

Adaptation to Spatial Climatic Variability and the Implications for Productivity and Risk Management in the Nile Basin, Ethiopia

By
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Abstract:

Ethiopia is one of the most vulnerable countries to harsh climatic conditions (ILRI, 2006). Ethiopia suffers from extreme climates, mostly manifested in the form of frequent droughts. A recent mapping on vulnerability and poverty in Africa (ILRI, 2006) puts Ethiopia as one of the countries most vulnerable to climate change and with least coping ability. A recent climate prediction model shows dramatic variation in the future rainfall patterns (UNEP, 2007). Designing appropriate and cost-effective adaptation strategies for future climate changes is imperative for countries like Ethiopia to minimize severe adverse effects of future climate change. This paper presents an empirical analysis of the determinants of adaptation strategies to climate change and their implications on farm productivity and farmers' spatial risk exposure. The analysis relies on primary data on 740 farms producing *teff* in the Nile Basin, Ethiopia. The Thin Plate Spline method of spatial interpolation was used to impute the household specific rainfall values using latitude, longitude, and elevation information of each household (see Wahba, 1990 for details). The rainfall data is disaggregated at season level (*mehere* and *belg*). The econometric analysis is conducted in three steps. In the first step, a farm level yield function is estimated. Then, the error term from the first stage is used to measure risk

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exposure in terms of crop variability and crop failure. The role of adaptation is included in the model via a binary variable that capture the adoption of yield-related adaptation strategies. A Heckman selection procedure is used to control for the observable factors that affect adoption so as to isolate the productivity gain. Spatial specific fixed effects are also inserted.

We found that changes in rainfall patterns in both seasons increase the probability of adoption of yield-related adaptation strategies. And this adoption, in turn, is positively correlated with productivity. Extension services (both external and farmer to farmer) and access to credit affect adaptation positively and significantly. Farm households with larger access to social capital are more likely to adopt yield-related adaptation strategies. This adoption seems also very important for risk management at the farm level. We found, indeed, that adopting adaptation strategies reduces crop variability and the risk of crop failure.

1. General Introduction

Global climate change is no longer a hypothesis, and we need to better understand its impact on ecosystems, and society (IPCC, 2001). Africa is particularly vulnerable to climate variability as its economies are largely based on weather-sensitive agricultural production systems (Stige et al, 2006). This vulnerability has been demonstrated by the devastating effects of the various prolonged droughts in the 20th century and recent flooding. To develop effective adaptation strategies to cope with climatic variability and change, we need detailed knowledge about how different crop and livestock types respond to climatic variation in different regions of Africa (Stige et al, 2006).

A recent mapping on vulnerability and poverty in Africa (ILRI, 2006) puts Ethiopia as one of the countries most vulnerable to climate change and with least capacity to respond. Ethiopia already suffers from extremes of climate, manifested in the form of frequent drought (1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, and 2002) and recent flooding (1997, and 2006). Agriculture is the source of livelihood to an overwhelming majority of the Ethiopian population and is the basis of the national economy. It employs more than 80% of the labor force, and accounts for 45% of the GDP, and 85% of the export revenue (MoFED, 2007). Ethiopian agriculture is heavily dependent on natural rainfall, with irrigation agriculture accounting for less than 1% of the total cultivated land in the country. Thus, the amount and temporal distribution of rainfall and other climatic factors during the growing season is an important influence of crop yields and can induce food shortages and famine. Yet, studies on the impact of climatic change (particularly rainfall and temperature) on crop yield are very scanty. Most of the studies are conducted either at macro level (DFID, 2007) or focusing on the physical processes and geographical distributions (Bewket and Conway, 2007) with very little significance in terms of designing effective adaptation strategies. Micro-level economic studies on impacts of climate change are almost non-existent^d. Even the existing few studies on impact of climate variability suffers severe methodological deficiencies. One of the major analytical deficiencies is omitted variable bias. Unless one controls possible adaptations strategies in farming, changes in farm profit/risk exposure can't be fully attributed to changes in climatic factors. Farmers are likely to respond to changing climatic factors by

^d The only exception is that of Temesgen (2006) where he employed the "Ricardian" approach where the cost of climate variability is imputed from capitalized land value. This study wrongly applied the "Ricardian" approach to a country where land markets are missing and hence difficult to impute cost of climate variability from capitalized land value. (For detailed critics of this paper, see Yesuf (2007).

