

# **Empirical Evidence of Climate Change: Effects on Rice Production in the Northern Region of Ghana**

<sup>1</sup> Franklin Nantui Mabe  
<sup>2</sup> Daniel Bruce Sarpong  
<sup>2</sup> Yaw Osei-Asare

<sup>1</sup> Department of Agricultural and Resource Economics  
Faculty of Agribusiness and Communication Sciences  
University for Development Studies  
Nyankpala, Tamale.

<sup>2</sup> Department of Agricultural Economics and Agribusiness  
College of Agriculture and Consumer Science  
University of Ghana  
Legon, Ghana

---

## ABSTRACT

The evidence of climate change is very crucial in finding alternative solutions to dealing with its effects on agricultural productivity. This study analysed the empirical evidence of climate change and its effects on rice production in the Northern Region of Ghana. The study used paired t-test to establish that climate change is evident in the study area. The climatic conditions in the area have become warmer over the past 40 years. Yield response regression model used to determine the effects of temperature and rainfall on rice yield indicated that if an average annual temperature increases by 1°C, rice yield will decrease by 0.15mt/ha. The study recommends that NGOs and District Assemblies should introduce water conserving measures such as rain harvesting technology to farmers. Farmers should be encouraged to plant trees or integrate trees in their rice farms to serve as canopies to reduce the amount of temperature reaching rice plants.

*Keywords: Climate Change, Ghana, Northern Region, Paired t-test, Rice and Rice Yield Response.*

## 1. INTRODUCTION

Climate change is a serious problem worldwide as it affects agriculture. Agricultural production and climate change have been of central focus to world leaders and researchers in recent days. The potential effects of climate change on agriculture which is driven by human activities cannot be underestimated. According to Stephens (1996), climate change which is mainly caused by accumulation of carbon dioxide, methane and other greenhouse gases is of much interest to scientists and politicians.

Horie (1991), Wu (1996) and Chang (2001) indicated that changes in climatic variables such as amount of rainfall, temperature, wind speed, relative humidity, sunshine duration, among others, are important in determining the yield of crops. The empirical evidence of climate change in developing countries has been of great concern. Stephens (1996) tests, however, observed significant difference in decade temperature during the era 1961-70, 1971-80 and 1981-90 for Ghana. The unpredictable nature of rainfall has changed the planting dates of crops in the Northern Ghana (Mensah-Bonsu, 2003). Ontoyin (1993) and Stephens (1996) have empirically determined the evidence of climate change in Ghana by quantifying the significant changes in temperature and rainfall without considering other climatic variables such as relative humidity and bright sunshine duration. To make research evidence based from the grass root level, this research is important in establishing the current status of climate change in the Northern Region; one of the major food basket regions in Ghana. A greater proportion of rice production in Northern Region and Ghana as a whole is rainfed (Dazé, 2007).

Rice is one of the major staple crops which is produced and consumed by both Ghanaians and foreigners in the country. The production of local rice in Northern Ghana has contributed much to the achievement of food security in the country. The need to meet the demand for local rice has become a major concern with the current increase in rice consumption in the country. Though there has been an increase in the production of local rice, this had not met domestic demand. Year after year, the importation of foreign rice is increasing considerably. The local rice has contributed much to Ghana's capability in achieving food security even though most urban dwellers consume imported rice. Ministry of Food and Agriculture, MoFA (2009) indicated that rice is ranked the second most important food staple in Ghana. For the past three decades, rice production in Ghana has increased but this does not correlate with rice yield. Though, local rice output has increased, the yield declined by close to 12% from 2.72 metric tonnes per hectare in 2008 to 2.40 metric tonnes per hectare in 2009 (Institute of Statistical, Social and Economic Research; ISSER, 2010). Meanwhile, the rice yield in Northern Region declined drastically from 2.40 metric tonnes per hectare in 1991 to 1.72 metric tonnes per hectare (a yield figure which is far below the national level of 2.40) in 2009. In addition to economic factors, changes in climatic and environmental conditions could be the likely reasons for this decline.

