THE IMPACT OF CLIMATE VARIABILITY ON CROP PRODUCTION IN ETHIOPIA: WHICH CROP IS MORE VULNERABLE TO RAINFALL VARIABILITY

Kassahun Aberra[1]

Abstract

This paper estimated the impact of rainfall variability on crop production using time series data spanning from 1970-2010. The Stock, James and Watson, Mark (1993) Dynamic OLS Technique has been employed. The estimation result shows that when the annual rainfall diverges from its long run mean, the level of production of all crops diminished significantly. Extreme rainfall has also diminished the productivity of fertilizer on crop productivity. Area cultivated, private consumption and labor have also affected crop production. The result showed climate change induced rainfall variability is an inevitable treat to crop production in Ethiopia. Thus, to sustain economic growth and reduce poverty, policy makers should intensify adaptation and mitigation measures such as soil and water conservation, livelihood diversification, environmental rehabilitation, irrigation and water harvesting schemes.

Key words: climate change, rainfall variability, crop production, *Stock- Watson*

[1] Ethiopian Economics Association/Ethiopian Economic Policy Research Institute

1. Introduction

Climate change and the associated weather extremes continue posing serious challenges to our planet. Some of the adverse impacts of extreme weather include economic slowdowns, food shortages, broke-up of chronicle diseases, and loss of biodiversity and wildlife. The tsunami that hit and claimed more than 25,000 lives in 2011 in Japan indicate that developed countries are not immune from the adverse effect of climate change.

Ethiopia, like many countries in the tropical and subtropical regions, has been seriously challenged by climate calamity. The agriculture sector which contributes about 43% of the gross domestic product and more than ¾ of the labor force and foreign exchange earnings is the most vulnerable sector. Specifically, Crop and Livestock agriculture which accounted for more than 80% of the agricultural value added are the most affected sub-sectors to climate variability[2.] .

High dependency of the crop sector with nature combined with low irrigation and population pressure makes climate change a big challenge in Ethiopia. More than 12 million small scale farmers who produce 95% of the crop production depend on nature to their livelihoods (CSA, 2011).

Ethiopia has huge ground and surface water potential suited for small-medium scale irrigation schemes. However, only less than 5% of the land has been irrigated so far (MoFED, 2010). Combined with backward farming practice and low technology adaptation, climate change affected the production and productivity of crop sector by decreasing soil fertility, increasing pests and crop diseases and increasing the frequency of droughts and floods which transmits into life threatening famines. In the last four decades alone, the country has experienced at least five major national droughts that occurred in (1963, 1973, 1984, 1992, and 2003) and dozens of local droughts.

Had the drought in 2003 not occurred, the poverty in 2004/05 would have been lower by 14% (UNDP, 2008). In normal years, more than seven million small holder farmers in rainfall shortage areas have been supported by food and cash aid from Productive Safety

[2] Climate variability is a fluctuation of climate parameters such as temperature and precipitation from the normal values whereas climate change is a change in the long term mean values of a particular climate parameter- it is a persistent and long term change of climate parameters.

Net Program showing the vulnerability of farm households to weather variability. The share of commercial farmers who use irrigation has never exceeded 3% in terms of both area and production of crop sector. For instance, in 2009/10 production year, commercial farms constituted only 2% of area covered by grain and 3% of total crop production (CSA, 2011).

Following the global food price shock, there are some positive trends on large scale foreign direct investors on the agriculture sector. In 2011 about 3.6 million hectare of land has been given to foreign investors and this figure may double at the end of 2014/15 (Desalegn 2011). The impact of foreign direct investment on climate change and food security is still a debatable issue that will be looked in the future.

The objective of this paper is to empirically estimate the impact of rainfall deviation from its long run mean level (optimal level) on selected crops produced by small holder in Ethiopia.[3]

The remaining sections of the paper are organized as follows. Section two summarizes the evolution of climate change in recent years globally and in Ethiopia. Section three reviews recent literatures on the impact of climate change in Ethiopian. Section four reviews the Ethiopian climate changes policy. Section five presents Methodology and Data. Section six discusses the results and Section 7 Concludes.

2. Evolution of Climate Change

Climate scientists unanimously agreed that the global system has been warming over the last 100 years. The causes of the climate change did not, however, settled yet. There are only hypothesis that have been forwarded by different group of climate scientists[4.] Whatever the causes may be, the earth's temperature has been rising continuously over the last century and will continue at alarming rate in coming century (IPCC, 2007). As Figure 1 shows, the mean temperature of the earth debate by about 0.8^{0}C from the long run mean in the last 100 years starting form low level of -0.4^{0}C in 1860s.