varying, among other things, the crop mix, planting and harvesting dates, proper application of soil and water conservation measures to mitigate the potential harmful effects of climate change. Thus controlling these adaptation strategies is vital to indicate the pure effect of climatic change on farm profit. Second, the existing few studies have only estimated the impact of climate variability on average yield (first moment) or perhaps yield variability (second moment). However, understanding the impact of climate variability on average yield and/or yield variability alone also doesn't say much in terms of policy design since the variability could go in either directions (up or down). Adding one more dimension into the analysis (third moment or skeweness) would produce important result for climate change policy analysis since it helps us to estimate the impact of climate variability on the probability of crop failure or the magnitude of down side risk. Furthermore, adding a measure of yield-related adaptation variable and analyzing its impact on three moments of yield will have paramount importance in terms of designing effective adaptation strategies.

This study tries to partly fill these gaps in the literature. Using the current state-of-art of econometrics techniques and moment based approach, both determinants of yield-related adaptation strategies, and their impacts on first, second, and third moments of *teff* yield are estimated.

The study is conducted based on plot level data collected on 1000 households located within the Nile Basin of Ethiopia. The analysis relies on primary data on 720 farms producing *teff* in the Nile Basin, Ethiopia. The Thin Plate Spline method of spatial interpolation was used to impute the household specific rainfall values using latitude,

longitude, and elevation information of each household (see Wahba, 1990 for details).

The rainfall data is disaggregated at season level (*mehere* and *belg*).

Estimation of the three moments of yield are conducted in three stages. In the first step, a farm level production function is estimated. Then, the error term from the first stage is used to measure risk exposure in terms of crop variability and crop failure. The role of adaptation is included in the model via a binary variable that capture the adoption of adaptation strategies. A Heckman selection procedure is used to control for the observable factors that affect adoption so as to isolate the productivity gain. Spatial specific fixed effects are also inserted.

We found that changes in rainfall patterns in both seasons increase the probability of adoption of adaptation strategies. And this adoption, in turn, is positively correlated with productivity. Extension services (both external and farmer to farmer) and access to credit affect adaptation positively and significantly. Farm households with larger access to social capital are more likely to adopt yield-related adaptation strategies. This adoption seems also very important for risk management at the farm level. We found, indeed, that adopting yield-related adaptation strategies reduces crop variability and the risk of crop failure. A set of simulations is conducted to show robustness of these results under different weather scenarios.

2. The study site, and survey procedures and instruments

The study was conducted based on rural household survey conducted on 1000 households located within the Nile Basin of Ethiopia. The sampling frame considered traditional typology of agro-ecological zones in the country (namely, *Dega*, *Woina Dega*, *Kolla*,

Bereha), percent of cultivated land, degree of irrigation activity, average annual rainfall, rainfall variability, and vulnerability (number of food aid dependent population). The sampling frame selected the *weredas* in such a way that each class in the sample matched to the proportions for each class in the entire Nile basin. The procedure resulted in the inclusion of 162 *gots/villages*. Random sampling was then used in selecting 50 households from each got. The distribution of sampled *weredas/gots* is listed in Fig. 1 and Table A1 in the appendix.

In order to ensure quality of data, experienced supervisors were centrally recruited and trained on the survey instrument. We formed clusters of 2 to 4 *weredas* based on their proximity and assigned 2 supervisors, who worked together, to each cluster. The supervisors with the support of the research team recruited and trained the 7 enumerators for each cluster of *weredas* to conduct the interview. On the average a questionnaire needed a day and half to complete.

In the survey, a number of instruments were designed to collect information on (i) household characteristics; (ii) household assets, basic services, diseases and shocks; (iii) land tenure issues, (iv) detailed information on production inputs and outputs of annual and perennial crops measured at plot-level and at different stages of production; (v) water usage for irrigators; (vi) livestock production; (vii) access to extension, markets and credits; (viii) expenditure on food and income; (ix) perception questions on climate change and adaptations, and (x) social capital.

Like in many parts of Ethiopia, the farming system in our survey sites is still very much traditional with plough and yolk (animals draught power), and labor as the major means of production during land preparation, planting and post harvest processing. Rain-fed agricultural is a common practice for many farm households with only few (0.6 %) are using irrigation water to grow their crops. Thus, only rain-fed production was considered in this study.

Production input and output data was collected for two cropping seasons, i.e. *Meher* (long rainy season), and *Belg* (the short rainy season). However, quite few plots gets bi-annual cropping pattern (grow both during *Meher* and *Belg* season). Thus we estimated a production function only for *Meher* cropping season.

