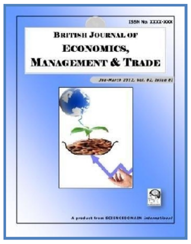

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Empirical Evidence of Climate Change: Effects on Rice Production in the Northern Region of Ghana

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Authors' contributions

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

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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 40years. 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 1ºC, 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.

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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 [1], 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[2], