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Impact of Climate Variability on Cool Weather Crop Yield in Ethiopia

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Abstract

The research examined effect of climate variability on yield of the two dominant cool weather cereals (wheat and barley) in central highland and Arssi grain plough farming systems of Ethiopia using eight round unbalanced panel data (1994-2014). The stochastic frontier model result revealed that production inputs for producing wheat and barley in the two farming system had significant effect. Crop season rainfall increment had negative and significant effect on technical efficiency of smallholders to produce wheat as to the model result. Technical efficiency of two crops responded differently for cropping season rainfall variability, in which wheat had negative and significant interaction with it while barley had positive. Given this, cropping season temperature had significant and positive effect on technical efficiency of both wheat and barley. Having this into account, yield of the two crops responded similarly for changes in production inputs like working capital, human labor and fertilizer. In general, rainfall inconsistency at the different stages of the production period had strong effect on yield of the two crops. Given this, the study forwarded an assignment to plant scientists in order to have further investigation on how the two crops responded differently to temperature variability.

Keywords:
climate variability, crop yield, technical efficiency, smallholder, rainfall, temperature

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INTRODUCTION

By the end of the 21st century, climate change would have a substantial impact on agricultural production and aggravate poverty level (Slater et al., 2007). Intergovernmental Panel Climate Change (IPCC), 2007) argued that there have been widespread changes in extreme temperatures and longer droughts and frequency of heavy precipitation over most land areas. Climate change affects developed and developing nations differently. For example, the latter ones suffer from serious food shortage and starvation as of the problem while developed ones face relatively simple problems (FAO, 2008). Land productivity and crop yield have been expected to decline because of climate change more or less continuously in recent times, and have experienced sharp decline in some places (Asha et al., 2012).

Agriculture is the most sensitive sector for climate change and variability (Cruz et al., 2007). Climate variability is currently the dominant cause of short-term fluctuation in rain-fed agricultural production of developing regions. In semi-arid and sub-humid areas, rainfall deficiency reduces crop yields and productivity drastically. Households pursuing crop production as the only source of livelihood are more affected by climate variability (Corinne et al., 2004). The problem is severe in Sub Saharan African (SSA) region specifically in which crop production is the main source of generating food and income for households. A study done by Wolfram and David (2010) argued that yield of many cereal crops will decline by 10% in 2050 nearly in all SSA countries due to rainfall inconsistency. Fractional variation in one of the climate elements would have devastating impact on smallholder production system as well as overall futurity of agriculture in most of African nations. Since Ethiopian agriculture is purely rain-fed type each variation in either rainfall or temperature, or combination of them would have huge effect on crop yield. Variation in national yields due to climate variability is common in most of the rural areas of Ethiopia (Getnet & Mehrab, 2010).

Ethiopia is one of SSA nations that suffer most from climate change and variability. Agriculture contributes 40% to the GDP, 84% of labor force employment and more than 90% to the export of the country. Agriculture survey in 2010 showed that cereal crop production takes the lion's share (85.94%) in the overall grain crop production of the country followed by pulses (10.5%). In the same production year, wheat and barley respectively took 19.8% and 11.27% proportion from the overall cereal production. Nearly 66% of the cereals produced in Ethiopia were used for household consumption (Central Statistics Agency (CSA), 2010), which means variability in yield of those crops may have huge impact on livelihood.

Since agriculture is the crucial sector in employment and livelihoods of Ethiopia, loss of agricultural productivity due to climate change may affect the entire economy strongly. Cereal crop damage sourced from rainfall inconsistency showed increment from 2006 to 2008 production years. Pest infestation and crop diseases outbreak were also high in the previously specified time interval. Major causes of crop damage in Ethiopia as to the response of smallholder farmers were hailstone, too much rain, frost and flood all of which are related to climate variability. CSA (2010) reported that hailstone was the major cause of crop damage followed by too much rain. Rain-fed agriculture of the country encountered different problems sourced from the ongoing climate variability. Each change in one or more of the climate variability elements results in huge production loss and starvation in most parts of the country. Researchers conducted before have not examined crop level responses to climate variability elements by employing time series or panel type of data. Thus, this research identified the impact of climate variability on the cool weather cereal crops (wheat and barley) yield in Central Highlands and Arssi Grain Plough farming systems of Ethiopia.

MATERIALS AND METHODS

Description of the Data Source

ERHS was conducted in the seven dominant farming systems of the country except pastoralism. The survey considered 15 villages and covered different aspects like demographic, consumption, production, asset holding, purchases and sales, landholdings and livestock ownership. This study considered central highland and Arssi grain plough farming systems of Ethiopia in which five villages (out of six for ERHS) were samples due to focusing only on wheat and barley yield.

Sampling Unit and Design

Farming system was an important stratification base in selecting sample villages in ERHS (Dercon & Hoddinott, 2011). The survey collected data for seven rounds from 1994 to 2009 having unbalanced period gap. Each survey followed a similar format of sample units that were already determined in the first survey in 1994. This study directly accepted all sample households from the two sample farming systems, considered by the previous survey in 2009 from each village, to collect the eighth round data in 2014. To have representative sample households from the farming systems, the research considered the whole households (502) in the five villages (Table 1), which were considered by ERHS in 2009, to collect the eighth round data in 2014.

This farming system took 40% of the total population of the country based on CSA (1994) and 56.4% sampling share of ERHS in 1994 (Dercon & Hoddinott, 2011).