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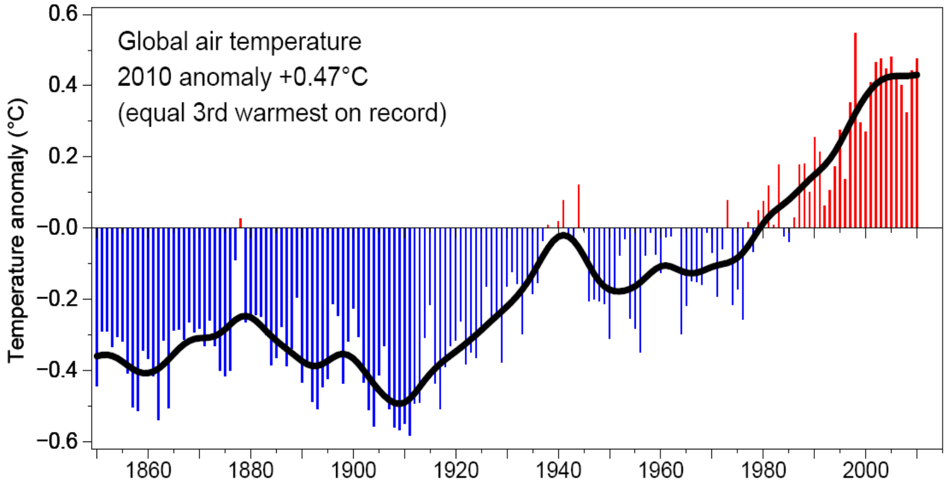
[3] The long run mean rainfall has been taken as the optimal label because too much and too little rainfall has detrimental effect on crop production as the data shows in Ethiopia

[4] Changing of the solar variability, volcanic activity and the composition of atmospheric GHGs are the common cause of climate change.

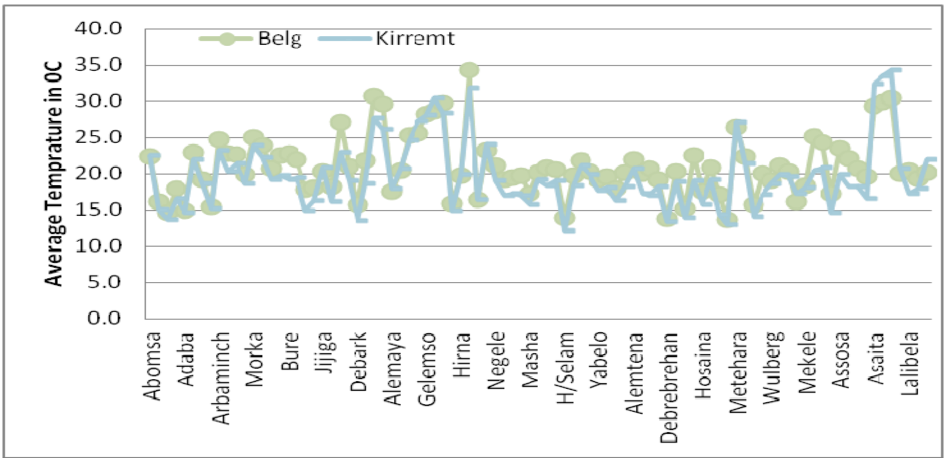
Figure 1: Trend of global air temperature



Source: IPPC, 2007.

Ethiopia, being located near the equator, has endowed with various altitude, temperature and precipitation variations. On average, over the last six decades, temperature varies from 35-10 ^{0}C at country level. There are, however, extreme cases in Ethiopia. For instance, the Denakil Depression has over 40^{0}C and places like the upper mount of Ras Dashen that registers less than ^{0}C throughout the year.

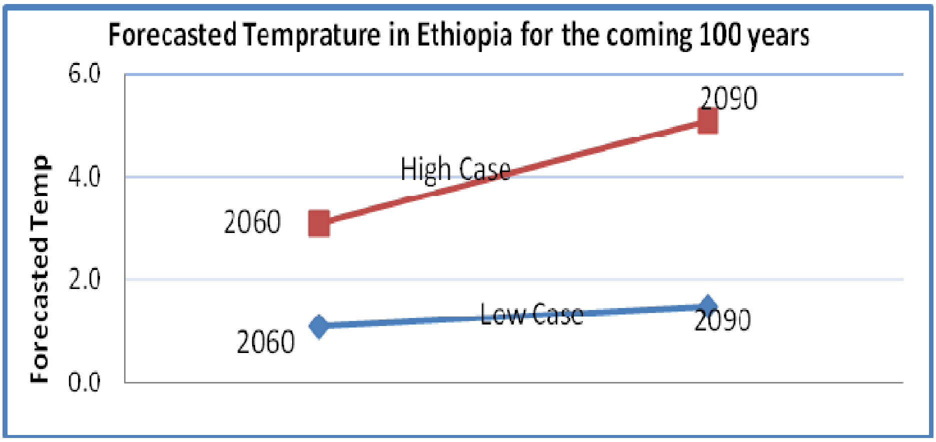
Figure 2: Spatial distribution of Temperature in Ethiopia during Belge and Kiremt Seasons



Source: Ethiopian Meteorology Agency

In the last six decades, as the climate parameters showed climate change has become prevalent in Ethiopia. For instance, the mean annual temperature has risen by 1.3 ^{0}C or (0.28^{0}C per decade) which is much higher than the global average. Consequently, the frequencies of 'cold days'[5] and 'cold' nights have decreased by 5.8% and 11.2% respectively (UNDP, 2008). According to climate models, the average will increase to 27^{0}C for the coming 100 years from an average of 23.08 ^{0}C in 1961-1990. Further temperatures rise will diminish crop production by limiting water availability and growth of plants (Temesgen et al, 2008, WB, 2008).

Figure 3: Evolution of Average Temperature in Ethiopia



Source: Various Forecasting Models and Own Computation

Climate change forecasting models predicts that, if the current climate conditions continue in Ethiopia, the mean annual temperature will rise by about 5.1^{0}C in 2090 in the worst (high) case scenario and by 1.5 ^{0}C in the better (low) case scenario. In both cases, the Ethiopian temperature is forecasted to be higher than the global average. As a result, the frequency of hot days and hot nights that are considered 'cold' in the current climate conditions will be increasing.

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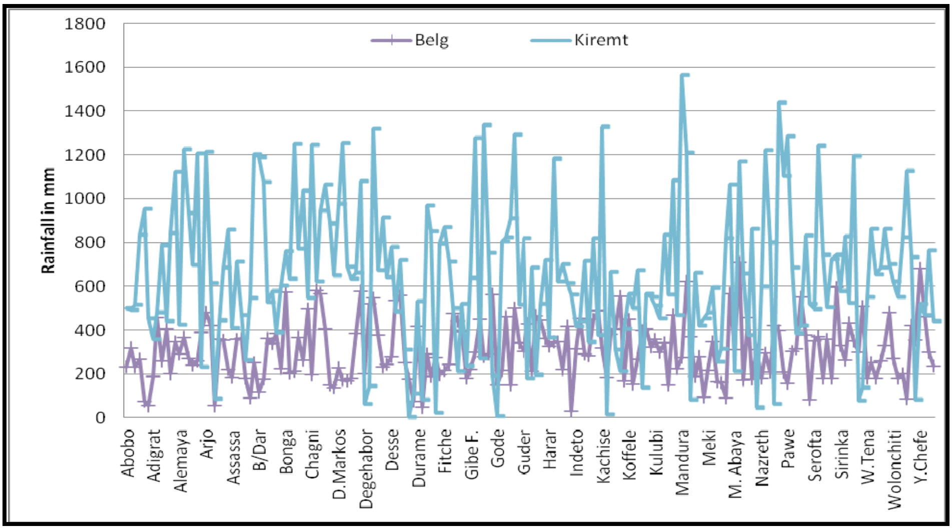
[5] Cold days/nights is defined as the temperature below which 10% of days/nights are recorded in the current climate

Figure 4: Long Term Spatial Distribution of Rainfall in Ethiopia



Source: Ethiopian Meteorology Agency

Unlike the temperature trends, it is very hard to detect the long term rainfall trend in Ethiopia due to high inter-annual and inter-decadal rainfall variability. While middle and high altitudes receive an average rainfall of 900 mm, the low lands have erratic and rainfall of 600mm. The exception is the west low lands which get high rainfall throughout the year. National average rainfall figures do not capture the large spatial variations in rainfall across different parts of the country. Some arid and semi arid or drought prone areas have lower average annual rainfall. The variable rainfall makes crops production erratic and unpredictable. Thus, rainfall variability is the major source of risk for farmers who depend on crop production in Ethiopia. The summer (Kiremt) rains which begin in March and May in South West and continue in July to September in most parts of the country is source of production for more than 90% of crop production (CSA, 2011). As Figure 4 showed there is huge precipitation variation among stations and during Bega and Kiremt seasons.

Historically, lack or excess of 'Kiremt' rains causes the major droughts that led to dreadful famines and floods (World Bank, 2006). As Table 1 shows about 12 major droughts affected the country over the last five decades that resulted in substantial loss of lives and livelihoods. Most of these droughts have caused food insecurity and transient poverty, destroying watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. For instance, the 1972/73 drought was the cause of for the death of 200,000 people. Similarly, the 1984 drought dropped the agricultural GDP by more than 20% and the 2002/03 drought surged the poverty level by 14% (World Bank, 2006, UNDP, 2008 and Alebachew, 2011). Further, climate reduced up to one third of water resource that flows to Nile Tributary) and causes encroachment of malaria in lower altitudes, widespread loss of life and illness (NMA, 2007).

Table 1: A Chronology of Ethiopian Drought and Famines since 1950s

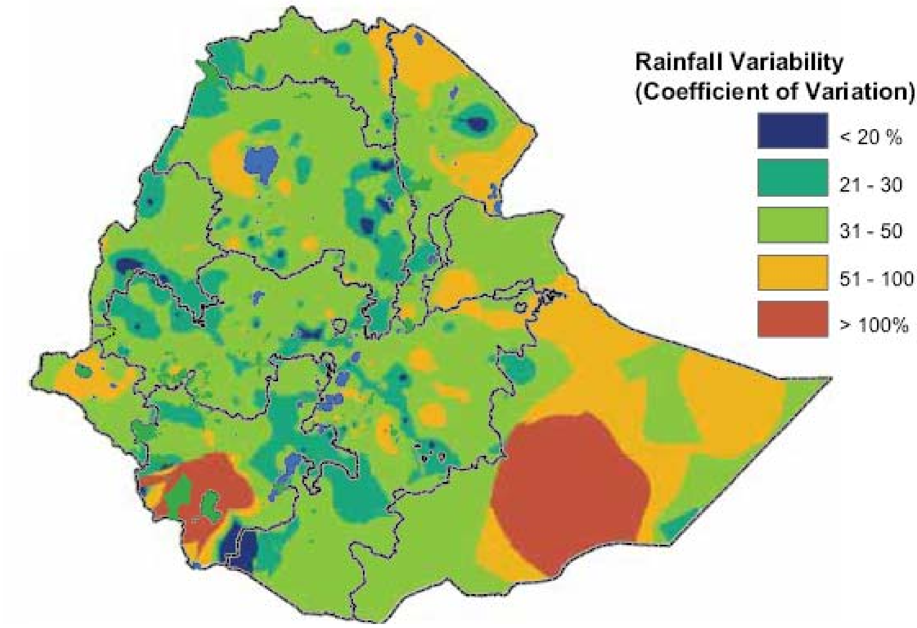
Year	Affected Regions	Triggers and Severity
1957/58	Wello and Tigray	Rain failure in 1975; locust infection in 1958
1964-66	Wello and Tigray	Very severe
1971-75	Whole of Ethiopia	Rain failure, 250,000 people dead 50% livestock dead in wello and Tigray
1978/79	Southern Ethiopia	Failure of the 'belg' rain
1982	Northern Ethiopia	Unseasoned rains
1984/85	Whole of Ethiopia	Rain failure; 1 million people died
1987/8	Whole of Ethiopia	Drought in low land areas
1990-92	Most of Ethiopia	Rain failure, regional conflicts
1995-96	Afar, South Oromia	Livestock death
1999/00	Amhara, Tigray, Afar, Somali, South Oromia	Drought, severe water shortage, livestock death
2002/03	Whole of Ethiopia	11.3 million people required emergency food assistance
2008	Wello and Tigray, Eastern Ethiopia	Rain failure / drought

