. It is obvious that as poverty line increases more and more households will become vulnerable to climate change and poverty. Accordingly, the proportion of vulnerable households increased from 7.1% at 1.25 USD to 87.5% at 2.25 USD a day income. However, as the poverty line increases male and female headed households' vulnerability is at par, i.e. at higher level (2.25 USD) of poverty line. The mean vulnerability line shows a sharp rise between 1.5 USD and 2 USD showing sensitivity of households to a small change in the poverty line. However, the trend of male headed households in the same interval seems relatively stable compared to their counterparts.

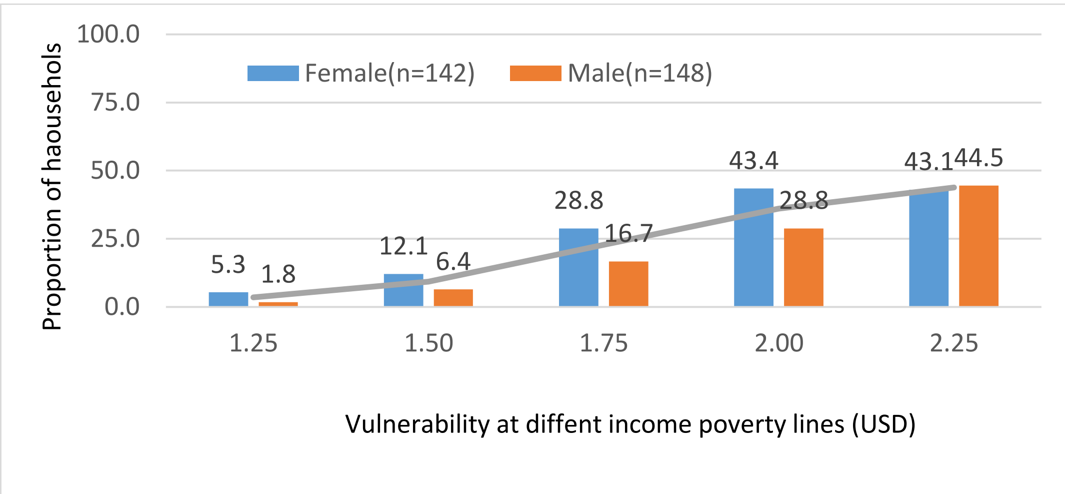

Fig 2. Gender vulnerability to climate change

A separate analysis of gender vulnerability by district indicates that households at ATJK district were more vulnerable than those at Adama at all levels of poverty line and for both female and male headed households (Fig 3). This might be due to the negative productivity impact of the relatively lower amount of precipitation and its higher level variability in ATJK district than in Adama. The overall comparison showed that male farmers at Adama faced relatively lower vulnerability.

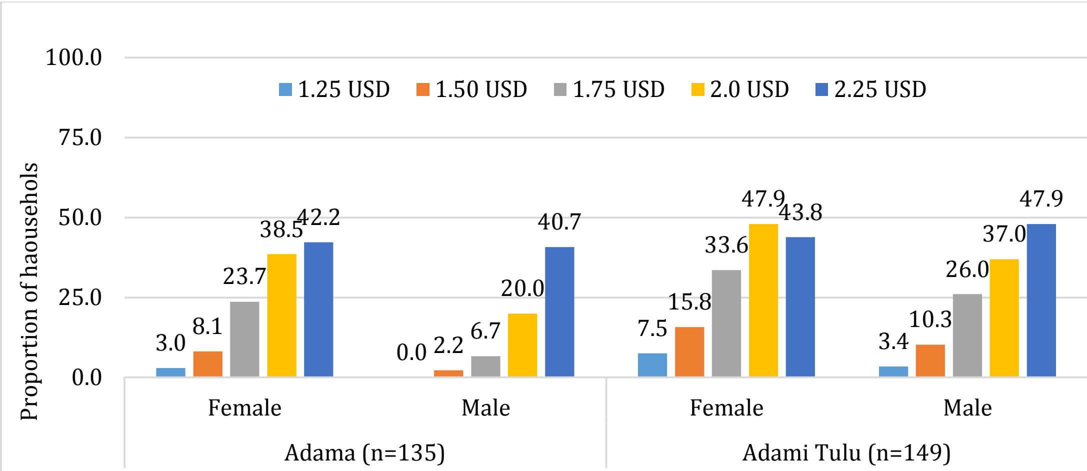

Fig 3. Gender vulnerability by district at varying poverty lines (USD)

In general, the study showed that farmers' vulnerability to poverty and hence climate change is highly sensitive to their minimum per day income requirement (poverty line), the gender of the household head and the agro-ecological settings. This implies that when the minimum daily requirement is higher, most smallholder farming households will be vulnerable to poverty, whereas vulnerability is lower when the minimum requirement is lower. This could be due to the lack of capacity to generate income beyond the threshold level in the face of adverse or threatening climate change scenario. Another implication is that the female headed households were more vulnerable than their male counterparts. Furthermore, farmers living in drier areas were relatively more vulnerable to extreme climate events than farmers living in relatively moist and relatively higher employment opportunity areas. The result implies that gender disaggregated approach of interventions is critical to reduce smallholder farmers' vulnerability to climate change under changing poverty lines.

Summary and Conclusion

Ethiopia's economy is particularly vulnerable to climate change due to its dependence on rain-fed agricultural sector. This vulnerability has been demonstrated by the devastating effects of the various prolonged and frequent droughts.

This study was conducted in the Central Rift Valley of Ethiopia to assess vulnerability to poverty and association it to climate change vulnerability. Climate change was conceptualized as one of the major external risks smallholders' face that contributes to household poverty and vulnerability because it affects the welfare of the household. Furthermore, vulnerability to climate change was conceptualized to vary according to the gender of the household head. Therefore, the major objective of the study was to assess the vulnerability of smallholder farm households to climate change. Descriptive statistics and vulnerability to poverty approaches were used to address this objective.

Results of descriptive analysis showed that the smallholder farmers in the study area were aware of climate change mainly from their own observation about the trends in climate variables through, village meetings, and personal relationships. Information from mass media such as radio and BoA extension services are very limited. This may imply the need for active involvement of mass media in creation of awareness and the extent of the impacts of climate change so that farmers may be able to taking different adaptation options. The major climate extremes experienced in the study area include seasonal drought, variability of onset of rainfall, early sensation of rainfall and long dry spells in order of importance. Planting of early maturing varieties of crops, selling of livestock and off-farm employment were used as adaptation options by some farmers. This indicates the need for concerted effort to inform and avail different climate change adaptation options to reduce the impact of climate change.

Results of the vulnerability assessment model revealed that female headed households were more vulnerable to climate change than their male headed counterparts. The result implies that a gender focused adaptation options and intervention are critical to address the impacts of climate change under changing income poverty lines.

Furthermore, household's vulnerability to poverty and hence climate change increases with the increase in their minimum daily income requirement. Therefore, besides adaptation options there are a crucial need to increase and diversify smallholder farm households' income. Moreover, the status of male and female groups is fragile in terms of poverty line changes and rampart policy support is required to help farmers generate more income.

The study also showed that farmers living in drier areas were relatively more vulnerable to extreme climate events than farmers living in relatively moist areas. This implies adaptation option must also take in to account agro-ecological differences to reduce vulnerability of smallholder farmers.

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