Detailed cost of production data (labor, tools and machinery, animal power, seeds, fertilizers, chemicals, irrigation, farm buildings, pumps, petrol and electricity consumption) was collected at different production stages (i.e. land preparation, planting, weeding, harvesting and post harvest processing). Labor inputs were disaggregated as adult male, adult female, and children. This approach of collecting data (both inputs and outputs) at different stages of production and at different levels of dissaggregation, we believe, reduces cognitive burden on the side of the respondents, and increases the likelihood of retrieving a better retrospective data.

In our production function, the three forms of labor were aggregated as one labor input using adult equivalents. Furthermore, responses on non-labor and seed inputs are very few and as a result only labor and seed inputs were considered in our production function.

Finally, although a total of 48 annual were grown in the basin, the first five major annual crops (*teff*, maize, wheat, barely and beans) cover 65% of the plots. Our estimation of production function is limited to only one of these crops, i.e *teff*, a major staple food in many parts of Ethiopia. The average yield in the study sites is about 11 quintals for *teff*.

Selected descriptive statistics on some of the survey instruments are attached in tables A2-A6 in the appendix.

3. Climate change and adaptations in the sample sites

One of the survey instruments in the survey was designed to capture farmers' perception and understanding on climate change, and their approaches on adaptations. Questions were included whether they have noticed changes in mean temperature and rainfall over the last 20 years, and reasons for observed changes. About 54% and 75% of the farmers indeed observed changes in temperature and precipitation over the last 20 years. In order to check the robustness of their responses, the same questions were asked but in terms of whether the number of hot days, and rainy days has increased over the last days. The responses to these questions are consistent with the earlier question on their perception of changes in mean temperature and rainfall.

About 79% of the farmers attributed these observed changes in climate change to changes in vegetation cover. The results of the perception questions on temperature and rainfall are stated in tables A7-A13 in the appendix.

In response to long term shift in temperature, about 45% of the farm households took different adaptation measures to mitigate the impacts on their yield whereas 55% of the farm households took no adaptation measures for various reasons (depending on adaptation measure taken) including lack of information, shortages of labor and money. Similarly, in response to long term shift in rainfall, 58% of the farm households took a number of adaptation measures whereas 42% took no adaptation measures for various reasons (depending on adaptation measure taken) including lack of information, shortages of labor and money. Adaptation to long-term shift in temperature includes change of crop variety, implementation of soil and water conservation measures. And adaptation to long-term shift in rainfall include implementation of soil and conservation, water harvesting, changing crop variety and early and late planting (see tables A14-A15 for details).

4. Estimation strategy

The econometric analysis approach is conducted in three steps. In the first step, a farm level yields function is estimated. Then, the error term from the first stage is used to measure risk exposure in terms of crop variability and crop failure. The role of adaptation is included in the model via a binary variable that capture the adoption of adaptation strategies. A Heckman selection procedure is used in the first step to control for the observable factors that affect adoption so as to isolate the productivity gain. Spatial specific fixed effects are also inserted.

Let the role of spatial production uncertainty \mathbf{v} as represented by the stochastic production function $y = g(\mathbf{x}, \mathbf{v})$. This indicates a need to assess the probability distribution

of $g(\mathbf{x}, \mathbf{v})$. Following Antle (1983), we explore the moment-based approach to this assessment.

Consider the following econometric specification for $g(\mathbf{x}, \mathbf{v})$:

$$g(\mathbf{x}, \mathbf{v}) = f_1(\mathbf{x}, \beta_1) + [f_2(\mathbf{x}, \beta_2) - (f_3(\mathbf{x}, \beta_3)/k)^{2/3}]^{1/2} e_2(\mathbf{v}) + [f_3(\mathbf{x}, \beta_3)/k]^{1/3} e_3(\mathbf{v}), \quad (1)$$

where $f_2(\mathbf{x}, \beta_2) > 0$, and the random variables $e_2(\mathbf{v})$ and $e_3(\mathbf{v})$ are independently distributed and satisfy $E[e_2(\mathbf{v})] = E[e_3(\mathbf{v})] = 0$, $E[e_2(\mathbf{v})^2] = E[e_3(\mathbf{v})^2] = 1$, $E[e_2(\mathbf{v})^3] = 0$, and $E[e_3(\mathbf{v})^3] = k > 0$. This means that the random variables $e_2(\mathbf{v})$ and $e_3(\mathbf{v})$ are normalised (i.e., they are each distributed with mean zero and variance 1). In addition, $e_2(\mathbf{v})$ has zero skewness ($E[e_2(\mathbf{v})^3] = 0$) while the random variable $e_3(\mathbf{v})$ is asymmetrically distributed and has positive skewness ($E[e_3(\mathbf{v})^3] = k > 0$). It follows from (4) that