Each year, Northern Region is where much area expansion of rice cultivation takes place (Abdulai and Huffman, 2000). Rice is very sensitive to climatic, environmental and soil conditions. Changes in these climatic factors are expected to affect rice yield adversely. Irrigation Company of Upper Regions, ICOUR (2007) indicated that due to the recent increasing population of farmers without the corresponding expansion of irrigation facilities, the irrigation dams are not enough to serve all interested and potential users. The few irrigation facilities are being overstressed. Also, rice farmers are shifting from upland ecological system of farming to lowland system without any documented reasons. The reasons that make upland rice farmers shift into lowland rice farming have not been ascertained. The level of the effects of climate change indicators (changes in temperature, amount of rainfall, relative humidity, wind speed and sunshine duration) need to be established to conclude on the reasons why farmers demand for more irrigation facilities as well as shifting from upland to lowland systems of farming. This study aims at empirically testing for the significant changes in climate variables (rainfall amount, temperature, relative humidity and sunshine duration) in the study area. Also, the study quantifies the effects of climate change indicators on rice yield from 1980 to 2009

## 2. MATERIAL AND METHODS

### 2.1 Paired t-test for comparing decade means of climate variables

Testing the differences between two means can be done using different methods. Stephens (1996) used analysis of variance to test for significant differences between monthly maximum temperatures of 1931-60 and 1961-90. Intergovernmental Panel on Climate Change, IPCC (2007) defined climate change as “change in the state of the average weather conditions which can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties which persists for an extended period, typically decades or longer”. This study used paired t-test to compare two decades’ means of climate variables (temperature, amount of rainfall, relative humidity, wind speed and sunshine duration) so as to establish whether the difference is significant or not. The hypotheses tested are:

$$H_0: \bar{\chi}_{2i} = \bar{\chi}_{1i}$$

$$H_A: \bar{\chi}_{2i} > \bar{\chi}_{1i} \text{ for temperature and bright sunshine duration.}$$

$$H_A: \bar{\chi}_{2i} < \bar{\chi}_{1i} \text{ for rainfall and relative humidity.}$$

The t-calculated is given as

$$t - calculated = \frac{\bar{\chi}_{2i} - \bar{\chi}_{1i}}{SE_i} \quad (1)$$

Where  $\bar{\chi}_{2i}$  and  $\bar{\chi}_{1i}$  are the means for the current and the previous decades compared for  $i$ th climate variable respectively and  $SE_i$  is the standard error for  $i$ th climate variable. If  $t - calculated$  is greater than the critical  $t^*$  value from the conventional student t-statistical distribution at a determined significant level, the null hypothesis is rejected in favour of the alternate. If the null hypothesis is rejected, it implies there is significant difference between the two decades’ means compared. Therefore, climate has change with respect to that particular variable. The reverse is true if  $t - calculated$  is less than the critical  $t^*$  value.

### 2.2 Effects of climate change indicators on rice yield

#### 2.2.1 Empirical framework

Chen and Chang (2005), Lobell et al. (2007) and Chang (2001) have estimated crop yield response functions by using field data on crop yields, climate and non-climate related variables. According to these researchers, the yearly impact of climate change can be linked to the respective year’s crop yield. Crop yield response model in this study uses a production function approach which was adopted by Chang (2001) to quantify the effects of climate change indicators on rice yield for the past 30years (1980-2009). The basic concept of this model is that the trend of rice yield is affected by climatic variables especially changes in temperature and rainfall and non-climatic variables such as socioeconomic factors, technology and soil conditions (Lobell et al., 2007). According to Chang (2001), rice yield response (production) function is given as:

## Yield = f (Climate, Technology, Management, Land) (2)

The yield is the output in metric tonnes per hectare; climate and land denote climatic factors and soil conditions respectively. The climatic variables (rainfall, temperature, relative humidity and sunshine duration) are not controlled by farmers and hence are exogenous factors. At individual level, each farmer tries to maximize yield by choosing endogenous variable inputs such that the resulting yield becomes a function of exogenous variables such as rainfall, temperature, relative humidity and sunshine duration, price of output, price of inputs and soil conditions (Mendelsohn et al., 1994). Chen and Chang (2005) indicated that temperature and rainfall are the major climatic variables that affect crop yield even though other climatic factors may have significant effects.

### 2.2.2 Rice yield response to climate variables

According to Lobell et al., (2007), the contribution of climate to crop yield trends can be estimated by modelling the crop yield data without removing trend factor as a function of both time and climatic variables. Mainardi (2010) assumed that the effects of the previous years' crop yield on the current years' crop yield measure the technological changes. Soil condition can be proxied by the slope of the land in the study area. The slope of the land depends on the area that each farmer cultivates rice. Following Chang (2001), management of farms can be measured as the ratio of full-time farm households to total farm households in the area. Since rice yield data is not taken at the farmer level but at the regional level, the soil condition and the management variables are excluded in the model used in this study.