Source: Webb and Braun (1984), Nicholls (1993), NMA (2007), UN-ISDR (2010) adopted from Alebachew, 2011)

The average precipitation rate has been 2.04 mm per day in 1961-1990. This rate is forecasted to reach as low as 1.97 mm in the coming 100 years. This is highly related with increasing global and local temperature with the location Ethiopia is found. Climate change is expected to have varying effect on the distribution of precipitation among different parts of Ethiopia. While it will be decreasing in the Northern part of the country, the Southern part would see an increasing of precipitation in the coming years (World Bank, 2009).

In addition to spatial variation, temporal variation of rainfall measured by coefficient of variation is common in Ethiopia (see Figure 5). Rainfall variability greater than 30 is risky for farmers who depend on crop production. As Figure 5 indicates, while few highlands in the West get rainfall for most of the months of the year (May-October), most parts of country get rain during July-September for the 'Meher' season and during February–May for the 'Belge 'season. As one can also refer from the figure, some crop producing areas have rainfall variability in the range of 31-50% which is risky for sustainable crop production ((IFPRI, 2011)

Figure 5: Rainfall Variability in Ethiopia



Source: Adapted from IFPRI, 2011

Crop production has significantly increased in the last four decades from average annual production of 64.2 quintal in 1970-1980 to more than 114.5 quintal per annum in 2001-2010. In 2010 production season alone, cereals production has surged to more than 155 million quintals (CSA, 2011). Small holders are the major players in the sector. Twelve million private farmers produce 95% of the crop production. Although crop production has been increasing, there is still un-meet demand in the local market that causes high food prices surge in recent years. As Table 2 shows the major source of production was area expansion. Area cultivated by cereals has surged from 5 millions of hectares per annum in 1970-1980 to about 8 millions of hectares per annum in 2001-2010. On the other hand, on average, productivity of cereals has been remained stagnant at 12 quintals per hectare throughout the past four decades. This is not surprising because only less than 5% of the total cultivated land is under improved seeds and less than 10% of farmers adopt for improved seeds (David J. et al, 2009). The figures depict that expanding area as a major source of growth may bring in an additional challenge to sustain it in the face of climate change.

Table 2: Average Production and Yield of Major Crops

Crop Type	Area, production and yield	1970-1980	1981-1990	1991-2000	2001-2010	1970-2010
Cereals	Area cultivated in millions of hectares	5.3	4.7	6	7.9	6
	Growth rate (%)	-	-11	28	31	16
	Share in total crop area cultivated (%)	82	84	81	80	82
	Production in millions of quintals	64.2	54.6	69	114.5	75.3
	Growth rate (%)		-15	27	66	26
	Share in total Production (%)	86	88	88	86	87
	Yield: Quintal/Hectare	12	12	12	14	12
	Growth rate (%)	-	-4	-1	24	6
	Area cultivated in millions of hectares	1	0.7	1	1.3	1
	Growth rate (%)		-28	46	25	14
	Share in total crop area cultivated (%)	15	13	14	13	14
Pulses	Production in millions of quintals	10	6.6	8.1	13.9	9.7
	Share in total Production (%)	13	11	11	11	11
	Growth rates (%)		13	14	13	14
	Yield: Quintal/Hectare	10	9	8	11	10
	Area cultivated in millions of hectares	0.2	0.2	0.3	0.7	0.3
	Growth rate (%)	-	13	14	13	14
	Share in total crop area cultivated (%)	3	4	4	7	5
Oilseeds	Production in millions of quintals	0.7	0.8	1.7	4.4	1.9
	Growth rate (%)		13	14	13	14
	Share in total Production (%)	1	1	1	3	2
	Yield: Quintal/Hectare	4	4	5	6	5
	Growth rates (%)	-	13	14	13	14

Source: EEA/EEPRI Economic Database, 2010

3. Impact of Climate Change: Literature Review

The strong link between agricultural, poverty and climate change, makes climate change issues a major concern to policy makers and the academia. The overall impact of climate change on agricultural sector has been estimated to be more than 10% at continent level (Ariel et al, 2008). The Expected variability of temperature, precipitation, atmospheric carbon content and extreme events are forecasted to have profound effects on plant growth and yields, crop production, livestock production and water availability at continent level. The impact of climate change varies among countries based on altitude and other factors. While some countries such Mauritania, Mali and Niger are expected to benefit by climate change induced lengthened growing seasons, sub-humid countries such as some parts of Mali, Burkina Faso and Ghana are expected to suffer from reduction in rainfall (Ariel et al, 2008).

