Climate Change and Its Impact on Agricultural GDP Growth in Ethiopia: a Time Series Analysis

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Abstract

Climate change is now a global phenomenon with growth, poverty, food security, and stability implications, and is one of the greatest challenges the world is facing today. The economic impact of climate change mainly depends on the sectoral composition of the economy. That is certain sectors like agriculture are more sensitive to climate change and the associated variability. The main objective of this paper is to investigate the impact of climate change on agricultural gross domestic product growth in Ethiopia. This study uses time-series annual data from 1992/93to 2017/18 and, an effort is made to identify the long run and short-run impact of climate change in Ethiopia using an autoregressive distributed lag (ARDL) and error correction methods. The results of the study provide evidence that climate change and variability affect real agricultural gross domestic product growth negatively in the long run. The coefficient of the error term that captures the speed of adjustment toward the long-run equilibrium is found with the correct sign and magnitude. The overall findings of the study underlined the importance of building resilience to climate change and minimizing the adverse impacts of climate change to promote agricultural output and hence economic growth in Ethiopia.

Introduction

Climate change is the variation in global or regional climates over time. It reflects changes in the variability or average state of the atmosphere over time scales. Climate change describes a change in the average conditions, such as temperature and rainfall, in a region over a long period.

The Earth’s climate is rapidly changing as a result of increases in the concentrations of greenhouse gases (GHGs) in the atmosphere mainly caused by human activities, particularly the burning of fossil fuels, agriculture and deforestation (Stern, 2006; IPCC, 2007; Zegeye, 2013). Scientists believe that the global average surface temperature has risen over the past century. Since 1900, the global average surface temperature has risen by 0.76°C (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) asserts that continued emissions of GHGs at or above the current rates would cause an increase in the global average surface temperature of 1.8 to 4.0°C by 2100. On the other hand, precipitation has shown different spatial and temporal patterns (increases or decreases) in different regions of the world (IPCC, 2007).

Climate change and its impact would touch every region of the world, though some regions would be adversely affected. Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate-sensitive sectors such as agriculture (Stern, 2006).

The depth and consequences of climate change on the performance of a country's economy are governed by the sectoral composition of the economy (IPCC, 2007). The structure of the Ethiopian economy is characterized as an economy where the agricultural sector has a significant contribution to the overall economic performance.

Ethiopian agriculture is highly rainfed, and like many countries in sub-Saharan Africa, it is highly constrained by old practices, low farmland per capita resulting in less than one hectare per household, low technology application, and poor marketing conditions. Thus, mitigating and adapting to climate change, though costly, can sustain growth in the country.

A handful of studies on the economic impact of climate change on the agriculture sector used the Ricardian approach. However, the reliability of the Ricardian approach depends crucially on the assumption that land markets operate properly (Deschenes and Greenstone, 2007). The approach is based on the theory that in competitive market economies, land value is measured by the present value of expected net revenues that are derived from the most economically efficient management and use of land. But the Ethiopian land market characteristic makes the findings of this approach unreliable.

Besides, these studies do not take account of additional adverse impacts due to potential increased climate variability around mean trends rather they focus on the trend of climate variables like temperature and rainfall. But Climate change impacts are complex in that more or less rain or temperature may lead directly to smaller agricultural yields. So analysis based on temperature and rainfall amount may lead at least to unreliable conclusions.

The stack of studies on the economic impact of climate change on Ethiopian agriculture is quite limited. So, this work will try to fill this gap by considering the strategic importance of the agricultural sector, while understanding its sensitivity to climate change. This paper will try to examine the impact of climate change on the economic performance of the Ethiopian agricultural sector by taking climate variability around mean trends into account at a macro level. This research chooses to apply the production function approach to analyze the economic impact of climate change due to its suitability to measure the relationship between agricultural production and climate change.

Agriculture currently accounts for about 34.9% of Ethiopia's output and serves as the main source of input to the existing industrial sector. Any impact on the agricultural sector can significantly affect the entire economy. Therefore, studies on the impact of climate change on economic growth in Ethiopia, mainly in the agricultural sector, have policy relevance.