Type and Methods of Data Collection

Both primary and secondary data were considered in this study, in which the former one was from sampled villages listed in Table 1. The survey in 1994a[1] considered about 1,477 households and these households have been re-interviewed in 1994b[2] as well as in 1995, 1997, 1999, 2004 and 2009. The eighth round of data in 2014 could help understand the recent circumstances of sample smallholders from selected villages. The primary data collected in 2014 adopted the questionnaire (after having amendment as to the objective of this research) used by the previous agency in collecting the seventh round in 2009. Including the previous seven rounds (1994a-2009) and the recent one in 2014,

Table 1
Sample Distribution in Each Village

Name of village	Sample households in 2009	Current sample households	Percentage
Debre Berhan	168	168	33.47
Korordegaga	106	106	21.12
Yetmen	51	51	10.16
Sirbana	82	82	16.33
Turufe	95	95	18.92
Total	**502**	**502**	100

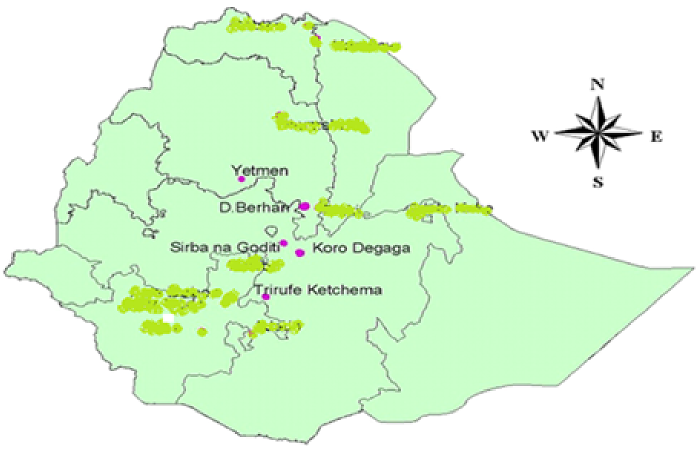

Figure 1. Geographical location of sample villages
Source: Community survey Ethiopian Rural Household Survey 1994

[1] There were two round data collection in 1994 and this study consider the first one as 1994a
[2] The second round data collected in 1994 is named as 1994b

the research had eight rounded unbalanced panel data for sample households of the five villages. In addition to the panel data collected by ERHS and this research, the study also used other secondary data collected by different national and international organizations.

Methods of Data Analysis

Crops have different optimal temperature and precipitation level for the well performance of them. Movement away from these levels may be damaging for crops, especially in countries where the current temperature and precipitation levels are already close to the tolerance limit. Production per unit of land yield was the dependent variable to analyze the impact of climate variability on agricultural productivity in Greek (Nastis et al., 2012). Gupta et al. (2012) adopted Cobb-Douglas production function for investigating impact of climatic variability on rice, sorghum and millet productivity utilizing panel data. Thus, this research considered wheat and barley yield in analyzing impact of climate variability and adopted Cobb-Douglas production system where the model assumes that agricultural production is a function of many variables like cultivated area, oxen power, fertilizers, labors, working capital, rainfall and temperature.

Functional form of the model is:

$$TP_{iht}=F\{AS_{iht},IFA_{iht},AL_{iht},WC_{iht},DP_{iht},R_{irt},T_{irt}\} \quad (1)$$

where:-i=1, 2,…., 5 (for the five cereals)

h=1, 2, ….,H (the sample household)

t=1, 2, ….,8 (the eight round sample years)

TP_{iht} = Total Production of sample cereal i for smallholder h at year t

AS_{iht} = crop-wise Area Sown by each smallholder h at year t

IFA_{iht} = Inorganic Fertilizer Application for each crop by smallholder h at year t

AL_{iht} = Agricultural Labor of each smallholder h for each crop at year t

DP_{iht} = Draught Power of each smallholder h for each crop at year t

WC_{iht} = the Working Capital budgeted by smallholder h for each crop at year t

R_{irt} = Cropping season rainfall level for each crop i from the nearest meteorological site r at time t

T_{irt} = Average cropping season temperature for crop i from the nearest meteorological site r at time t

Thus, total production (TP) should be divided by area sown (AS) of each sample cereal i to get yield, then the above equation (1) would become:

$$(TP/AS)_{iht}=Q_{iht}=F\{IFA_{iht},AL_{iht},WC_{iht},DP_{iht},R_{irt},T_{irt}\} \quad (2)$$

$(TP/AS)_{iht}=Q_{iht}$ is yield of crop i for each household h at year t. After computing yield of each cereal, then the above equation would take the following form:

$$Q_{iht}=F\{IFA_{iht}, AL_{iht},WC_{iht},DP_{iht},R_{irt},T_{irt}\} \quad (3)$$

Thus, equation 3 can be rewritten following Battese & Coelli, (1992):

$$lnQ_{iht} = ln(f(X_{it},\beta)\ exp(V_{it}-U_{it}) \quad (4)$$

And

$$U_{it}=\eta_{it}U_i=\{exp(-\eta[(t-T_i)]\}U_i \quad (5)$$

Q_{iht} represents yield of cereal i for the hth household at the tth period; $f(X_{it},\beta)$ is a suitable function of a vector, X_{it}, of factor inputs associated with production of ith cereal in the tth period, and a vector, β, of unknown parameters. The random effect, U_i is independent and identically distributed (iid) non-negative truncations with $N(0,\sigma_\mu^2)$, V_{it} is also iid $N(0,\sigma_V^2)$ random errors and independent of μ_i. η is an unknown scalar parameter that shows the type of yield variation. Household's technical efficiency (TE) tends to improve, remain constant if not decrease in producing cereals towards the base year, 2014 if $\eta > 0$, $\eta = 0$ or $\eta < 0$, respectively. The time period t = 1, 2……, Ti periods for which observations for the ith household are obtained.