Downing (1992) examined the impact of climate change on food security in three African countries such as Zimbabwe, Kenya and Senegal and concluded that potential food production would increase with high temperature and greater rainfall in high lands of Kenya. However, in semi-arid areas particularly that have vulnerable socio-economic groups would face serious difficulties as yield decreases further as a result of insufficient rainfall. He also indicated that a 20C increase in temperature would decrease the core agriculture by one-third in Zimbabwe and significantly affects the carrying capacity of the rain-fed agriculture in Senegal.

In Ethiopia, very few works are available on the impacts of climate change and on crop production. The scant works so far available use micro-econometric technique and most of them relay the perception of farmers'. In this regard, Assefa Admassie et al (2008) and Temesgen Deressa et al (2008) examined the perception of small- scale farmers and pastoralists in most vulnerable parts of the country. Both studies identified that female headed households and households with low level of education are the most affected groups by climate change because of their excessive reliance on natural resources to their livelihoods and luck of diversified source of livelihood. They also showed that climate change affects regions differently. While regions with arid, semi-arid, and dry sub humid low lands are more vulnerable, low lands which are not arid or not semi-arid are less vulnerable to climate change. Some of the adaptation measures that have been taken by the households according to the above study includes: diversification of livelihoods, migration, nonfarm activities, sales of assets, settlement and resettlement activities, and the adoption of improved water management system.

Mahmud et al (2008) examined the impact of climate change on food production in Ethiopian. According to their study, farm households who have adapted to climate change have better food production level than farm households without any adaptation measures. They also found a significant share of farmers perceived that the mean temperature of Ethiopia has increased over the past 20 years. The following adaptation measures have been taken by households included in the study: changing crop varieties, adapting soil and water conservation measures, harvesting water and planning trees and changing planting and harvesting periods.

The study also indicated that access to climate information, agricultural extension and credit services are major determinants of farmers to take the above adaptation measures.

Deressa et al (2008), studied the vulnerability of farmers to climate change. And they found that increasing the incomes of farmers reduces their vulnerability because vulnerability is highly sensitive to their minimum daily requirement (poverty line). When the daily minimum income is fixed at 0.3 United States dollars (USD) per day, only 12.4 percent of farmers will be vulnerable to climate extremes, whereas 99 percent of farmers will be vulnerable when the minimum requirement is fixed at 2 USD per day (Deressa, T. et al 2008).

The Word Bank's climate projections model showed that global warming leads to rainfall variability with a rising frequency of both severe flooding and droughts in Ethiopia. The Economy-wide impacts of climate change studied by the World Bank on Ethiopia indicated that the GDP losses will be significant in Ethiopia due to climate change. The model highlights the high degree of vulnerability of Ethiopian agriculture and infrastructure to the climate shocks. Climate change brings about increased weather variability, which translates into large swings in the growth rate of agricultural GDP (World Bank, 2006).

Ariel et. al. (2008) have identified tropical and subtropical African countries which are more vulnerable to climate change. Ethiopia has been found to be one of the countries that have been affected by climate change. The researchers employed CROPWAT[6] model to stimulate yield response and crop water for two cereal crops –maize and sorghum. The study showed that high temperature will increase the evaporation rate in tropical and sub-tropical African countries. Consequently, there will be rainfall reduction will drop yield by 40-70%. They have also mentioned some adaptive measures that farmers are taking: small scale irrigation and water harvesting, minimizing evaporative demand by using mulch, and applying soil moisture conservation technique and crop management system that reduce sensitivity to water stress.

4. Policies on Climate Change in Ethiopia

Policy makers play an important role to reduce the impact of climate change in their respective countries. Recently, many countries are mainstreaming climate change in to their development plans. The Ethiopian Growth and Development Plan (GTP) address issues pertaining to climate change. It also commends that the current population has to use resources without compromising the survival of future generation. Though Ethiopia's share to global green house gas emission is very minimal, emissions from agriculture and energy sectors doubled over the last twenty years. Agriculture and energy are the major emitters accounting for 85% and 15% of the total gas emission[7] respectively (NMA, 2007). This shows that there is high potential of decreasing imitation via mitigation through these sectors. Clean Development Mechanisms (CDM) measures from agriculture and hydroelectric plants, geothermal and wind turbine, conservation of energy through efficient and switching energy sources, usage of compact and efficient vehicles, changing means of transport to fuel efficient modes of transport and usage of efficient stoves are some of the strategic directions that the Ethiopian government is promoting. These directions are consistent with the United Nations Framework Convention on Climate Change (UNRCCC) recommendations.

In addition, the Ethiopian government gives emphasis to climate change adaptation and mitigation issues in the GTP document. The document embodied climate change as the top priority issue to make national development paths more sustainable as compared to the previous Plans. Although it's difficult to evaluate the effectiveness of the plan in

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6 CROPWAT is the FAO crop model which refers crop-water designed to analyze the bench mark values of major crop yields

7 CH_4 and N_2O are the major gasses which accounted for 95% of the total gas emitted from agriculture sector.

terms of implementation at this stage, it gave emphasis to the construction of hydroelectric dams and medium to large scale irrigation schemes, and the development of other renewable energy sources like wind, solar and bio-fuel which could reduce the vulnerability of the economy to climate calamities.