The corresponding differences in annual minimum and maximum temperature and rainfall are included in the model in order to measure the influence of departure from normal climatic conditions on rice yield (Chang, 2001). These variables also capture the extreme event on rice yield. According to Mendelsohn et al., (1996), when one omits the variation term of temperature or rainfall, the estimation of the effects of global warming on crop yield will be bias. Temperature and rainfall have a non-linear effect on rice yield. The actual yield response model is given as:

$$Y_t^R = \delta_0 + \delta_1 Y_{t-1}^R + \delta_2 T_t + \delta_3 T_t^2 + \delta_4 R_t + \delta_5 R_t^2 + \delta_6 VarT_t + \delta_7 VarR_t + \xi_t \quad (3)$$

where  $\delta_{t-1}$ ,  $\delta_1$ ,  $\delta_2$ ,  $\delta_3$ ,  $\delta_4$ ,  $\delta_5$ , and  $\delta_6$  are the slope coefficients of the explanatory variables  $Y_{t-1}^R$ ,  $T_t$ ,  $T_t^2$ ,  $R_t$ ,  $R_t^2$ ,  $VarT_t$  and  $VarR_t$  respectively.  $Y_t^R$ ,  $Y_{t-1}^R$ ,  $T_t$  and  $R_t$  denote rice yield (metric tonnes per hectare) in year  $t$ , previous years rice yield (metric tonnes per hectare), average annual temperature ( $^{\circ}\text{C}$ ) in year  $t$ , annual rainfall amount (mm) in year  $t$  respectively.  $VarT_t$  and  $VarR_t$  represent differences between monthly minimum and maximum average temperatures ( $^{\circ}\text{C}$ ) and total rainfall amount (mm) in year  $t$  respectively. The non-linear temperature and rainfall amount variables are shown by  $T_t^2$  and  $R_t^2$  respectively. Lastly,  $\xi_t$  is the stochastic error term which satisfies the classical normal regression assumptions.

Chang (2001) used linear-log functional form to estimate crop yield response model based on the fact that temperature and rainfall have non-linear relationship with crop yield. The same functional form was used in this research because it addresses the issue of non-linear relationship between rice yield

$$Y_t^R = \delta_0 + \delta_1 Y_{t-1}^R + \delta_2 \ln(T_t) + \delta_3 \ln(T_t^2) + \delta_4 \ln(R_t) + \delta_5 \ln(R_t^2) + \delta_6 \ln(VarT_t) + \delta_7 \ln(VarR_t) + \xi_t \quad (5)$$

**Table 1: Apriori expectations of rice yield response model**

| Variables                                           | Parameters | A priori Expectations |
|-----------------------------------------------------|------------|-----------------------|
| Previous years rice yield ( $Y_{t-1}^R$ )           | $\delta_1$ | Positive              |
| Temperature ( $T_t$ )                               | $\delta_2$ | Negative              |
| Extremely high temperature ( $T_t^2$ )              | $\delta_3$ | Negative              |
| Rainfall ( $R_t$ )                                  | $\delta_4$ | Positive              |
| Rainfall Square/extremely high rainfall ( $R_t^2$ ) | $\delta_5$ | Negative              |
| Maximum - minimum temperature; extreme ( $VarT_t$ ) | $\delta_6$ | Negative              |
| Maximum - minimum rainfall; extreme ( $VarR_t$ )    | $\delta_7$ | Negative              |

Source: Author's analysis (2011)

### **2.2.3 Statements of hypothesis**

- A.  $H_0$ : Extreme variations in temperature ( $VarT_t$ ) have no effect on rice yield.  
 $H_1$ : Extreme variations in temperature ( $VarT_t$ ) have negative effect on rice yield.  
Extreme variations in annual rainfall amounts ( $VarR_t$ ), normal level of temperature ( $T_t$ ), extreme level of temperature ( $T_t^2$ ) and extremely level of rainfall amount ( $R_t^2$ ) follow similar hypotheses stated above.
- B.  $H_0$ : Normal rainfall amounts ( $R_t$ ) have no effect on rice yield.  
 $H_1$ : Normal rainfall amounts ( $R_t$ ) have positive effect on rice yield.
- C.  $H_0$ : Advanced in technology ( $Y_{t-1}^R$ ) have no effect on rice yield.  
 $H_1$ : Advanced in technology ( $Y_{t-1}^R$ ) increases rice yield

### **2.2.4 Validation of hypothesis**

The student t-statistic test is used to test the null hypotheses stated above. It is used to determine whether the estimated parameters are significantly different from zero.

## **2.3 Data**

This research used pooled time-series data to estimate the effects of climate change on rice yield in the Northern Region of Ghana. The years considered in the current study are from 1970 to 2009. Rice yield in metric tones per hectare were obtained from the Statistics, Research and Information Directorate (SRID) of Ministry of Food and Agriculture (MoFA). Temperature, rainfall amounts, relative humidity, wind speed and sunshine duration were obtained from Ghana Meteorological Agency (GMA). Chang (2001) in a similar analysis used the quarterly average temperature and rainfall data. Since the study area of this research has only one rainy season, the average annual climate variables were used instead of the quarterly average climate change variables.

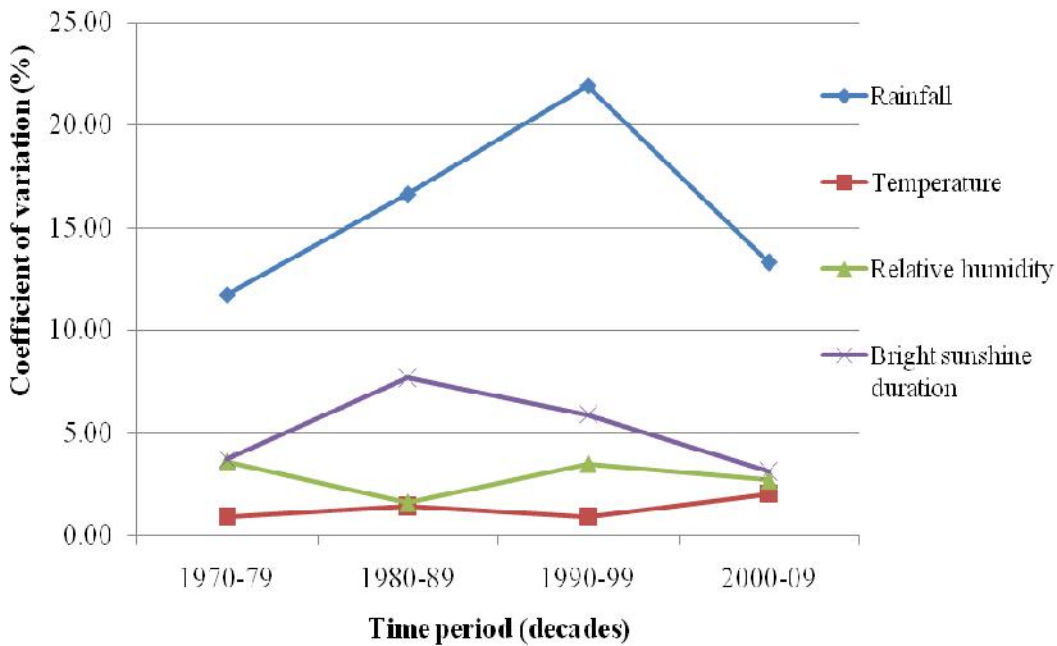
## **3. RESULTS AND DISCUSSION**

### **3.1 Variability in climatic variables**

Figure 1 shows line graphs that describe the coefficient of variation for each of the climatic variables over the past four decades. The graphs indicate the variability of rainfall, temperature, relative humidity and bright sunshine duration. From the figure, the dispersion or variability of rainfall amount relative to the mean is highest (21.9%) during the third decade (1990-99). The first decade (1970-79) recorded the lowest coefficient of variation in rainfall amount (11.7%) and this is followed by the fourth decade (2000-09).

The coefficient of variation for temperature has been the lowest among the other climatic variables for the past four decades. The variability in temperature fluctuates slightly over the decades. The graph for bright sunshine duration indicates that there is a general rise in the dispersion of bright sunshine duration from 3.7% in the first decade to 7.7% in the second decade and this declined thereafter to 3.1% in the fourth decade.

**Figure 1: Variability in climatic variables**



Source: Author's analysis based on GMA data (2011)

### 3.2 Empirical evidence of climate change

This section tests the evidence of climate change by comparing means of any two decades' rainfall amount, temperature, relative humidity and bright sunshine duration.

#### 3.2.1 Empirical evidence of changes in rainfall

Table 2 indicates the paired t-test for comparing decades' means of total annual rainfall to establish whether there is significant change in the means. The t-statistics and the p-values shown in the table indicated that none of the two decades' means of total annual rainfall values compared is statistically significant. This implies that there is no significant difference in the decades' means of total annual rainfall between 1970–79 and 1980–89; 1970–79 and 1990–99; 1970–79 and 2000–09; 1980-89 and 1990-99; 1980-89 and 2000-09; and 1990-99 and 2000-09. Therefore, climate has not changed in terms of rainfall amount.