From equation 4 and 5 TE of household h for producing the ith cereal at time t would be:

$$TE_{iht}= Q_{iht}/(Q_{iht}^*)= (f(X_{it},\beta)exp(V_{it}-U_{it}))/ (f(X_{it},\beta)\ exp(V_{it}))=exp(-U_{it}) \quad (6)$$

To deal with factors affecting smallholder's efficiencies in cereal production, different socio-economic and climate variability elements were considered on the regression using Generalized Least Squares (GLS). This model was employed because the TE scores of all the observations were between 0 and 1, but not 0 or 1, which allowed to have linear type of dependent variable. Since the dependent variable was based on panel data, the appropriate regression model was GLS that consider hetroscedasticity and panel-autocorrelation problems. The functional form of the efficiency equation could be:

$$TE_{iht} = \sum \alpha_i X_{ht} + \upsilon_i + \varepsilon_{it} \quad (7)$$

where: TE_{iht} = the TE scores of smallholder h for cereal i at time t

α_i = a vector of unknown parameters ought to be estimated

X_{ht} = a vector of explanatory variables i (i = 1, 2, ..., k) for household h

υ_i= an error term that is iid, N $(0, \sigma_\upsilon^2)$, and it is the time invariant part of error term

ε_{it} = the time variant error term that should be iid, N $(0, \sigma_\varepsilon^2)$ independently of υ_i

RESULTS AND DISCUSSION

Crop yield trend in the two farming systems

Cereal crops that are produced in different agro-ecology of the country contributed around 86% of the national grain production. Major grain crops of the country including *teff*[3], wheat and barley (categorized as primarily cool weather crops), maize, sorghum and millet are warm weather cereals (Dereje & Yilma, 2003).

Table 2 shows that overall average yield of each crop was better in Arssi grain plough as compared to central highland farming system. The test results also revealed that yield of wheat had a significant difference in the two farming systems (p<0.01), but there was no significant difference in yield of barley (p-value = 0.317) for the sample production years.

There was no wider gap in the overall yield of sampled crops, and ups and downs of them happened mostly on the same production year. For instance, in 1999, there was yield reduction for both crops and this overall reduction also happened in 2009 exactly after ten years for wheat. Rainfall inconsistency was the main reason for those drastic yield reductions as to the view of respondents.

Yield of the two crops showed drastic increment in central highland for production years of 2009 and 2014. After 1999, yield of the two crops showed better and successive improvement in central highlands than Arssi grain plough farming system. Table 3 reveals that there was a significant difference in yield of wheat and barley for most of the production years.

Average level difference of the two farming systems in yield of the two crops was low for some of the production years. Variability in production of the two crops revealed that wheat and barley respond similarly, though it is not statistically proved, for each production input variation.

Trend of crop season rainfall and temperature in the two farming systems

Meteorological data collected from the nearest sites of each sample village of the two farming systems revealed that starting from 1994 production year rainfall condition of some sites showed similar trend in the ups and downs, es-

Table 2
Average Crop Yield in the Two Farming Systems

Description	Crop type	Central highland	Arssi	p-value	Combined Average
Area in hectare	Barley	0.91	0.30	0.000	0.72
	Wheat	0.43	0.48	0.000	0.44
Production in kg	Barley	736.50	321.58	0.000	617.30
	Wheat	405.78	673.38	0.000	497.57
Yield in kg/ha	Barley	939.56	978.72	0.317	950.81
Yield in kg/ha	Wheat	1068.56	1262.20	0.000	1134.97

[3] *It is an Ethiopian indigenous crop produced only in the country*

Table 3
Crop Yield Trend of the Two Farming Systems

Year	Wheat (kg/ha)		p-value	Barley(kg/ha)		p-value
	Central highland	Arssi		Central highland	Arssi	
1994a	901.91	895.57	0.000	1187.20	1043.74	0.012
1995	803.40	970.39	0.000	1169.93	942.36	0.000
1997	1216.25	1555.67	0.018	995.06	1242.19	0.056
1999	1112.00	921.36	0.029	1028.69	1003.68	0.003
2004	1181.62	1104.09	0.000	987.76	869.02	0.314
2009	1236.58	1308.43	0.020	1373.19	1185.56	0.000
2014	2091.49	1460.48	0.000	2322.04	1178.98	0.000
Average	**1220.46**	**1173.71**		**1294.84**	**1066.50**	

Source: Data from Ethiopian Rural Household Survey (1994a-2009) and researcher in 2014

pecially in those that have geographic proximity. Rainfall trend of sites in Arssi grain plough farming system was lower as compared with others in central highlands.

Crop seasonal rainfall in central higland farming system was higher in all of the production years compared with the other farming system, and it showed greater inconsistency in some of the production years registering the highest amount in 2010 (see Figure 2). Rainfall gap between the two farming systems became wider in recent years, mostly after 2006. There was cyclical type of movement in rainfall of central highlands farming system having reduction after three to five years of interval. Though it was not clear enough like the central highlands', but rainfall trend of Arssi grain plough also had cyclical type of movement to some extent and exhibited extrem reduction in few years like 2002 and 2012 exactly after ten years.