Though Ethiopia has abundant water resources and hydroelectric potential capacity, only less than 5% of the water has been developed for irrigation purpose so far (Desalegn 2011). The per capita electricity consumption is one of the least in the world with more than 80% of the population living without access to electricity and relying on firewood, charcoal, animal dung, kerosene, gas and bio-gas as a major source of energy (MoFED 2010).

The government is currently undergoing the construction of a large scale dams including the biggest Renaissance Dam on Abay River which has an installed capacity of 6000 MW. When these projects completed, the total supply of energy from renewable sources will increase to 10,000MW (MoFED, 2010).

Increasing the electricity supply from renewable sources will help to realize the ongoing rural electrification access program and increase the coverage at country level to 75% from existing low level of 20%. It will also help to significantly decrease our dependency on volatile rain-fed agriculture MoFED, 2010).

Further, Ethiopia has suitable land for bio-fuel development. The major targets of the government regarding bio-fuel are to increasing bio-ethanol from almost nonexistent to 194.9 million litters, to increasing bio-diesel up to 1.6 million litters and increasing the number of blending facility of benzene –ethanol to 8 and bio-diesel to 72 by the end of the plan period MoFED, 2010).

The GTP also promises to use the water resources properly through expansion of small scale irrigation. If properly implemented, there are good promises in this document that help to reduce the impact of weather variability on crop production.

Further, the government promises to ensure environmental sustainability via integrating the principles of sustainable development into the country’s policies and programs; reverse loss of environmental resources; reducing biodiversity loss; reducing people without sustainable access to safe drinking water and by improving basic sanitation the lives of slum dwellers (ibid).

5. Data and Methodology

The basis for the theoretical framework is the traditional Ramsey growth model adjusted for the Ethiopian context by incorporating rainfall variability in crop production as a major determinant. The affect of other factor such as fertilizer, labor, area, consumption etc has also been controlled in the model. The crop sector has also been decomposed into cereals, pulses, oilseeds, coffee and other crops. The Cob Douglas tye production function for each crop production has been taken adjusted for Ethiopian case and transformed into log form in Equation (2) so coefficients will be elasticities for the later have better economic interpretation. In addition to traditional determinants of crop production, autoregressive and moving average variables have also been captured in to the model in Equation (3) to make the model dynamic. To correct for simultaneity bias, the lead and lag of regressors have been incorporated.

The major data sources are Ministry of Finance and Economic Development (MoFED), National Bank of Ethiopia (NBE), Central Statistical Agency (CSA) and Ethiopian Economics Association database. The sample size of the data set runs from 1970-2010. The Stock, James and Watson, Mark (1993) Dynamic OLS estimation technique has been used. This technique was chosen since it has some advantage relative to other time series techniques such as two-stage Engle-Granger and the Johansson Maximum Likelihood procedures because: it is robust in the context of a small sample size, suitable to estimate co-integrated variables of different order, and corrects simultaneous and small sample bias by inclusion lead and lag of variables and shares the asymptotic properties of Johansen and Juselius multivariate analysis (Hariis, R., Sollis,R.,2003).

Model Specification

$$OACROP_{it} = \beta_0 * (RAINVAT_{it})^{\beta_1} \prod_{i=1}^{k} (Z_{it})^{\beta_i} \varepsilon it \qquad \textbf{(1)}$$

$$log(OACROP_{it}) = \beta_0 + \beta_1 log(RAINVT_{it}) + \sum_{i=1}^{k} \beta_i log(Z_{it}) + \varepsilon it.. \qquad \textbf{(2)}$$

By adding the lead and lag of regressors, Equation (2) will be further transformed into equation

$$log(OACROP_{it}) = \beta_0 + \beta_1 log(RAINVAR_{it}) + \beta_2 log(RAINMD_{it}(-1)) + \beta_3 log(RAINMD_{it}(+1) + \beta_4 log(FERCROP_{it}) + \beta_5 log(FERCROP_{it}(-1)) + \beta_6 log(FERCROP_{it}(+1)) + \beta_7 log(ARCROP_{it}) + \beta_8 log(ARCROP_{it}(\_1)) + \beta_9 log(ARCROP_{it}(+1)) + \beta_{10} log(NRURW_{it}) + \beta_{11} log(NRURW_{it}) + \beta_{12} log(NRURW_{it}(-1)) + \beta_{13} log(NRURW_{it}(+1)) + \beta_{14} log(CONS_{it}) + \beta_{15} log(CONS_{it}(-1)) + \beta_{16} log(CONS(+1)) + AR(1) + MA(1) + \varepsilon it. \quad \textbf{(3)}$$

Where:

$OACROP_{it}$ - Value added of Crop i at time t, $RAINVAR_{it}$ - Deviation of rainfall from its mean for crop i at time t , $FERCROP_{it}$ - Applied fertilizer for crop i at time t, $ARCROP_{it}$ - Area covered by crop i at time t, $NRURW_{it}$ - Labor engaged in crop i at time t, $CONS_{it}$ - Private consumption of crop i at time t, $AR(1)$ - Autoregressive Variable , $MA(1).$ - Moving Average , εit - Random error term, i = (Cereals, Oilseeds, Pulses, Coffee and other crops) and t= (1970, 1971…2010)