**Table 2: Paired t-test for comparing decades' means of average total annual rainfall**

| Decades | Mean Rainfall | n  | df | t-Statistic | t-Critical (one tail) | P-Value (one tail) |
|---------|---------------|----|----|-------------|-----------------------|--------------------|
| 1970–79 | 1065.77       | 10 |    |             |                       |                    |
| 1980–89 | 1062.76       | 10 | 9  | -0.0599     | 1.8331                | 0.4768             |
| 1970–79 | 1065.77       | 10 |    |             |                       |                    |
| 1990–99 | 1119.92       | 10 | 9  | 0.8235      | 1.8331                | 0.2157             |
| 1970–79 | 1065.77       | 10 |    |             |                       |                    |
| 2000–09 | 1060.07       | 10 | 9  | -0.0829     | 1.8331                | 0.4679             |
| 1980–89 | 1062.76       | 10 |    |             |                       |                    |
| 1990–99 | 1119.92       | 10 | 9  | 0.6642      | 1.8331                | 0.2616             |
| 1980–89 | 1062.76       | 10 |    |             |                       |                    |
| 2000–09 | 1060.07       | 10 | 9  | -0.0322     | 1.8331                | 0.4875             |
| 1990–99 | 1119.92       | 10 |    |             |                       |                    |
| 2000–09 | 1060.07       | 10 | 9  | -0.5814     | 1.8331                | 0.2876             |

Source: Author's analysis based on GMA data (2011)

n and df represent the number of years and degree of freedom respectively.

### 3.2.2 Empirical evidence of global warming

The paired t-test results in table 3 show the empirical evidence of changes in decades' means of annual temperature. The difference between 1970–79 and 1980–89 decades' means of average annual temperature is statistically significant at 10% and consistent with the a priori expectation. The difference in the decades' means of average annual temperature between 1970–79 and 1990–99 is highly significant at 1% and consistent with the a priori expectation. This means there is significant difference between decades' means of average annual temperature values of 28.60°C and 28.07°C. The t-test value of 2.99 implies that the difference between 1970–79 and 2000–09 means of average annual temperature is statistically significant at 1%. Therefore, there is a significant difference between 1970–79 mean value of 28.07°C and 2000–09 mean value of 28.66°C. It also supports the a priori expectation that climate is becoming warmer.

**Table 3: Paired t-test for comparing decades' means of average annual temperature**

| Decades | Mean temperature | n  | df | t-Stat | t-Critical (one tail) | P-Value (one tail) |
|---------|------------------|----|----|--------|-----------------------|--------------------|
| 1970–79 | 28.0658          | 10 |    |        |                       |                    |
| 1980–89 | 28.2658          | 10 | 9  | 1.8349 | 1.8331                | 0.0523*            |
| 1970–79 | 28.0658          | 10 |    |        |                       |                    |
| 1990–99 | 28.5983          | 10 | 9  | 4.9202 | 1.8331                | 0.0004***          |
| 1970–79 | 28.0658          | 10 |    |        |                       |                    |
| 2000–09 | 28.6559          | 10 | 9  | 2.9861 | 1.8331                | 0.0077***          |
| 1980–89 | 28.2658          | 10 |    |        |                       |                    |
| 1990–99 | 28.5983          | 10 | 9  | 2.5272 | 1.8331                | 0.0162**           |
| 1980–89 | 28.2658          | 10 |    |        |                       |                    |
| 2000–09 | 28.6559          | 10 | 9  | 1.8335 | 1.8331                | 0.0585*            |
| 1990–99 | 28.5983          | 10 |    |        |                       |                    |
| 2000–09 | 28.6559          | 10 | 9  | 0.3011 | 1.8331                | 0.3851             |

Source: Author's analysis based on GMA data (2011)

\*, \*\*, \*\*\* represent 10%, 5% and 1% levels of significance respectively

Also, the difference between the mean temperatures of 1980–89 and 1990–99, and 1980–89 and 2000–09 are statistically significant at 5% and 10% respectively. This implies there is a significant difference between the mean value of 28.60°C from 1980–89 and that of 28.27°C from 1990–99. Additionally, the mean value of 28.27°C obtained from 1990–99 and 28.67°C obtained from the period 2000–09 are not statistically the same. Meanwhile, there is no significant difference between the mean

decade temperatures of 1990–99 and 2009–09. So, in terms of temperature, climate change is evident in Northern Region of Ghana.