Literature Review

Empirical Review of Impact of Climate Change on Agriculture

Depending on countries' natural conditions and economic structure, climate change affects countries differently. For example, Sub Saharan Africa is more vulnerable to an increase in climate variability, with projected large losses in their national output (Thurlow, 2009). Countries with large delta regions, such as Vietnam, are projected to be hit hard by rising sea levels, with strong implications for food security and the rural poor (Yu et al., 2010). Countries that are already experiencing water stress, especially those in the Middle East and North Africa, are likely to experience additional declines in agricultural yields, resulting in negative effects on rural incomes and food security (Breisinger et al., 2010).

In contrast, interestingly enough, climate change is also expected to result in some beneficial effects, particularly in temperate regions (Mendelsohn et al., 2009). The initial benefits arise partly because more carbon dioxide in the atmosphere reduces "water stress" in plants and may make them grow faster (Long et al., 2006). The lengthening of growing seasons, carbon fertilization effects, and improved conditions for crop growth are forecast to stimulate gains in agricultural productivity in high-latitude regions, such as in northern China and many parts of northern America and Europe. Besides, Climate change may increase the amount of arable land in high-latitude regions by reduction of the number of frozen lands (IPCC, 2007).

The Fourth Assessment Report of the IPCC provides some illuminating results about the impact of climate change on African development. For instance, projected reductions in yields in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-farm holders being the most affected. It will also aggravate the water stress currently faced by some countries - about 25% of Africa's population (about 200 million people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 350–600 million by 2050 while between 25 and 40% of mammal species in national parks in sub-Saharan Africa will become endangered (Boko et al., 2007).

The regression analysis by the Roberts Strauss centre for international security and law revealed that the performance of Ethiopian agriculture is highly and significantly influenced by the trends in rainfall. Simulation exercises revealed that the level of economic growth is lowered by 3.6–6.1% of current GDP as compared to the baseline scenario of no change in climate from 1990 to 2008 (Aragie, 2013).

A key research finding depicted that climate change is being felt and reacted to everywhere in Ethiopia. Yet it is only one of many challenges with which people are confronted in their daily lives. Ethiopia's mainly rural societies are rendered vulnerable by several factors, including its fast-growing population, deforestation, soil degradation and overstocking (GIZ, 2011). According to UNDP (2007) estimate, due to climate-linked factors, cereal yields in Ethiopia, Eritrea, Gambia, Ghana and Zambia will decline up to 5% by the 2080s. According to Zenebe et al. (2011), over the last 50-years, the projected reduction in agricultural productivity may lead to 30% less average income, compared with the possible outcome in the absence of climate change.

Research Methodology

The study considers the Ethiopian economy. It relied on secondary data (time series data) to investigate the impact of climate change on Ethiopian Agricultural GDP growth. The major sources of data for the study are the Ethiopian National Metrology Agency (NMA) and satellite data (TAMSAT) for climate variables, the National Bank of Ethiopia (NBE) for real agricultural GDP and the Central Statistical Agency (CSA), World Food and Agriculture Organization (FAO), World Bank Development Indicators Data Base, Ethiopian ministry of Agriculture for fertilizer, improved seed, agricultural land and labour force data. Depending on obtained data, the researcher used descriptive analysis to study the trend of variables over time and used the econometric model for detailed empirical analysis.

A yearly time series data on Real Agricultural Gross Domestic, Coefficient of variation of rainfall and mean monthly annual temperature (as an indicator for climate change), Land input used for agricultural production, total labour force employed, an area under fertilizer usage, and Improved seed usage is gathered covering the period from 1992/93 to 2017/18. The choice of the period is based on the availability of data. Relying on data on these variables, the econometric model is used to estimate the long-run and short-run elasticity of the variables.

In this study, to test the existence of a long-run relationship between the dependent variable AGDP and the other explanatory variables, the autoregressive distributed lag bound testing approach developed by Pesaran et al. (2001) is used. This approach is chosen since this technique has the advantage of being more efficient for studies with a small sample and applies to series that are integrated of order 1, level 0 or mutually cointegrated, unlike the traditional tests such as Engle and granger, Johansen and Juselius, etc.