$$E[g(\mathbf{x}, \mathbf{v})] = f_1(\mathbf{x}, \beta_1), \quad (1a)$$

$$E[(g(\mathbf{x}, \mathbf{v}) - f_1(\mathbf{x}, \beta_1))^2] = f_2(\mathbf{x}, \beta_2), \quad (1b)$$

and

$$E[(g(\mathbf{x}, \mathbf{v}) - f_1(\mathbf{x}, \beta_1))^3] = f_3(\mathbf{x}, \beta_3). \quad (1c)$$

Equation (1) provides a convenient representation of the first three central moments of the distribution of $g(\mathbf{x}, \mathbf{v})$.^e Indeed, from (1a), the first moment (the mean) is given by $f_1(\mathbf{x}, \beta_1)$.^f From (1b), the second central moment (the variance) is given by $f_2(\mathbf{x}, \beta_2) > 0$,

^e Recently, the stochastic production function approach has been criticised by Chambers and Quiggin (2000) who suggested the adoption of the “state- contingent” approach to model production uncertainty.

^f This means that $f_1(\mathbf{x}, \mathbf{v})$ represents an ‘average’ production function. It may differ from a ‘frontier’ production function if we allow for technical inefficiency. As discussed by Battese *et al.* (1997), Kumbhakar (2002) and O'Donnell and Griffiths (2006), accounting for technical inefficiency can be done by decomposing the disturbance term into two additive components: one symmetrically distributed (accounting for measurement errors), and one exhibiting negative skewness (accounting for technical inefficiency). However, such specifications neither distinguish between downside risk exposure and technical inefficiency, nor allow for positive skewness. Our empirical

and from (1c), the third central moment (measuring skewness) is given by $f_3(\mathbf{x}, \beta_3)$. This provides a flexible representation of the impacts of inputs \mathbf{x} on the distribution of output under production uncertainty. In addition, if we treat the distribution of $e_2(\mathbf{v})$ and $e_3(\mathbf{v})$ as given, then the three moments $f_1(\mathbf{x}, \beta_1)$, $f_2(\mathbf{x}, \beta_2)$ and $f_3(\mathbf{x}, \beta_3)$ are sufficient statistics for the distribution of $g(\mathbf{x}, \mathbf{v})$ in the specification (4). In general, expected output $f_1(\mathbf{x}, \beta_1)$ in (1a) will exhibit positive and decreasing marginal productivity with respect to inputs \mathbf{x} : $\partial f_1 / \partial \mathbf{x} > 0$ and $\partial^2 f_1 / \partial \mathbf{x}^2$ being a negative definite matrix. However, the effects of inputs \mathbf{x} (i.e. adaptation strategies) on the variance and skewness of output is largely an empirical issue. For example, from (1b), the i -th input can be variance increasing, variance neutral, or variance decreasing as $\partial f_2 / \partial x_i > 0, = 0, \text{ or } < 0$, respectively. Similarly, from (1c), the i -th input can be skewness increasing, skewness neutral, or skewness decreasing as $\partial f_3 / \partial x_i > 0, = 0, \text{ or } < 0$, respectively. Of special interest here are the effects of adaptation strategies on the variance as well as skewness of production.

5. Data and variable generation

In estimating our stochastic production function, *teff* yield (after harvest) per hectare is used as our dependent variable. The independent variables include average temperature for *mehere* season and rainfall for four seasons, labor usage per hectare, seed application per hectare, a dummy variable to capture whether households have used any adaptation measures in response to long term shift in average temperature and/or rainfall. Applications of other inputs including manure, fertilizer and improved seeds are quite few and hence are not included in our production function estimation.

results show situations where skewness is positive, indicating that the error decomposition proposed in previous literature to account for technical inefficiency would not be suitable for our analysis. Addressing this issue appears to be a good topic for future research.

The rainfall and temperature data was collected from all the metrological stations in a district (wereda) and average value was assigned for each wereda. Then we used the Thin Plate Spline method of spatial interpolation was used to impute the household specific rainfall and temperature values using latitude, longitude, and elevation information of each household (see Wahba, 1990 for details). The rainfall data is disaggregated at season level (*Meher* and *Belg*). The temperature data is collected only for *meher* (June-December) season. Information on own and hired labor was collected for three major categories of labor (adult male, adult female, and children), at each stage of production. A standard adult equivalent conversion factor was used to aggregate the three forms of labor into one category of labor. The results of our stochastic production function estimate on average yield and variability is discussed in the next section.