### 2.2.3 Empirical evidence of changes in relative humidity

Table 4 below depicts paired t-test for comparing decades' means of annual relative humidity. The t-test results show that there are no significant differences between any of the decades' means of relative humidity even though some of them met the a priori expectation. Therefore, climate has not changed in terms of relative humidity.

**Table 4: Paired t-test for comparing decades' means of average annual relative humidity**

| Decades | Mean Relative Humidity | n  | df | t-Statistic | t-Critical (one tail) | P-Value (one tail) |
|---------|------------------------|----|----|-------------|-----------------------|--------------------|
| 1970–79 | 76.1833                | 10 |    |             |                       |                    |
| 1980–89 | 75.8611                | 10 | 9  | 0.3262      | 1.8331                | 0.3759             |
| 1970–79 | 76.1833                | 10 |    |             |                       |                    |
| 1990–99 | 75.8333                | 10 | 9  | 0.3778      | 1.8331                | 0.3571             |
| 1970–79 | 76.1833                | 10 |    |             |                       |                    |
| 2000–09 | 76.0772                | 10 | 9  | -0.0853     | 1.8331                | 0.4670             |
| 1980–89 | 75.8611                | 10 |    |             |                       |                    |
| 1990–99 | 75.8333                | 10 | 9  | -0.0263     | 1.8331                | 0.4898             |
| 1980–89 | 75.8611                | 10 |    |             |                       |                    |
| 2000–09 | 76.0772                | 10 | 9  | -0.2878     | 1.8331                | 0.3900             |
| 1990–99 | 75.8333                | 10 |    |             |                       |                    |
| 2000–09 | 76.0772                | 10 | 9  | -0.2131     | 1.8331                | 0.4180             |

Source: Author's analysis based on GMA data (2011)

### 3.2.4 Empirical evidence of changes in bright sunshine duration

The empirical evidence of climate change shown by changes in decades' means of bright sunshine duration is illustrated in table 5. The paired t-test for the differences in bright sunshine duration between 1970–79 and 1980–89 is statistically significant at 5%. This is supported by the p-value of 0.0367. This implies that there is a significant difference between the decades' means of average annual bright sunshine duration values of 7.4299hours and 7.0083hours. The difference between the means is not consistent with the a priori expectation meaning the test does not support that bright sunshine duration is increasing. Hence, bright sunshine duration had decreased from 7.42992hours (1970–79) to 7.00833hours (1980–89).

**Table 5: Paired t-test for comparing decades' means of average annual bright sunshine duration**

| Decades          | Mean sunshine duration | n         | df       | t-Stat         | t-Critical (one tail) | P-Value (one tail) |
|------------------|------------------------|-----------|----------|----------------|-----------------------|--------------------|
| <b>1970 – 79</b> | <b>7.4299</b>          | <b>10</b> |          |                |                       |                    |
| <b>1980 – 89</b> | <b>7.0083</b>          | <b>10</b> | <b>9</b> | <b>-2.0296</b> | <b>1.8331</b>         | <b>0.0365**</b>    |
| 1970 – 79        | 7.4299                 | 10        |          |                |                       |                    |
| 1990 – 99        | 7.2047                 | 10        | 9        | -1.2294        | 1.8331                | 0.1250             |
| 1970 – 79        | 7.4299                 | 10        |          |                |                       |                    |
| 2000 – 09        | 7.3558                 | 10        | 9        | -0.9564        | 1.8331                | 0.1819             |
| 1980 – 89        | 7.0083                 | 10        |          |                |                       |                    |
| 1990 – 99        | 7.2047                 | 10        | 9        | 0.9115         | 1.8331                | 0.1929             |
| <b>1980 – 89</b> | <b>7.0083</b>          | <b>10</b> |          |                |                       |                    |
| <b>2000 – 09</b> | <b>7.3558</b>          | <b>10</b> | <b>9</b> | <b>2.2050</b>  | <b>1.8331</b>         | <b>0.0275**</b>    |
| 1990 – 99        | 7.2047                 | 10        |          |                |                       |                    |
| 2000 – 09        | 7.3558                 | 10        | 9        | 1.0343         | 1.8331                | 0.1640             |

Source: Author's analysis based on GMA data (2011)

\*\* represents 5% level of significance

Also, there is a significant difference between the decades' means of average annual bright sunshine duration of 1980–89 and 2000–09. The p-value of 0.0274 indicates that the test is significant at 5%. The difference in the mean values is consistent with the a priori expectation. This means the decades' means of average annual bright sunshine duration value of 7.0083hours (1980–89) is significantly different from that of 7.3558hours (2000–09).