Following the literature (particularly Eberhardt and Teal, 2012), a Cobb-Douglas production function can be applied to analyze the impact of climate change on agricultural production output. Thus, to quantify the impact of climate change on the economic performance of Ethiopian agriculture, this analysis uses the Autoregressive distributed lag approach on the following empirical production function, which relates agricultural output to the various factors of production.

The functional equation is based on the assumption that a country's agricultural production is a function of technology, capital, labour and climate. Based on the extant literature, a model is specified to perform the relationships between Real Agricultural Gross Domestic Product, Coefficient of variation of annual mean monthly temperature and Coefficient of variation of mean annual rainfall. Since Agricultural Production broadly is a function of capital, labour, and technology; Land input used for agricultural production, total labour force employed, fertilizer usage and improved seed usage are included in the model as control variables. That is: -

RAGDP = f (**CVT, CVR, LD, FA, IS, LF**)

The model employed in this study can be written as follows.

$$\Delta \ln(AGDP_t) = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta \ln(AGDP_{t-i}) + \sum_{i=1}^{q} \alpha_{2i} \Delta CVT_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta CVR_{t-i} + \sum_{i=1}^{q} \alpha_{4i} \Delta \ln(LD_{t-i})$$
$$+ \sum_{i=1}^{q} \alpha_{5i}\, \Delta \ln(FA_{t-i}) + \sum_{i=1}^{q} \alpha_{6i}\, \Delta \ln(IS_{t-i})$$
$$+ \sum_{i=1}^{q} \alpha_{7i} \Delta \ln(LF_{t-i}) + \beta_1 \ln(AGDP_{t-1}) + \beta_2 CVT_{t-1} + \beta_3 CVR_{t-1} + \beta_4 \ln(LD_{t-1})$$
$$+ \beta_5 \ln(FA_{t-1}) + \beta_6 \ln(IS_{t-1}) + \beta_7 \ln(LF_{t-1}) + U_t --------------- (\mathbf{1})$$

The coefficient of variation (CV) is defined as the ratio of the standard deviation to the mean. It shows the extent of variability with the mean of the population. According to Hare (2003), CV is used to classify the degree of variability as less ($CV < 20$), moderate ($20 < CV < 30$), and high ($CV > 30$).

Coefficient of variation as a measure of climate change-induced variability is used since it includes two commonly used measures of temporal climate variability, mean and standard deviation, in one value. The mean value has some drawbacks in providing full information about a population's true characteristics since it is highly affected by extreme values. The coefficient of variation gives an estimate of variability around the average around 67% of the time. It is a measure of relative variability.

The Rainfall and temperature data used to calculate the coefficient of variation are national-level data and annual data is used in the computation is satellite data. But to further analyze the consistency of the empirical result coefficient of variation in each synoptic station (those presenting a general view of the whole country) is computed and the average result is taken in the regression analysis. Furthermore rainfall and temperature coefficient of variation of the country's main wet season, the Meher season has been calculated and analyzed to check the robustness of the empirical result.

Result And Discussion

Before proceeding to the estimation of long-run and short-run models the study summarizes the variables compactly included in the model using graphical representations.

According to the Ethiopian National Bank report, Ethiopia's agricultural GDP growth shows fluctuations over the 26 year study period. To visually analyze the relationship between the coefficient of variation of rainfall and temperature and agricultural GDP growth rate the following graph is generated by the author. From the graph, it is clear that the AGDP growth rate and cvr have a distinct relationship which is negative i.e. AGDP is moving in the opposite direction from cvr.

Econometric Analysis

ARDL approach for cointegration needs that the variables under consideration should be either integrated of order zero or integrated of order one (i.e. I (0) or I (1)) or their combination. Both ADF and PP test results for stationarity indicate that all variables under consideration are either I (0) or I (1). And in both of the tests, there is no variable which is integrated into order two.

The test for the long-run relationship is done using the F-statistic, which will be compared with the lower and upper bounds of Narayan critical values. The result indicates that the F-statistics fall above the Narayan critical value bounds at1% level of significance, which means a conclusive decision can be reached that there is one cointegration equation. As indicated in the above table the F-statistics value which is 5.266 falls above the upper bound critical value which is 4.43 at a 1% level of significance. So, it is conclusive to say there is a cointegrating relationship among the variables under consideration.