Crop season temperature of Arssi grain plough farming system was consistently higher than central highland, and some ups and downs happened more frequently in the latter farming system. Test of equality of variances showed significant difference in crop season temperature of the two farming systems having p-value of 0.004.

Model Result for Stochastic Frontier

The dependent variable was in physical quantity, yield, then explanatory variables should be also in quantity but not dummy type non-input variables. This research employed different equations to regress yield of wheat and barley that are most common cereals in the two farming systems. The coefficient of μ (mu) was significant for

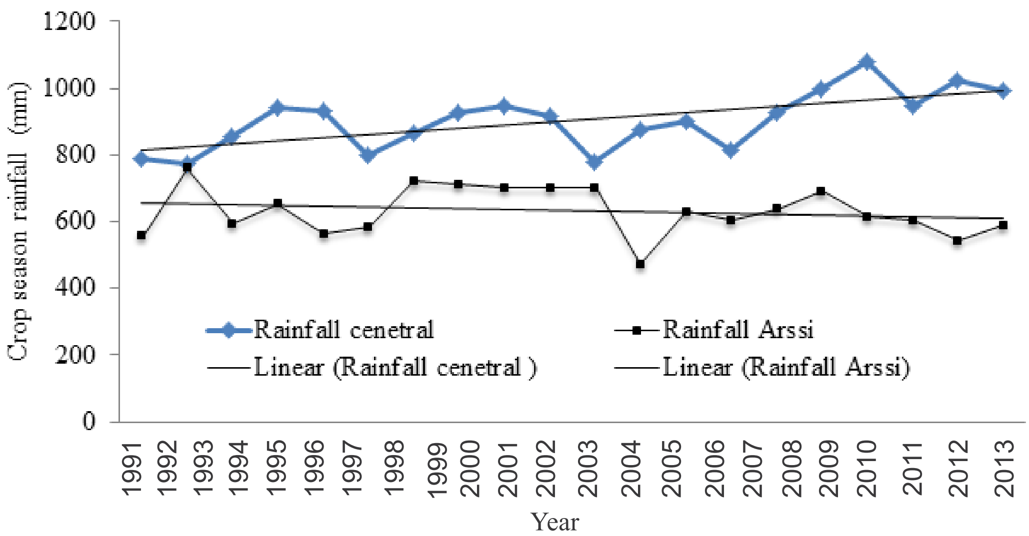

Figure 2. Crop season rainfall of sample farming systems
Source: Ethiopian National Meteorology Agency, 2014.

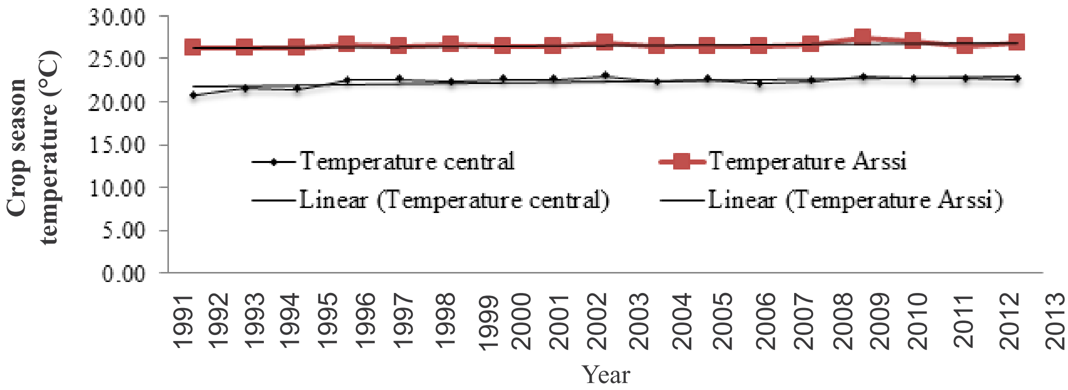

Figure 3. Crop season temperature of the two farming systems
Source: Ethiopian National Meteorology Agency, 2014

the time variant frontier model of the two cereals (Table 4), which showed presences of time variant efficiency variability as well as fitness of the model, Stochastic frontier. The returns to scale of producing those cereals in the two farming systems were not in constant returns since the coefficient of μ was significant.

The relatively large value of μ for wheat testified strong variability of the returns to scale for the across time (Table 4). The value of η (Eta) in the following model result revealed significant production inefficiency reduction towards the base year, 2014. The inefficiency level decays towards the base year, since value of η (Eta) is positive for the two cereals. Technical inefficiency reduction for barley was the higher than wheat (Table 4). The inefficiency for those cereals had significant time variant component that was normally distributed with a constant mean and variance level. Households in the two farming systems were highly inefficient in producing wheat, wherein they had unutilized potential of 61.50%. Households in the two farming systems could increase wheat yield by more than 60% from the given inputs at the existing technology.

Table 4
Time Variant Frontier Model Result

Description	Wheat		Barley	
	Coefficient	Standard error	Coefficient	Standard error
Ln man equivalent	0.129***	0.047	0.105**	0.043
Ln Fertilizer	0.098***	0.012	0.082***	0.011
Ln Oxen	0.050*	0.028	0.027	0.026
Ln Capital	0.041***	0.007	0.028***	0.007
In Cropping season rainfall	-0.124*	0.067	0.332***	0.108
In Cropping season temper	0.984***	0.214	0.564***	0.162
Constant	3.576***	0.846	2.764***	1.043
Mu (μ)	0.901***	0.191	0.466***	0.151
Eta (η)	0.023***	0.004	0.056***	0.011
Ln sigma2	-0.161***	0.044	-0.637***	0.037
Ilgt gamma	-0.919***	0.154	-2.774***	0.317
sigma2	0.852		0.529	
Gamma	0.285		0.059	
sigma_u2	0.243		0.031	
sigma_v2	0.609		0.498	
Log likelihood	-2870.6		-2089.6	
P-value	0.000		0.000	

Note: ***, ** and * implies 1%, 5% and 10% level of significance, respectively
Ln represents natural logarithm   Ilgt implies inverse logit
Source: Model result, 2016

Table 5
Determinants of technical inefficiency, GLS regression result

Variables description	Wheat		Barley	
	Coefficient	Standard error	Coefficient	Standard error
Summer rain on time	0.004	0.008	0.159***	0.0119
Harvesting time rain	-0.142***	0.008	-0.178***	0.012
Pests	-0.090***	0.009	-0.123***	0.015
Shocks	-0.050***	0.007	0.0098	0.012
Family size	0.029***	0.008	-0.081***	0.012
Age of head	0.051***	0.011	0.061***	0.016
Ln TLU	-0.009***	0.003	0.033***	0.008
Credit access	0.036***	0.008	0.095***	0.012
Off -farm	-0.034***	0.006	-0.040**	0.014
Constant	-0.878***	0.053	-0.640***	0.080
P-value	0.000		0.000	

Note: The dependent variable was technical efficiency in percent
The coefficients showed two dimensional changes
Source: Model result, 2016

The dependent variable in the random effect GLS regression model was generated based on the stochastic regression result presented below. P-value of each model result, on the last row of Table 5, indicated that the models for regressing technical efficiency were best fit. The independent variables were different from zero and had partial contribution in the technical efficiency variation. The test value enable to reject the null hypothesis with high confidence level of above 99.99% and each of the covariate had individual effect, either significant or insignificant, on the dependent variable.

Estimation result of technical efficiency [4]

The technical efficiency scores computed from frontier model result were between 0 and 1, and this revealed that none of the sample smallholder was either at the frontier level or producing 0 from the given input combination. The whole sample households were technically inefficient in producing the two crops. Since there were not censored observations, the study rejecting tobit model instead the best alternative model for linear type of observation GLS was employed.

The regression result presented in Table 5 considered three broadly categorized types of explanatory variables that affect smallholders' technical efficiency in producing the two crops. Wheat and barley responded similarly for variation in some of the covariates considered as an explanatory.

DISCUSSION

Interaction of crop yield with crop season rainfall and temperature

The main crop season harvest for some households in Arssi grain plough in 1994a was very low and it was the worst when compared with previous five years (Dercon & Hoddinott, 2011). The study also showed that in 2009 production year there was a poor distribution of rain for many of the households in the two farming systems, which resulted in huge reduction in yield of some crops. Households in Arssi grain plough farming system were suffering from rainfall inconsistency in a great extent and they tried to collect crops they needed by covering larger cropland. Some of the problems related to rainfall condition got extremity and drastic increment in their frequency of happening in each sample village of the two farming systems. For instance, many households in the two farming systems were suffering from untimed rainfall near harvesting period in 2009 production season.

The optimum and maximum crop season temperature for producing the two cool weather crops (wheat and barley) respectively were 25°c and 30.2°c in the sampled farming systems of this research. Given this, maximum crop season rainfall of the two farming systems was 1321mm. For better yields, water requirements should be 350-500mm depending on climate and length of

[4] *To avoid complications for readers the dependent variable was technical efficiency but not inefficiency*

Table 6
Number of Households Reported About Rainfall Inconsistency

Variables description	Number of households				Percentage change	
	In 1999		In 2009			
	Central highland	Arssi	Central highland	Arssi	Central highland	Arssi
Wheat	20	15	22	10	10.00	-33.33
Barley	26	1	12	3	-53.85	200.00
Total	150	117	156	44		

Source: Own data in 1999 and 2009

growing period, which is an amount lower than the average level (676.42mm) in the sampled farming systems of this research. Temperature increment may reduce yield and thereby exacerbate vulnerability in food supply (Joshi et al., 2011).

Rainfall inconsistency in the onset and cessation period showed greater variation from 1999 to 2009 within 10 years as per the data collected. This inconsistency and other elements of climate variability may be the main reasons for the lower crop production. In 1995 households in the two farming systems suffered from problems related to climate and weather variability in which 34.4% of the households who produce wheat were affected moderately or drastically. This resulted in a drastic reduction in yield for some households in central highlands farming system. Spearman correlation test of rainfall with wheat yield showed a significant interaction between them having p-value of 0.094 in central highland farming system. Spring rainfall is becoming highly unreliable for households in the two farming systems because of greater variability and sometimes complete absence, which frequently result in loss of yield (Dercon & Hoddinott, 2011). Sample households replied that spring season production is usually risky because of variability, delay or absence of rain.

Findings of Asha et al. (2012) revealed that reduction in rainfall was the major reason for yield reduction followed by pests and diseases outbreak; and changes in temperature and seasonal patterns of rainfall quoted as other reasons for yield reduction. In the same fashion, many households in Arssi grain plough farming system faced insufficient rainfall for their crop production and this resulted in serious crop damage in some production years. Overall rainfall shortage and poor distribution were the problems that happened in the two farming systems frequently miffed many of the sampled households (Table 6).