6. Results

Table 1 reports the estimates of the Heckman procedure. Results show that spatial rainfall pattern can affect yield in non liner way. Indeed the quadratic effect of the rainfall in Belg is negative and statistically significant. Almost all the conventional inputs exhibit signs consistent with theory. The exception is fertilizer whose quadratic term is positive but not statistically significant. The estimated *lambda* and *rho* are positive, thus indicating the there is a positive contribution of adaptation strategies on yields and that the selection procedure seems appropriate. The null hypothesis of independence between the selection equation and the yield equation can be rejected at 1% level of statistical significance. Table two reports the risk implication of the adoption of the adaptation strategies. Results show that adaptation strategies can play a significant role in the management of risk. The

estimated coefficient is negative in the variance equation and positive in the skewness equation. Adopters, therefore, are exposed to less yields variability and hedge against the risk of crop failure. The role of spatial rainfall patterns depends crucially on the season. More rainfall in *meher* can increase yields variability and the risk of crop failure. Rainfall in the *belg* season, instead can reduce the yield variability and the risk of crop failure.

7. Concluding remarks

In this study the impact of climate variability and adaptations to climate change on mean yield and risk has been quantitatively estimated using a flexible stochastic production function specification. The results highlight season specific differences in climate impacts on yield levels and variability. The role of adaptation is included in the model via a binary variable that capture the adoption of adaptation strategies. Rainfall patterns in both seasons increase the probability of adoption of yield-related adaptation strategies. And this adoption, in turn, is positively correlated with productivity. Extension services (both external and farmer to farmer) and access to credit affect adaptation positively and significantly. Farm households with larger access to social capital are more likely to adopt adaptation strategies. This adoption seems also very important for risk management at the farm level. We found, indeed, that adopting adaptation strategies reduces crop variability and the risk of crop failure. These results could also be considered when future crop insurance programs are being considered and yield related-adaptations strategies are envisaged.

References

- Antle, J. (1983). Testing the Stochastic Structure of Production: A Flexible-Moment Based Approach. *Journal of Business and Economic Statistics*. 1: 192-201.
- Antle, J.M. 1987. Econometric estimation of producers' risk attitudes. *American Journal of Agricultural Economics*, 69: 509-522.
- Bewket B., and D. Conway. 2007. A note on the temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia. *International Journal of Climatology*
- Buccola, S.T., and B.A. McCarl. 1986. Small sample evaluation of the mean-variance production function estimators. *American Journal of Agricultural Economics*, 68: 732-738.
- Chen, C-C, B.A. McCarl, and D.E. Schimmelpfenning. 2004. Yield variability as influenced by climate: A statistical investigation. US-Department of Agriculture, *mimeo*.
- G. Wahba. 1990. Spline models for observational data. Philadelphia: Society for Industrial and Applied Mathematics
- DFID. 2007. Reducing Vulnerability in Ethiopia: Addressing the implication of climate change. Unpublished report.
- ILRI. 2006. Mapping climate vulnerability and poverty in Africa.
- IPCC. 2001. Climate change: The scientific basis. <http://www.ipcc.ch/>
- MoFED. 2006. Survey of the Ethiopian Economy. Addis Ababa, Ethiopia.
- Saha A., C.R. Havenner, H. Talpaz. 1997. Stochastic production function estimation: small sample properties of ML versus FGLS. *Applied Economics*, 29: 459-469.
- Stige, L.C., J. Stave, K.Chan, L. Ciannelli, N. Pattorelli, M. Glantz, H. Herren, N. Stenseth. 2006. The effect of climate variation on agro-pastoral production in Africa. *PNAS*, 103: 3049-3053.
- Temesgen T., 2006. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. CEEPA discussion paper no. 25

Fig. 1 Map of Woredas selected for sample in Nile Basin of Ethiopia (see Table 1 for Woreda names)