### 3.3 Effects of climate change indicators on rice yield

Table 6 below shows the mean values of the climate and non-climate variables used for estimating the rice yield response model.

**Table 6 Mean values of climate and non-climate variables**

| Variable                           | Mean   |
|------------------------------------|--------|
| <b>Non-climate</b>                 |        |
| Rice yield (Mt/ha)                 | 1.65   |
| Lag rice yield (Mt/ha)             | 1.63   |
| <b>Climate</b>                     |        |
| Temperature ( $^{\circ}\text{C}$ ) | 30.36  |
| Rainfall (mm)                      | 90.08  |
| <b>Climate variations</b>          |        |
| Temperature ( $^{\circ}\text{C}$ ) | 30.95  |
| Rainfall (mm)                      | 257.81 |

Source: Author's computation based on GMA data (2011)

Table 7 presents regression results on the effects of climate change indicators on rice yield in the study area. Linear-log model was used because it gave better estimators and goodness of fit than other models. The coefficient of determination ( $R^2$ ) shown in the table indicates that 62% of the variations in rice yield is explained by the variations in the previous years' rice yield ( $Y_{t-1}^R$ ), temperature ( $T_t$ ), rainfall ( $R_t$ ), variations between maximum and minimum temperature ( $VART_t$ ) and rainfall ( $VARR_t$ ). The F-statistic also shows that the explanatory variables jointly and significantly affects rice yield. The Durbin-Watson value of 2.3 implies that there is no linear relationship between any of the explanatory variables (no multicollinearity). Additionally, the White test with p-value of 0.041 of the computed chi-square indicates that Heteroskedasticity is absent. This implies that the variance of the error term is constant.

**Table 7: Yield Response to climate change variables**

| Variable effects   | Coefficients | Std. Error            | t-Statistic | Prob.      | Marginal |
|--------------------|--------------|-----------------------|-------------|------------|----------|
| $Y_{t-1}^R$        | 0.3184       | 0.1749                | 1.8207      | 0.0811*    | 0.32     |
| $\ln(T_t)$         | -4.4716      | 1.3415                | -3.3332     | 0.0028***  | -0.15    |
| $\ln(R_t)$         | -0.4495      | 0.5197                | -0.8649     | 0.3957     |          |
| $\ln(VART_t)$      | 0.4191       | 1.0443                | 0.4013      | 0.6917     |          |
| $\ln(VARR_t)$      | 0.2387       | 0.3013                | 0.7920      | 0.4361     |          |
| C                  | 15.6462      | 7.1574                | 2.1860      | 0.0388     |          |
| R-squared          | 0.6844       | Mean dependent var    |             | 1.65400    |          |
| Adjusted R-squared | 0.6187       | S.D. dependent var    |             | 0.63272    |          |
| S.E. of regression | 0.3907       | Akaike info criterion |             | 1.13520    |          |
| Sum squared resid  | 3.6639       | Schwarz criterion     |             | 1.41543    |          |
| Log likelihood     | -11.0280     | F-statistic           |             | 10.40982   |          |
| Durbin-Watson stat | 2.2699       | Prob(F-statistic)     |             | 0.00002*** |          |

Dependent Variable: Rice yield ( $Y_t^R$ )  
Method: Least Squares  
Sample: 1980-2009  
White Heteroskedasticity-Consistent Standard Error & Covariance

\*, \*\*\* represent 10% and 1% levels of significance respectively

Source: Regression results computed from GMA data (2011)

From table 7, the coefficient of previous year's rice yield ( $Y_{t-1}^R$ ) which measures the effects of technological changes on rice yield is consistent with the a priori expectation. It is also significant at 10% indicating that technological changes significantly affects rice yield. More importantly, average annual temperature ( $T_t$ ) is consistent with the a priori expectation. It is significant at 1 percent meaning that average annual temperature has significant effects on rice yield in the study area. Therefore, an extreme increase in temperature reduces rice yield. In other words, the warmer the climatic conditions, the lesser the rice yield. In this study, the variations between minimum and maximum temperatures do not have significant effects on rice yield. From the table 7, the marginal effects for average annual temperature and previous year's rice yield are 0.15 and 0.32 respectively. This suggests that if average annual temperature increases by  $1^{\circ}\text{C}$ , rice yield will decrease by 0.15mt/ha. Lastly, a unit advancement in technology will result in an increase in rice yield by 0.32mt/ha.