Discussion with focal persons in Arssi grain plough farming system indicated that there was production of short seasoned crops in autumn in the last 15 to 20 years, but recently it is not possible due to rainfall inconsistency. Currently, households of the farming system produce only in the main cropping season because of autumn rainfall inconsistency. The number of households miffed by inconsistency in rainfall increased in 2009 production year especially those who produce wheat.

Model Result Discussion

Discussion on determinants of yield

Inorganic fertilizer had significant and positive effect on yield of the two crops as to the model result (Table 4), which means small unit increment in its application could enhance yield significantly. Sibiko et al. (2013) had similar finding about fertilizer usage on bean productivity. Any fertilizer usage increment could enhance wheat, maize, barley and sorghum productivity (Ajay & Pritee, 2013), which was a finding corroborated with the above model result for all cereal crops. The model result in Table 4 shows that inorganic fertilizer and working capital had significant and positive effect on cereals' yield for smallholders in both central highlands and Arsi grain plough farming systems of Ethiopia. Rahman & Umar (2009) and Ehsan et al. (2012) also claimed that there is positive relationship between wheat yield and fertilizer application, which was in support of the model result in Table 4. Increasing the available capital for purchasing inputs like seed, pesticides and insecticides resulted in significant cereal yield increment as to the model result.

Oxen power and human labor had similar effect on cereals yield in the study area. Their complement behaviors may be the reason behind having similar interaction between the two sources of power and cereals yield in the two farming systems. Cereals are laborious crops and smallholders in the two farming systems manage them by human and animal power starting from plowing to harvesting, thus each change in the available labor had significant effect on yield of the two crops. Smallholders' crop yield variation may not purely climate forcing that is determined solely by rainfall, but also by the use of yield-improving external inputs (Amikuzuno & Donkoh, 2012). Similarly, Akinseye et al. (2013) confirmed that optimum yield performance of any crop do not depend only on climatic parameters. Smallholder farmers in less drought-stricken regions may improve land productivity through budgeting more labor and other production inputs (James et al., 2008), which was a finding similar to Table 4 regarding effect of human labor and draught power. Since smallholders of the study area are purely dependent on animal and human power for producing their crop, this positive and significant effect of the inputs on cereal yield was expected.

Cropping season temperature increment had positive and significant effect on yield of wheat and barley as to the model result (Table 4). This indicated that temperature variation significantly changed yield of the two crops. If cropping season temperature of the area increased by 1%, yield of wheat and barley would increase by 0.98% and 0.56%, respectively, wherein the former crop was more sensitive for each temperature variation. This finding was similar to Joshi et al. (2011), wherein cropping season maximum temperature increment has positive contribution on wheat and barley yield variation. Similarly, Sommer et al. (2012) found that wheat yield would increase in the future with the projected climate change in the semiarid zone of Tajikistan.

The result in Table 4 was in contradiction with Geethalakshmi et al. (2011), who identified that mean temperature increment reduced barley yield. Liangzhi et al. (2009) argued that impact of growing season temperature on wheat productivity is region specific, wherein effect of the problem is relatively lower in China as compared to the other regions. Successive temperature increment would not affect crop yield if there were extensive rainfall or water supply to curve down the moisture loss of crops (Kutcher et al., 2010). This indicated that positive interaction between cropping season temperature and yield of those cereals might be due to the excessive cropping season rainfall of the study area. The rampant rainfall of cool and moderate agro-ecology of Ethiopia may reduce negative effect of the temperature rise. In the other direction, successive temperature increment may eradicate waterlogging problem of the heavy summer rainfall and enhance wheat and barley yield. Thus, it may be easy to conclude that yield of the two cool weather crops would increase due to continuous cropping season temperature increment.

Discussion on determinants of technical efficiency (TE) [5]

The regression result presented in Table 5 considered three broadly categorized types of explanatory variables that affect smallholders' TE in producing cereal crops. Wheat and barley responded similarly for variation in some of the covariates considered as an explanatory. Timely onset of summer rainfall in the two farming systems significantly increased smallholders' TE of producing barley, which was in support with Inoussa (2010) who claimed that precipitation intensity affected sorghum yield significantly. Consistent availability of rainfall starting from the beginning may create auspicious environment for producing the crop efficiently. The adequate rainfall at the beginning of summer may enable smallholders to sow cereals on time, which would enhance their TE in producing cool weather crops.

TE of smallholders in producing those cereals responded similarly to harvesting season rainfall. Frequent happening of this problem in harvesting

[4] *To avoid complications for readers the dependent variable was technical efficiency but not inefficiency*

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season could result in serious yield variability that might decrease smallholders' TE as to the model result (Table 5). The two cereal crops were strongly responsive to this problem. Smallholders' TE in producing barley and wheat respectively, decreased by 17.8% and 14.2% if there was harvesting season rainfall. The coefficients indicated that barley and wheat production were sensitive to one of the dimensions of climate variability, harvesting season rainfall.

Climate change will reduce crop productivity up to 14% by 2020 (Srivastava et al., 2010), and yields are likely to be affected even more in 2050 and 2080, which was a finding highly related to Table 5. Outbreak of pests and diseases significantly decreased TE of households in the study area for producing the two cereals, wherein barley was more sensitive (Table 5). In identifying impacts of current climate variability, Kettlewell et al. (1999) showed that heavy rainfall could result in fungal disease outbreak that would finally reduce yield.