The stationarity and validity tests have ensured that the appropriateness of the estimation technique we used. Most of the variables we employed are stationary at first difference except area of oilseeds and rural active labor force which are stationary at second difference (See Annex 1). Since we use the *Stock, James and Watson, Mark model*, combining variables with different degrees of integration is not a problem (Haris, R., Sollis, R., 2003). All the equations passed normality, heteroskedasticity and serial correlation tests (See Annex 2-4). The validation tests also showed that fitted lines mimics the actual data for all equations (Annex 5)

6. Result Analysis

After controlling the impact of, area cultivated, consumption, labor force etc, the impact of rainfall has an expected sign for all crop equations. In some of the crop equations such as cereals and oilseeds, the current year rainfall variability has an immediate, negative and significant impact on that year's production but in the case of coffee and other perennial crops (fruits and vegetables), rainfall variability affected production after one year. But in all the equation, what matters is not the amount of rainfall per se but how that rainfall diverges from its optimal level. There is also a significant difference on the impact of rainfall variability on annual and perennial crops the impact being severe on the former.

Fertilizer has also found to have negative impact on crop production perhaps the application of fertilizer in when there is rainfall variability (both excess and shortage) may increase the likelihood of crop failure. Increasing cultivated area has been found to be the major factor to crop production.

This is not surprising, however, since area expansion has been significantly increasing over the last four decades. Active labor force in agriculture has positive and significant impact on crop production. This may be because population pressure is one factor for the prevailed area expansion. The land ownership structure which is predominantly owned by small scale farmers with per capita land holdings of about ½ hectare may contribute for area expansion and land degradation.

Private consumption has been found to have a positive impact on all crops. This is perhaps it creates an incentive to farmers to produce more by expanding area since yield growths have been remained modest over the last four decades. The lag effect of the dependent variables showed, production slack at one period lag leads to low production for the next year perhaps farmers who lost their productive assets such as oxen and seeds in the previous year will spill over the on the production loss in the year to come. Overall, rainfall variability has significant and negative impact on all crop types though food crops (annual crops) are highly susceptible to rainfall variability.

Table 3: Estimation Result

	Cereals output		Oilseeds output		Pulses output		Coffee outputs		Other crops	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C	1.975	0.092	-6.209	0.121	-2.744	0.000**	-10.347	0.000**	-2.137	0.006**
Rainvar	-0.023	0.031*	-0.052	0.000**					-0.022	0.033*
rainvar(-1)			-0.056	0.000**	-0.031	0.002**	-0.011	0.263	-0.017	0.088
Rainvar(+1)							0.016	0.093		
Fertilizer	-0.012	0.344	-0.019	0.024*	-0.008	0.499				
Fertilizer(-1)										
Fertilizer((1)										
Area	0.321	0.043*	0.135	0.069			0.477	0.006**		
Area(-1)					0.065	0.305				
Area(+1)	-0.369	0.022*					0.339	0.049*		
Nrurw			-24.431	0.004*	0.32	0.000**				
Nrurw(-1)	0.218	0.198	9.85	0.151			1.174	0.000**	-2.137	0.006
Nrurw(1)			13.971	0.102						
Cons	0.231	0.114**	0.751	0.003*	0.32	0.054*			-0.022	0.033*
Cons(-1)			0.492	0.020*						
Cons(1)	0.304	0.031*	0.465	0.018*	0.283	0.035*	0.082	0.451		
DUMDR	-0.138	0.005**			-0.201	0.000**				
AR	0.512	0.011**	0.718	0.000**			0.303	0.093	-0.017	0.088
MA			0.97	0.000**	-0.909	0.000**				

Source: Estimation Result

7. Conclusions

Climate variability is an important factor that affects major crops grown in Ethiopia. Though it is difficult to see the impact of long term climate change on crop production for it demands a long time series data, the 40 years weather data shows rainfall variability impacts crop production seriously across all crop types. This entails that the government has to design appropriate adaptation measures across all the regions including reducing vulnerability of livelihoods of more than 12 million households who depend on the crop agriculture.

Rainfall variability affects all crops but the effect has been serious on staple crops (annual crops). This implies that climate change will jeopardize the food security effort of stake holders unless an appropriate and immediate action is taken to reduce its impact. In addition, rainfall variability coupled with the current rampant food inflation is a big challenge to Ethiopia. Thus, the government should intensify to adaptation and mitigation measures that have been implemented at small scale in some parts of the country such as irrigation and water harvesting schemes, introducing climate change resilient crop varieties, implementing suitable settlement and re-settlement policies, creating awareness on adjusting planting and harvesting periods and introducing appropriate land use rights. The currently undergoing land management and water shading activities in some parts of the country need to continue with sustainable and holistic manner.

Growth through area expansion should be stopped and should be substituted by improving the productivity of the sector for the former exacerbate the already degraded environment in the country and aggravate the climate change anomalies.

Since rainfall variability affects the productivity of fertilizer on crop production, applying fertilizer would not be productive alone. Thus, to due emphasis must also be given to medium to small scale irrigation schemes and renewable energy sources that dependent less on rainfall such as wind, solar and bio-fuel.

The World Bank and IPCC climate prediction models show that rainfall and temperature variability will be intensified for the 100 years to come in Ethiopia. Thus sustaining economic growth depending on rain-fed agriculture would not be viable. Hence, the government should change the structure of the crop sub-sector from rain-fed to irrigable agriculture which is relatively less sensitive to rainfall variability.