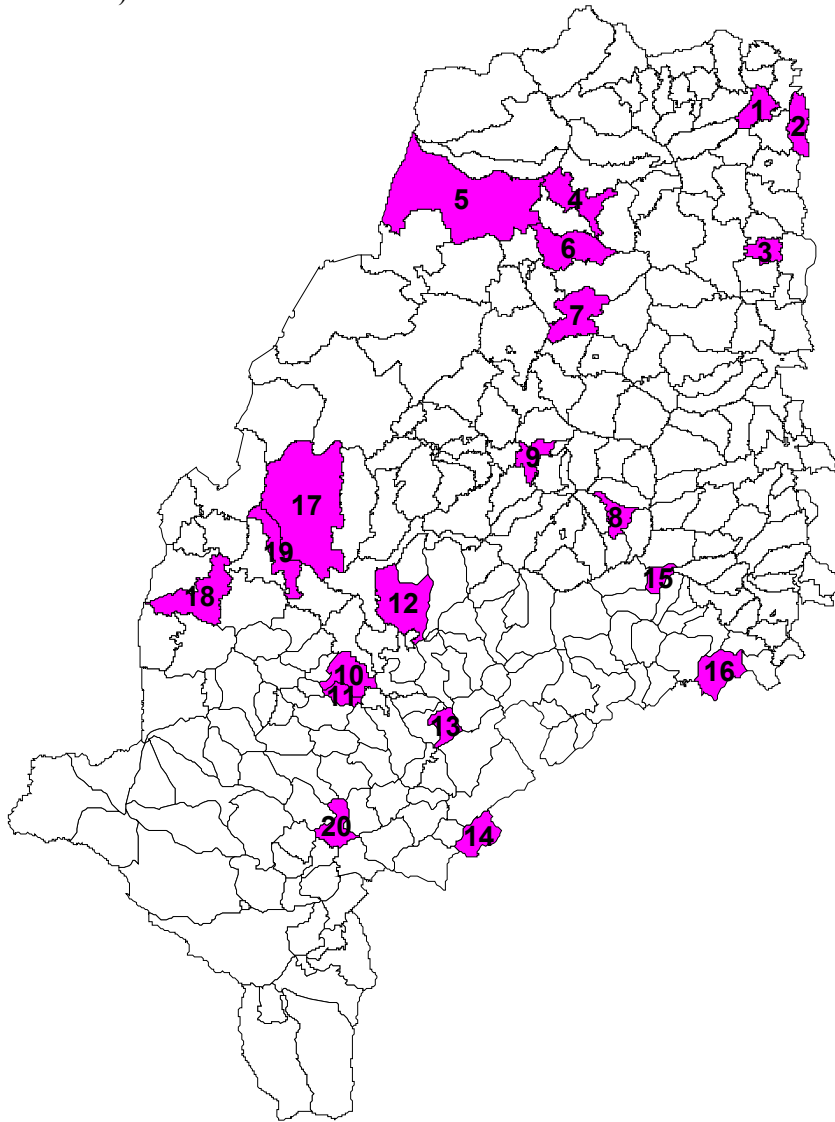


Table 1 Heckman procedure results

Variables	Coefficients	Std Err	Variables	Coefficients	Standard Err
Yields			Adaptation		
Soil fertility	34.3004	27.56	Soil fertility	0.1519**	0.068866
meher	1.53**	0.740193	Access to credit	0.224***	0.083175
Meher^2	-0.00069	0.001108	Farmer to farmer extension	-0.02461	0.09639
belg	1.461***	0.588589	Extension services	-0.68***	0.10263
Belg^2	-0.00077***	0.000255	Household size	0.041***	0.016647
Seeds	1.26709***	0.447291	Literacy	0.1374*	0.077891
Seeds^2	-0.00255	0.001691	Age	0.002699	0.003066
Fertilizer	0.463**	0.215242	Relatives	0.010998***	0.003025
Fertilizer^2	0.00014	0.000726	Meher	0.00233***	0.000357
Labor	2.697***	0.33596	Belg	0.006605***	0.001253
Labor^2	-0.0039***	0.000674	belg2	-2.93E-06***	5.37E-07
Constant	-1100.3***	361.383	Constant	-3.91356***	0.785158

Lambda 430.33 (s.e.= 27.55). Rho=.88 (s.e. = 0.0353); N=740; Robust standard errors have been used..

Significance levels are denoted by one asterisk (*)

at the 10 per cent level, two asterisks (**) at the 5 per cent level, three asterisks (***) at the 1 percent level.