Long Run Representation of the Model

Given the existence of cointegration or long-run relationship, the estimation of the long-run equilibrium model is performed.

Table 1

Estimated Long Run coefficients using the ARDL approach

Regressors	Coefficients	Standard Error	T-Ratio	[Prob.]
Cvr	-0.0074849	0.0033264	-2.25	[0.055]
Cvt	-0.2356451	0.0779818	-3.02	[0.017]
Lnld	1.049378	0.4279831	2.45	[0.040]
Lnfa	1.041066	0.2155637	4.83	[0.001]
Lnis	0.1768499	0.0329469	5.37	[0.001]
Lnlf	-0.3538967	1.057172	-0.33	[0.746]
The dependent Variable is lnagdp				
Source: Model result				
Note: - ARDL (1, 1, 1, 1, 1, 2, 2) selected based on Schwartz Information Criterion				

The above results show that all the explanatory variables in the model are significantly determining the real agricultural GDP growth of Ethiopia in the long run. The coefficient of variation of annual rainfall (***cvr***) and coefficient of variation of monthly mean annual temperature (***cvt***) is found to have a negative and significant impact on determining the real agricultural GDP growth of Ethiopia in the long run.

The negative and significant impact of the Coefficient of variation of annual rainfall and coefficient of monthly average annual temperature on real agricultural GDP growth of Ethiopia, in the long run, is consistent with the literature. Climate change and variability affect countries' economies and households through a variety of channels. Rising and changes in temperatures and rainfall patterns affect agricultural yields of both rain-fed and irrigated crops. Climate change and the associated variability will reduce agricultural production and lead to major economic costs (Stern 2006; World Bank, 2008).

In the long run, keeping other factors constant a one per cent (1%) increase in rainfall variability will reduce agricultural output growth by about 0.0075%. Ceteris paribus the reduction in agricultural output growth will be about 0.24% for a 1% increase in the coefficient of variation of temperature.

Table 2
Estimated Long Run coefficients using Synoptic Stations data

Regressors	Coefficients	Standard Error	T-Ratio	[Prob.]
scvr	-0.0034223	0.0014055	-2.43	[0.059]
scvt	-0.1945895	0.0500477	-3.89	[0.012]
lnld	0.4379032	0.2030135	2.16	[0.084]
lnfa	1.145346	0.1390402	8.24	[0.000]
lnis	0.190029	0.0390202	4.87	[0.005]
lnlf	-0.5548926	0.4151409	-1.34	[0.239]
The dependent Variable is lnagdp				

Source: Model result

Note

ARDL (2, 1, 2, 2, 1, 2, 2) selected based on Schwartz Information Criterion

To check the consistency of the regression result of the original model, the climatic variables are calculated by taking the average mean value of each variable from the seventeen synoptic stations which are distributed all over the country. The result obtained from the regression analysis is consistent with the original model's result. Both the variables included in the model to capture climate change and variability (scvr and scvt) has a negative and significant impact on agricultural output growth.

Table 3
Estimated Long Run coefficients using Meher data

Regressors	Coefficients	Standard Error	T-Ratio	[Prob.]
cvmr	-0.0332156	0.0079138	-4.20	[0.003]
cvmt	-0.321304	0.0587443	-0.55	[0.599]
lnld	1.202888	0.2714333	4.43	[0.002]
lnfa	0.9983285	0.1638767	6.09	[0.000]
lnis	0.1315124	0.0188771	6.97	[0.000]
lnlf	-3.403089	0.91345	-3.73	[0.006]
The dependent Variable is lnagdp				
Source: Model result				
Note: - ARDL (2, 1, 2, 2, 1, 0, 1) selected based on Schwartz Information Criterion				

The coefficient of variation of meher rainfall (***cvmr***) is found to have a negative and significant impact in determining the real agricultural GDP growth of Ethiopia in the long run. Whereas the coefficient of variation of monthly mean meher temperature (***cvmt)*** has a negative and statistically insignificant impact in determining the real agricultural GDP growth of Ethiopia in the long run. This analysis is carried out by taking the country's main wet season, Meher, coefficient of variation of rainfall and temperature. The result is consistent with the original model which takes the whole year long rainfall and temperature data as control climatic variables.