#### 4. CONCLUSIONS AND POLICY RECOMMENDATIONS

This study determined the empirical evidence of climate change using paired t-test. It also quantified the effects of climate change indicators (rainfall and temperature) on rice yield in the Northern Region of Ghana. The paired t-test revealed that climate has changed over the past 40years in terms of significant changes in decade temperatures and bright sunshine duration. Rainfall and relative humidity have not significantly changed during the period 1970-2009. Also, the results from the rice yield response regression model indicated that an increase in average annual temperature by  $1^{\circ}\text{C}$  will decrease rice yield by 0.15mt/ha.

It is recommended that District Assemblies, District MoFA Directorate and Non-Governmental Organisations (NGOs) should introduce water conserving measures (rain harvesting) to farmers to help them keep water for usage during rice production. Also, small dams and water reservoirs should be constructed in other rice farming communities to complement the existing small dams in Golinga, Botanga, Bunglung, Libga and Kukobila. Furthermore, farmers should be encouraged to adopt mulching as water conserving measure to reduce the detrimental effects of high temperature on rice in the field. Lastly, farmers should be encouraged to plant trees or integrate trees in their rice farms to serve as canopies to reduce the amount of temperature reaching rice plants.

#### COMPETING INTERESTS

"Authors have declared that no competing interests exist".

#### AUTHORS' CONTRIBUTIONS

Author 1' designed the entire study. He collected the data, performed the statistical analysis and wrote the first draft of the manuscript. Authors 2 and 3 compelled the relevant literature and made the necessary corrections to the manuscript. All authors read and approved the final manuscript.

#### REFERENCES

Abdulai A, Huffman W. Structural adjustment and economic efficiency of rice farmers in Northern Ghana. *Economic Development and Cultural Change*, 2000: 48: 503–520.

Chang CC. The potential impact of climate change on Taiwan's Agriculture. *Agricultural Economics*: 2001 27: 51–64.

Chen CC, Chang CC. The impact of weather on crop yield distribution in Taiwan: some new evidence from panel data models and implications for crop insurance. *Agricultural Economics*: 2005: 33:503–511.

355 Dazé A. Climate change and poverty in Ghana. Unpublished report by CARE International Ghana,  
356 Ghana: 2007.

357 Horie T. Model analysis of the effect of climate variation on rice yield in Japan. In: Proceedings of  
358 climate variations and change: Implications for Agriculture in the Pacific Rim. University of California,  
359 Davis: 1991: 159-168.

360 ICOUR. Annual Performance Report: Irrigation Company of Upper Regions. Bolgatanga. Ghana:  
361 2007.

362 IPCC: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the  
363 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon S, Qin D,  
364 Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds.)). Cambridge University Press,  
365 Cambridge, United Kingdom and New York, NY, USA: 2007.

366 ISSER: The State of Ghanaian Economy in 2009. Institute of Statistical, Social and Economic  
367 Research, University of Ghana, Legon. Accra: 2010.

368 Lobell DB, Cahill NK, Field BC. Historical effects of temperature and precipitation on California Crop  
369 Yields. *Springer Science Business Media B.V.*: 2007: 81: 187–203  
370

371 Mainardi S. Cropland use, yields, and droughts: spatial data modelling for Burkina Faso and Niger.  
372 Department of Informatics and Econometrics, UKSW—Card. S. Wyszyński University, Warsaw,  
373 Poland: 2010.

374 Mendelsohn R, Nordhaus WD, Shaw D. The impact of global warming on agriculture: A Ricardian  
375 analysis. *American Economic Review*: 1994: 84: 753–771.

376 Mendelsohn R, Nordhaus WD, Shaw D. Climate impacts on aggregate farm value: accounting for  
377 adaptation, agricultural. *Agric. Forest Meteorol*: 1996: 80: 55-66.  
378

379 Mensah-Bonsu, A. Migration and Environmental Pressure in Northern Ghana,  
380 Vrije University, Amsterdam: 2003.

381 MoFA. National Rice Development Strategy Draft, Ministry of Food and Agriculture, Accra: 2009.

382 Ontoyin Y. A comparative study of temperature as a climate indicator for the periods 1931-60 and  
383 1961-90: proceedings of a workshop on climate change and its impacts on water, ocean fishing and  
384 coastal zones. CSSIR, Accra, Ghana. 16-18th March, 1993.

385 Stephens CS. Some empirical evidence of global warming in Ghana. *Ghana Journal of Science*:  
386 1996: Volume 31-36.

387 Wu H. The impact of climate change on rice yield in Taiwan. In: Mendelsohn, R., Shaw, D. (Eds.). The  
388 economics of pollution control in the Asia Pacific. Edward Elgar, Cheltenham, UK: 1996.