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Annex 1: Unit- root test results

Variable	Augmented Dickey-Fuller t- statistic[8]	Test critical values:		
		1% level	5% level	10% level
ACER)	-8.419	-4.219	-3.533	-3.198
AOIL	-7.513	-4.235	-3.540	-3.202
APUL	-7.195	-4.219	-3.533	-3.198
AREA	-8.634	-4.212	-3.530	-3.196
AREACER	-8.563	-4.212	-3.530	-3.196
AREACOF	-6.893	-4.212	-3.530	-3.196
AREAOIS[9]	-10.976	-4.235	-3.540	-3.202
AREAPUL	-7.135	-4.212	-3.530	-3.196
CONS	-8.767	-4.219	-3.533	-3.198
FERCER	-10.160	-4.219	-3.533	-3.198
FERCOFF	-10.097	-4.219	-3.533	-3.198
FEROILS	-10.727	-4.219	-3.533	-3.198
FEROTHCROP	-10.097	-4.219	-3.533	-3.198
FERPULS	-10.339	-4.219	-3.533	-3.198
NRURW[10]	-5.818	-4.219	-3.533	-3.198
OACER	-5.917	-4.212	-3.530	-3.196
OACOFF	-4.364	-4.212	-3.530	-3.196
OAOILS	-5.862	-4.219	-3.533	-3.198
OAOTHERCROP	-5.743	-4.212	-3.530	-3.196
OAPULS	-5.768	-4.212	-3.530	-3.196
RAINVAR	-9.642	-4.212	-3.530	-3.196

Annex 2: Jarque-Bera Normality Test

Equation	Jarque-Bera	Probability
Cereals	4.672	0.097
Oilseeds	1.019	0.601
Pulses	0.775	0.679
Coffee	2.765	0.251
Other crops	2.475	0.290

[8] The null Hypothesis in all cases is the variable has a unit root except for those variables which are not stationary at first difference in that case the Null Hypothesis will be the first difference has a unit root.
[9] Stationary at second difference.
[10] Stationary at second difference.

Annex 3: Breusch-Godfrey Serial Correlation LM Test

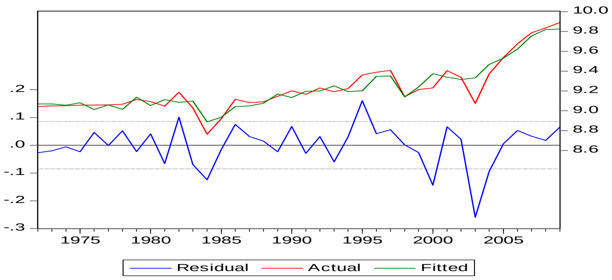
	Obs*R-squared	Prob.Chi-Square(1)
Cereals Outputs	1.226	0.27
Oilseeds Outputs	5.496	0.19
Pulses Outputs	3.992	0.14
Coffee Outputs	8.874	0.12
Other crops Outputs	3.599	0.058

Annex 4: White's Heteroskedasticity Test Result

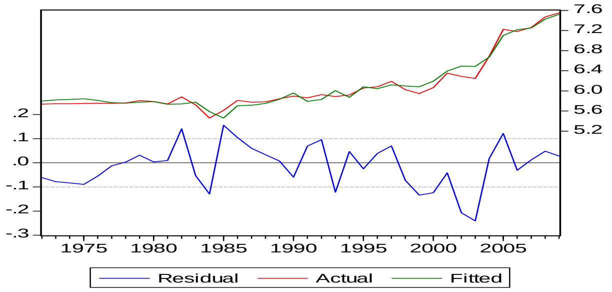
	F-statistics	Probability
Cereals Outputs	0.771	0.643
Oilseeds Outputs	0.664	0.775
Pulses Outputs	0.633	0.758
Coffee Outputs	1.432	0.225
Other crops Outputs	1.776	0.304

Figure 2: Validation Tests

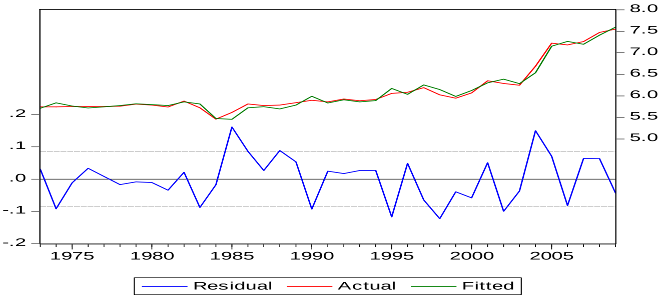
(a) Residuals of Cereals Outputs



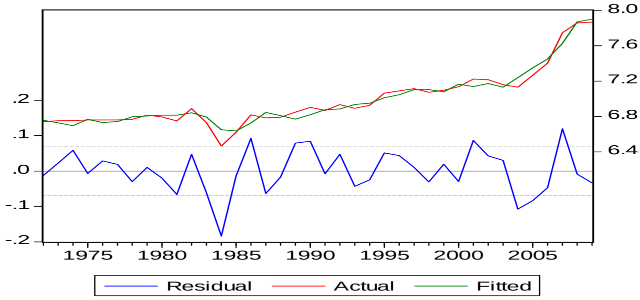
(b) Residuals of Oilseeds Outputs



(c) Residuals of Pulses Outputs



(d) Residuals of Coffee Output



(e) Residuals of Coffee Output