Generally from the regression results, we find that rainfall variability captured by the coefficient of variation has a negative and significant impact on agricultural output growth in the country. Ceteris paribus a 1% increase in the coefficient of variation of annual rainfall will reduce agricultural output by 0.0075%. This negative impact will be around 0.03% for a 1% increase in the coefficient of variation of meher rainfall. Similarly, ceteris paribus a 1% incremental change in the coefficient of variation of monthly mean annual temperature will reduce agricultural output by about 0.24%.

Error Correction Model

The coefficient of the error correction term that captures the speed of adjustment toward the long-run equilibrium is found with the correct sign and magnitude. The speed of adjustment is -0. 7184795, which implies that around 71.8% deviations from long-term equilibrium are adjusted every year. This also indicates once the disequilibria happened, it will take a little more than one year to adjust itself towards the long-run equilibrium.

Conclusion

The results of the study provide evidence that the Coefficient of variation of rainfall turns out to affect real agricultural gross domestic product growth negatively in the long run. Similarly Coefficient of variation of meher rainfall affects real agricultural gross domestic product growth negatively in the long run.

The coefficient of variation of monthly mean annual temperature affects real agricultural gross domestic product growth negatively in the long run. Future climate projections of the IPCC mid-range scenario show that climate change and variability will considerably increase. In light of this Ethiopia’s agricultural production will be adversely affected.

Policy Implications

The study has useful implications for policy and future research in the area of economics of climate change in Ethiopia. Since Ethiopia's contribution to global climate change is negligible, policy measures which enhance adaptive capacity and hence reduce the impact of climate change are recommended. The following policy implications emerge from the analysis of the thesis.

First, in the short run diversification into non-farming activities will help to compensate for the foregone income due to climate change. But in the long run, it is recommended to facilitate economic transformation and subsequently reduce reliance on the climate-sensitive sector, agriculture. Second, it is important to develop a long-term water use plan and devise an appropriate irrigation scheme for ensuring climatic resilience. Since rainfall variability is high the uncertainty associated with rainfall must be addressed through irrigation.

Third, it is advisable to assist farmers in coping with current climatic risks by providing value-added weather services to farmers. Farmers can adapt to climate changes to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations. Seasonal weather forecasts could be used as a supportive measure to optimize planting and irrigation patterns. Fourth, intensifying the agricultural production system by improving the technology, irrigation and input delivery system helps to reduce the adverse impact of climate change. It is also recommended to develop climate-resilient crop and livestock varieties that can tolerate the change in the climate.

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Figures

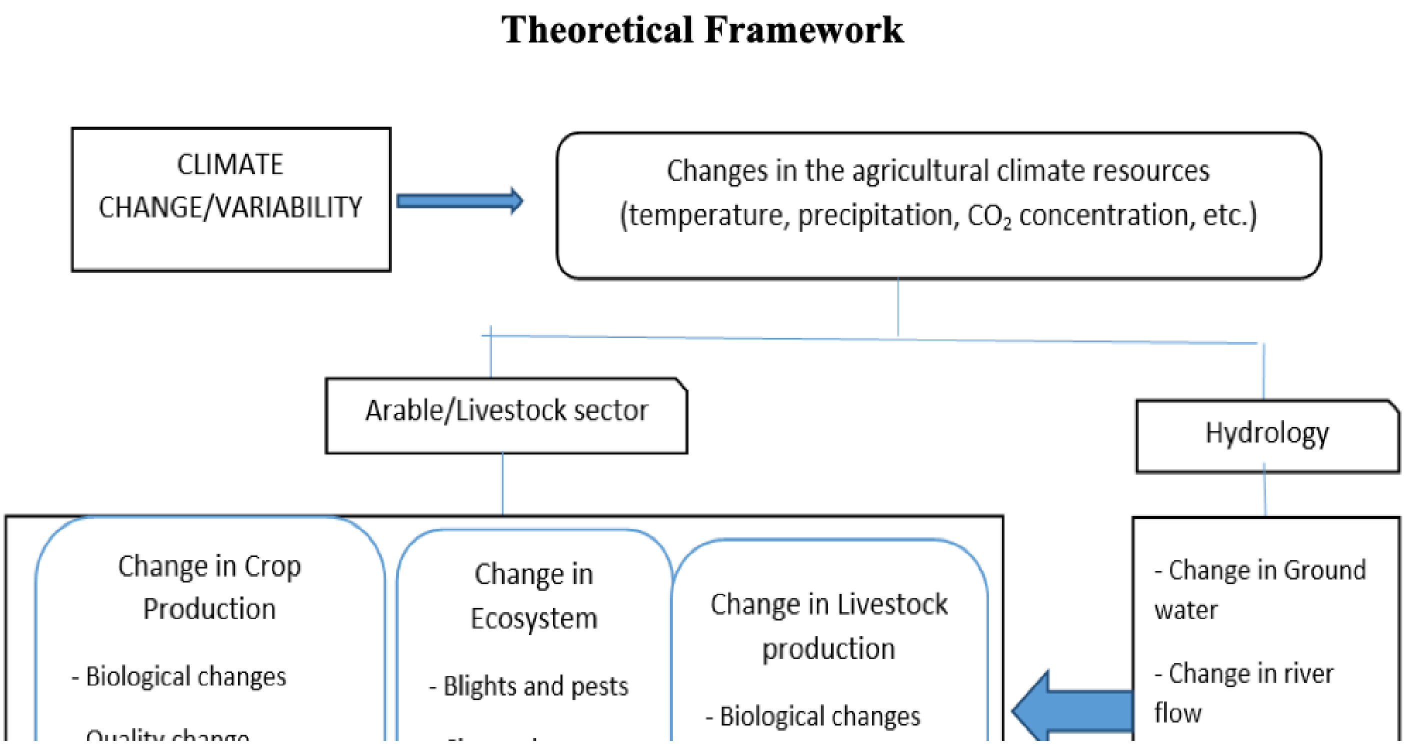

Figure 1

Impact of Climate Change on the Agriculture Sector

Source: based on various authors

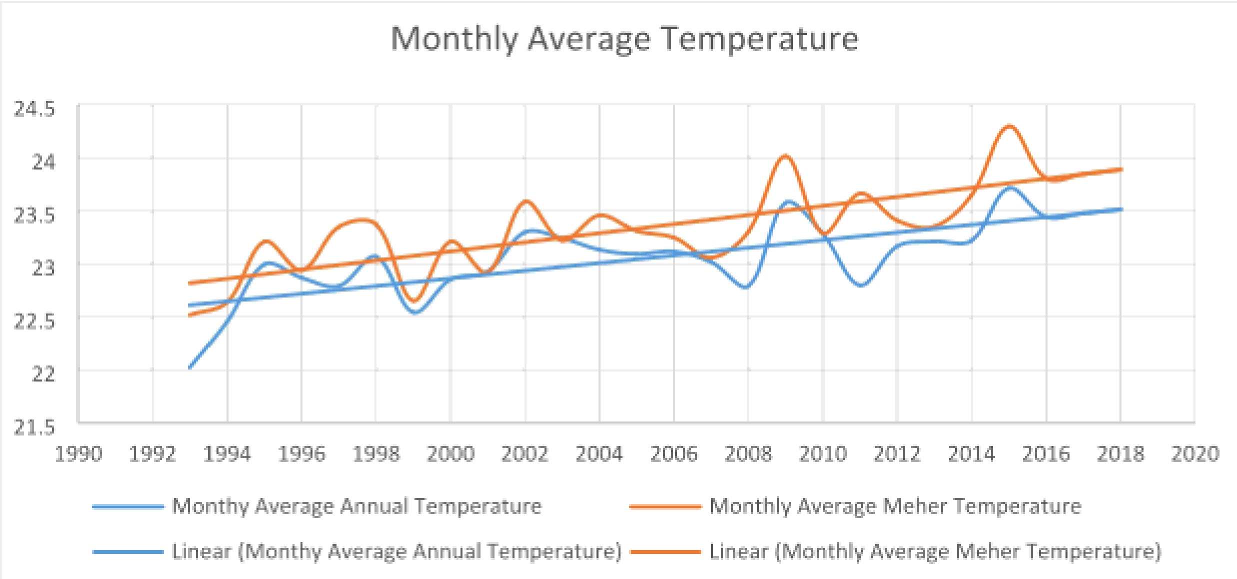

Figure 2

Mean annual Monthly Temperature trend (1993-2018)