The demographic related factors including age of the household head had similar effects on smallholders' TE of producing the two cereals. Experienced household heads would have significant effect on TE of smallholders in the two farming systems in producing cereals. Having experienced household head would significantly increase TE of households in producing the two crops, which was a finding in support of Hardwick (2009), Zenebe et al. (2012) and Sibiko et al. (2013). One of the critical crop production input, human labor, may be easily available if the household had larger family size, which would improve TE of producing cereals. Family size increment may be a source of labor power for the crop production that would enhance TE of wheat, which was a finding corroborated with Rahman and Umar (2009). Family size increment has both productive and consumption effect, wherein TE of households in producing cereals would be depending on magnitude of the two effects. The latter effect may be the reason for having negative effect of the covariate on TE of producing barley in the study area.

Given those covariates, the study also considered other economic factors as an explanatory variable that have significant effect on smallholders' TE in producing the two cereals. Household's TE of producing barley responded positively to the livestock holding level. Farmers with more livestock units, which are ready to convert into cash, can be able to buy modern inputs than those that own fewer (Fantu et al., 2011). Possession of large livestock could significantly increase TE, which may be due to having additional income and labor for the crop production (Table 5). Participation of households in off/non-farm activities had negative and significant effect on TE of producing wheat and barley in central highlands and Arsi grain plough farming systems of Ethiopia, which may be due to labor competition between the crop production and those activities.

CONCLUSIONS AND RECOMMENDATIONS

Long run crop season rainfall of Arssi grain plough farming system was becoming lower with the passing of time and there were frequent ups and downs recently in very short period gaps. Similarly, crop season temperature of central highland farming system showed continuous increment with the passing of time. Extreme low and high rainfall as well as severe droughts also became common in the two farming systems. These all notify that the global problem, climate variability, is also happening in Ethiopia and it would have devastating effect on poor smallholders who have nature dependent livelihood.

Data from focus group discussion indicated that wheat and barley production showed continuous improvement in the cool weather areas of central highland farming system especially the former one exhibited successive increment implying that the weather condition is becoming auspicious for its production.

Agricultural inputs like inorganic fertilizer and human labor are critical in improving productivity of the two crops in the two farming systems. However, successive input price increment was a strong threat to apply the inorganic fertilizer as to the standard level. Sample smallholders in the study area affirmed that the current time sky rocketing input price rise is going out of their capacity to purchase the production inputs.

Cropping season temperature increment positively affected yield of producing wheat and barley. Thus, successive increment of this input improved yield of the tow cereals significantly in the two farming systems of Ethiopia. Further increment of cropping season rainfall from the current level resulted in mixed effect on technical efficiency of the two cereals for households in the two farming systems of Ethiopia.

The rainfall inconsistencies especially in harvesting time, and outbreak of pests significantly affected smallholders' technical efficiency in producing wheat and barley. Yield of the two crops significantly affected by those climate variability elements.

Source of additional working capital like credit access have positive and significant effect on yield of the two cereals in the study area.

Smallholders should have easy access to agricultural inputs like inorganic fertilizer and draught power at an affordable price to enhance application of them as to the recommended level for improving yield of the two crops.

The current level of crop season rainfall and temperature may be above optimum of wheat and barley production in the near future even though yield of the two crops currently improved. Thus, there should due attention to keep the temperature on the optimum level.

There should be continuous effort from both the government and private stakeholders to reduce negative and significant effect of pest and disease outbreak in order to have better yield from the two crops in the two farming systems.

To have a better yield of the two crops in the sample farming systems there should be due attention from the concerned body to keep the moisture on its normal level through reducing any form of rainfall inconsistencies at the different stages of the crop production.

Mechanisms like credit access and diversified source of income should be expanded in the study area to have alternative source of capital for producing wheat and barley.

Since rainfall inconsistencies were critical bottlenecks in producing the two crops, there must be brainwashing and awareness creation for smallholders to make them clairvoyant about precautionary measures.

There should be further investigation on the wheat yield both in laboratory and extended field work to examine why it had negative interaction with the crop season rainfall.

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REFERENCES

Ajay, K., & Pritee, S. (2013). Impact of climate variation on agricultural productivity and food security in Rural India. Discussion Paper No. 2013-43: http://www. economicsejournal.org/economics/discussionpapers/

Akinseye, F.M., Ajayi, V.O., & Oladitan, T.O. (2013). Assessing the impacts of climate variability on crop yield over Sudano- Sahelian zone in Nigeria. *International Journal of Agricultural Science, 1*(7), 91-98. Retrieved from http://www.accessinterjournals.org/aijas

Amikuzuno, J., & Donkoh, S.A. (2012). Climate variability and yields of major staple food crops in Northern Ghana: Tamale, Ghana. *African Crop Science Journal, 20* (2), 349 – 360.

Asha, L.K.V., Gopinath, M., & Bha, A.R.S. (2012). Impact of climate change on rain-fed agriculture in India. *International Journal of Environmental Science and Development, 3*(4), 368-371.

Baltagi, B. H. (2008). *Econometrics*. 4th Edition. Springer-Verlag Berlin Heidelberg: Syracuse University. USA.

Battesse, G.E., & Coelli, T.J. (1992). Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. *The Journal of Productivity Analysis, 3*, 153-169

Corinne,V., Jere, L. G., Christian, J., Robert, Q., & Rigoberto, E. (2004). Coping and adapting to climate variability: The Role of Assets, Networks, Knowledge and Institutions.

http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=1255C45E22E18E1CBE48CDC283BE36AF?doi=10.1.1.201.7357&rep=rep1&type=pdf

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C., & Huu, N. (2007). Asia: Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability. IPCC (Inter-governmental Panel on Climate Change) Contribution of Working Group II to the Fourth Assessment Report. https://www.ipcc.ch/ publications _ and_data/ar4/wg2/en/ch10.html

CSA (Central Statistics Agency) (2010). *Agricultural sample survey 2009/10 (2002 e.c.)* Volume VII Report on Crop and livestock product utilization (private peasant holdings, meher season. Statistical bulletin 468 Addis Ababa, Ethiopia.