LR test (rho = 0): chi2(1) =39.74; Prob > chi2 = 0.0000

Table 2 role of adaptation on the variance and the skewness of yields

Variables	Coefficients	Standard Errors	Coefficients	Standard Errors
Variance function			Crop Failure	
adaption	-1.38E+07**	6986542	3010.649*	1623.906
Seeds	-32658.68**	15653.99	8.548291***	3.521951
Fertilizer	92264.3***	28438.88	-21.53903***	6.698737
Labour	-34094.47**	14859.58	8.80835***	3.476427
Belg	-14438.04***	4723.265	3.344623***	1.109154
meher	32744.1***	12266.75	-7.603324***	2.872466
Constant	1.23E+07***	4797056	-2793.892***	1122.492

N= 740; Robust standard errors have been used.. Significance levels are denoted by one asterisk (*)

at the 10 per cent level, two asterisks (**) at the 5 per cent level, three asterisks (***) at the 1 percent level.

Table A1: Distribution of sampled villages

Ref. No	Region	Zone	Woreda	Kebele	Number of villages
	Tigray	EastTigray	Hawzein	Selam	7
			Atsbi Wonberta	Felege Woinie	9
		South Tigray	Endamehoni	Mehan	3
	Amhara	North Gondar	Debark	Mekara	19
			Chilga	Teber Serako	10
			Wogera	Sak Debir	9
		South Gondar	Libo Kemkem	Angot	9
		East Gojam	Bichena	Aratband Bichena	11
		West Gojam	Quarit	Gebez	9
	Oromiya	West Wellega	Gimbi	Were Sayo	9
			Haru	Genti Abo	12
			Bereh Aleltu	Welgewo	5
			Hidabu Abote	Sira marase	10
		East Wellega	Limu	Areb Gebeya	11
			Nunu Kumba	Bachu	12
		Jimma	Kersa	Merewa	6
	Benishangul Gumuz	Metekel	Wonbera	Addis Alem	1
		Asosa	Bambasi	Sonka	1
		Kamashi	Sirba Abay	Koncho	1
	SNNP	Zone 1	Gesha Daka	Kicho	8
	Total				162

Table A2.1: Basic household and farm characteristics

	Minimum	Maximum	Mean	Std. Deviation
Gender of household head	0	1	0.90	0.30
Age of household head	14	92	45.09	13.84
Dependents less than 15 years old	0	11	2.83	1.73
Dependents older than 65 years old	0	2	0.13	0.37
Adult males (15-65 years old) in household	0	7	1.67	1.09
Adult females (15-65 years old) in household	0	6	1.53	0.87
Total adults (15-65 years old) in	0	13	3.20	1.52

household				
Literate household heads	0	1	0.47	0.50
Household Size	1	15	6.17	2.23
Labour used (person day)	0.0	337	29.84	26.24
Quantity of purchased seed used (kgs/plot)	0.0	180	5.08	14.87
Quantity of own seed used(kgs/plot)	0.0	500	25.03	31.44
Area of land	0.05	10.50	2.04	1.22

Table A2.2: soil fertility

Crop planted	Level of soil fertility					
	Highly Fertile		Moderately Fertile		Infertile	
	Plot Count	Percent	Plot Count	Percent	Plot Count	Percent
Barely	159	19.7	275	17.1	97	21.1
Teff	177	21.9	470	29.2	127	27.7
Maize	155	19.2	345	21.4	73	15.9
Wheat	216	26.8	296	18.4	91	19.8
Bean	100	12.4	224	13.9	71	15.5

Table A3: Occurrence of shocks

Type of shock encountered	Frequency	Percent
Drought	380	31.00
Hailstorm	225	18.35
Flood	142	11.58
Animal disease	112	9.14
Pests of crops before harvest	84	6.85
Illness of family member	71	5.79
Death of family member	57	4.65
Large increase in input prices	43	3.51
Fire outbreak	22	1.79
Theft of livestock	17	1.39
Other shocks	73	5.95
Total	1226	100

Table A4: Effects of reported main shocks

Effect/Result	Reported Shock							
	Drought		Hailstorm		Flood		Animal disease	
	Freq	%	Freq	%	Freq	%	Freq	%

Decline in crop yield	158	44	97	45.1	57	41.9	3	2.7
Food insecurity/shortage	51	14.2	29	13.5	23	16.9	2	1.8
Decline in consumption	46	12.8	25	11.6	9	6.6	3	2.7
Loss of assets	42	11.7	20	9.3	22	16.2	18	16.4
Loss of income	31	8.6	34	15.8	19	14	12	10.9
Death of livestock	30	8.4	9	4.2	5	3.7	72	65.5
Outcasted by neighbours	1	0.3	1	0.5				
Other					1	0.7		
Total	359	100	215	100	136	100	110	100