Source: Computed based on secondary data sources

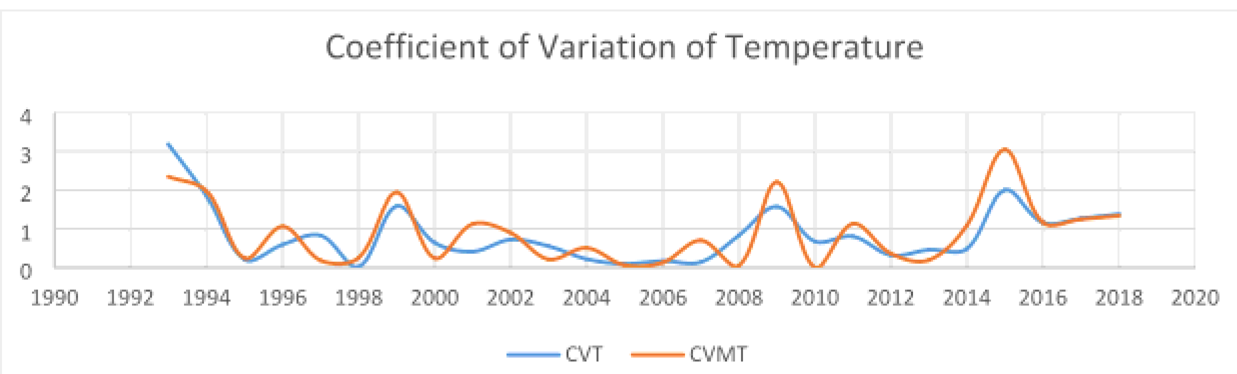

Figure 3

Trend of Coefficient of variation of mean annual monthly and Meher Temperature

Source: Computed based on secondary data sources

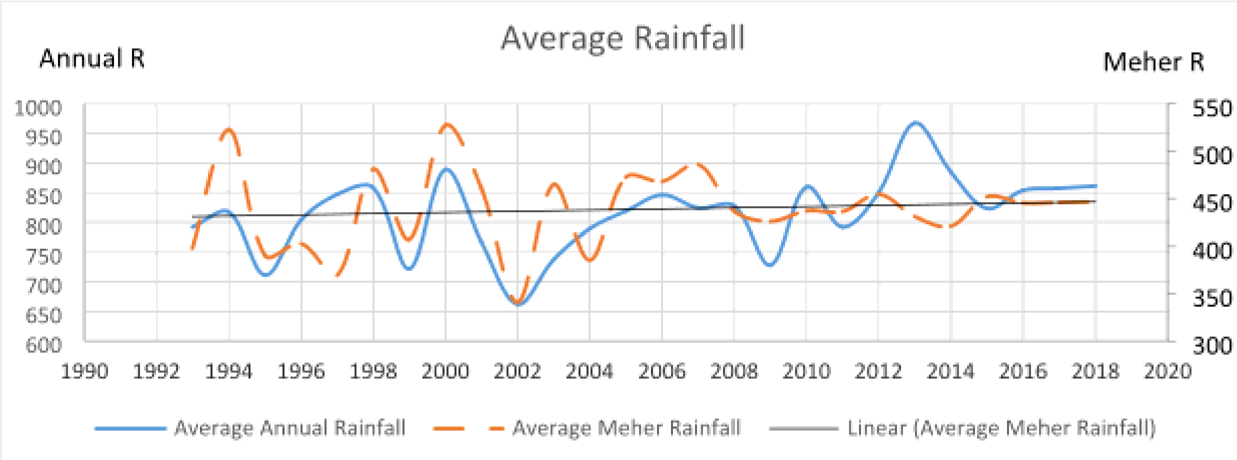

Figure 4

Average Annual Rainfall trend (1993-2018)

Source: Computed based on secondary data sources

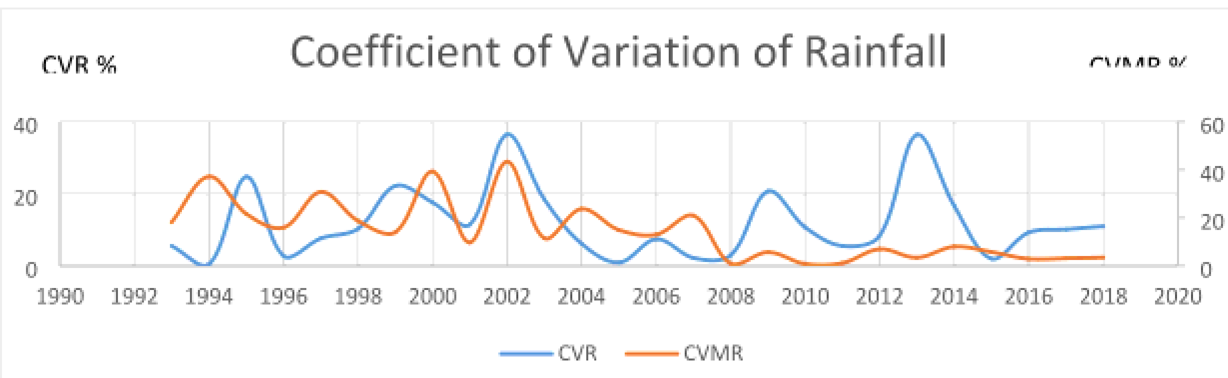

Figure 5

Trend of Coefficient of variation of mean annual and mean meher Rainfall

Source: Computed based on secondary data sources

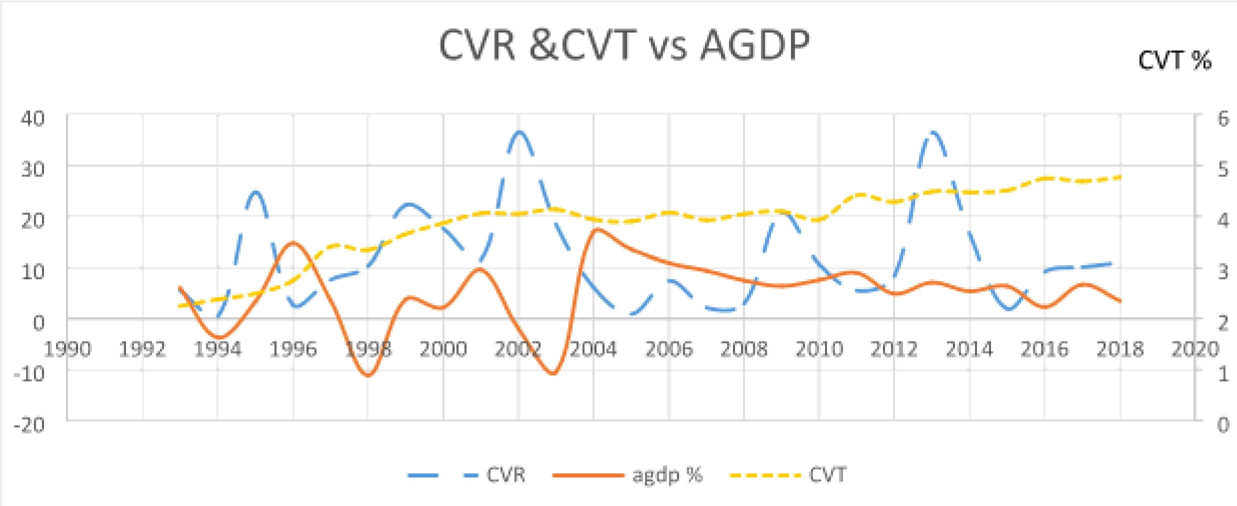

Figure 6

Trend of Coefficient of variation of annual mean monthly Temperature, mean annual Rainfall and Agricultural output growth

Source: Computed based on secondary data sources