Dercon, S., & Hoddinott, J. (2011). *The Ethiopian Rural household surveys 1989-2009: Introduction.* International Food Policy Research Institute. Addis Ababa: Ethiopia.

Dejene A., & Yilma S. (2003). Causes and variability of Ethiopian agriculture: modeling the relative importance of environment factors, external shocks, and state policies 1980–1997. Regional and Local Development Studies (RLDS), Addis Ababa University, Ethiopia

Ehsan, N., Mohammad, B., Mohammad, R. J., Paul, S., & Alireza, F. (2012). Agro-ecological zoning for wheat (*Triticum aestivum*), sugar beet (Beta vulgaris) and corn (Zea mays) on the Mashhad plain, Khorasan Razavi Province. *The Egyptian Journal of Remote Sensing and Space Sciences, 15*, 99–112.

Elodie, B. (2012). The impact of climate change on crop yields in Sub-Saharan Africa. *American Journal of Climate Change, 1*, 1-13

FAO (Food and Agriculture Organization) (2008). *The state of food insecurity in the world.* Food and Agriculture Organization of the United Nations, Rome, Italy.

Geethalakshmi, V., Lakshmanan, A., Rajalakshmi, D., Jagannathan, R., Sridhar, G., Ramara, Bhuvaneswari, A. P., Gurusamy, K. L., & Anbhazhagan, R. (2011). Climate change impact assessment and adaptation strategies to sustain rice production in cauvery basin of tamil nadu. *Current Science, 101*(03), 342-347.

Getnet, A. Z., & Mehrab, M. (2010). *Implications of land policies for rural-urban linkages and rural transformation in Ethiopia*. ESSP II Working Paper 15. Development Strategy and Governance Division, IFPRI Ethiopia Strategy Support Program (ESSP), Ethiopia.

Govinda, B. (2013). Effect of precipitation and temperature variation on the yield of major cereals in Dadeldhura District of Far Western Development Region, Nepal. *International Journal of Plant, Animal and Environmental Science, 3* (1).

Gupta, S., Sen, P., & Srinivasan, S. (2012). *Impact of climate change on Indian economy: Evidence from food grain yields*. Centre for Development Economics Working Paper 218, New Delhi.

IPCC (Intergovernmental Panel Climate Change) (2007). *Agriculture in climate change 2007: Mitigation*. Working Group III Contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press

Jaiswal, J.P. (2009). Climatic requirement for Wheat-temperature. Retrieved from http://agropedia.iitk.ac.in/content/climatic-requirement-wheat-temperature

Joshi, N., Maharjan, P., Keshav, L., & Piya, L. (2011). Effect of Climate Variables on Yield of Major Food-crops in Nepal: A Time-series Analysis. *Journal of Contemporary India Studies,1*:19-26

Kettlewell, P. S., Sothern, R. B., & Koukkari, W. L. (1999). UK wheat quality and economic value are dependent on the North Atlantic oscillation. *Journal of Cereal Science, 29,* 205–209.

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science, 319*, 607-610.

Lott, N., Ross, T., Smith, A., Houston, T., & Shein, K. (2011). Billion dollar U.S. Weather disasters, 1980 - 2010. National Climatic Data Center, Asheville, NC, USA. Retrieved from http://www.ncdc.noaa.gov/oa/reports/billionz.html

Morton, J. (2007). The impact of climate change on smallholder and subsistence agriculture. Proceedings of the National Academy of Sciences, USA 2007;104:19680-19685.

Nastis, S.A., Michailidis, A., & Chatzitheodoridis, F. (2012). Climate change and agricultural productivity. *African Journal of Agricultural Research, 7* (35), 4885-4893.

Samarah, N.H., Alqudah, A.M., Amayreh, J.A., & McAndrews, G.M. (2009). The effect of late-terminal drought stress on yield components of four barley cultivars. *Journal of Agronomy and Crop Science, 195* (6), 427-441

Sara, L. (2012). *Climate change, weather variability and food consumption: A multidisciplinary study of Rural Uganda*. Catholic University of the Sacred Heart. Via Emilia Parmense 84, 29122 Piacenza, Italy.

Schlenker, W., & Michael, J. R. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences, 106* (37),15594–15598.

Slater, R., Peskett, L., Ludi, E., & Brown, D. (2007). Climate change, agricultural policy and poverty reduction; how much do we know? Natural Resource Perspectives, 109.

Wolfram, S., & David, B.L. (2010). Robust negative impacts of climate change on African agriculture. Environmental Research Letters, 5 (1): IOP Publishing: http://iopscience.iop.org/1748-9326/5/1/014010

Wollenweber, B., Porter, J. R., & Schellberg, J. (2003). Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. *Journal of Agronomy and Crop Science, 189*, 142–150. (doi:10.1046/j.1439-037X.2003.00025.x) World Bank, 2004. Memorandum May 24.

Zerihun, G. (2012). *An analysis of the impacts of climate change on crop yield and yield variability in Ethiopia*. PhD Dissertation: Graduate School of Social Sciences: Department of Economics and Management. University of Trento: Italy

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