Table A5: Source of water

	Frequency	Percent
Rain-fed	5739	95.08
River	109	1.81
Swampy water body	49	0.81
Public surface canals from public dam	35	0.58
Spring	15	0.25
River Storage & public surface canals	15	0.25
Public river storage + private pumping	14	0.23
Public well + public pumping + public canals	12	0.20
Private well + private pumping	12	0.20
Public well+public pumping	9	0.15
Water harvesting	9	0.15
Public well + private pumping/transport	1	0.02
Total	6019	99.72
Missing	17	0.28
Total	6036	100.00

Table A6: Major annual crops and area coverage

Crop type	Number of plots	Area (in ha)
Teff	779 (17.6%)	375.50
Maize	574 (13%)	202.85
Wheat	605 (13.7%)	195.94
Barely	537 (12.1%)	159.94
Beans	397 (9%)	134.39
Others	1536 (34.7%)	1478.57
Total	4428	2547.19

Table A7: Farmers noticed changes in mean temperature over the last 20 years

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	163	16.3	53.6	53.6
No	141	14.1	46.4	100.0
Total	304	30.5	100.0	

Table A8: Response on the number of hot days stayed the same/Increased/Declined over the last 20 years

	Frequency	Percent	Valid Percent	Cumulative Percent
Stayed the same	144	14.4	28.5	28.5
Increased	342	34.3	67.7	96.2
Declined	19	1.9	3.8	100.0

Table A9: response on noticed changes in mean rainfall over the last 20 years

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	169	17.0	75.4	75.4
No	55	5.5	24.6	100.0
Total	224	22.5	100.0	

Table A10: response on the number of rainy days stayed the same/Increased/Declined over the last 20 years

	Frequency	Percent	Valid Percent	Cumulative Percent
Stayed the same	118	11.8	20.5	20.5
Increased	104	10.4	18.0	38.5
Declined	355	35.6	61.5	100.0

Table A11: Responses on observation of any changes in the no. of malaria cases over the last 20 yrs

	Frequency	Percent	Valid Percent	Cumulative Percent
No change	214	21.5	39.9	39.9
Increased	275	27.6	51.3	91.2
Decreased	47	4.7	8.8	100.0

Table A12: Reported reason for the change in rainfall

	Frequency	Percent	Valid Percent	Cumulative Percent
Declined due to poor vegetation cover	248	24.9	79.0	79.0
Declined due to unknown reason	46	4.6	14.6	93.6
Increased due to afforestation	19	1.9	6.1	99.7
DK	1	.1	.3	100.0

Table A13: Reported reason for the change in temperature

	Frequency	Percent	Valid Percent	Cumulative Percent
Temperature increase due to deforestation	266	26.7	87.2	87.2
Temperature increase due to unknown reason	36	3.6	11.8	99.0
Temperature decrease due to afforestation	2	.2	.7	99.7
DK	1	.1	.3	100.0

Table A14: adjustments made to long-term shifts in temperature

	Frequency	Percent	Valid Percent	Cumulative Percent
Nothing	552	55.4	56.8	56.8
Implement soil conservation schemes	28	2.8	2.9	59.7
Changed crop variety	194	19.5	20.0	79.6
Put trees for shading	87	8.7	9.0	88.6
Water harvesting	3	.3	.3	88.9
Afforestation	42	4.2	4.3	93.2
Sought off-farm activities	9	.9	.9	94.1
Late planting	4	.4	.4	94.5
Early planting	19	1.9	2.0	96.5
Migrated to urban area	2	.2	.2	96.7
Used irrigation	14	1.4	1.4	98.1
Sold livestock	14	1.4	1.4	99.6

Changed farming type (from crop to livestock)	2	.2	.2	99.8
Adopted new technologies	2	.2	.2	100.0

Table A15: adjustments made to long-term shifts in rainfall

	Frequency	Percent	Valid Percent	Cumulative Percent
Nothing	412	41.3	42.0	42.0
Implement soil conservation schemes	305	30.6	31.1	73.2
Changed crop variety	109	10.9	11.1	84.3
Planted trees	28	2.8	2.9	87.1
Water harvesting	34	3.4	3.5	90.6
Late planting	4	.4	.4	91.0
Early planting	40	4.0	4.1	95.1
Used irrigation	23	2.3	2.3	97.4
Migrated to urban area	3	.3	.3	97.8
Found off-farm activities	8	.8	.8	98.6
Changed farming type (from crop to livestock)	3	.3	.3	98.9
Reduced number of livestock	1	.1	.1	99.0
Adopted new technologies	4	.4	.4	99.4
Water conservation	6	.6	.6	100.0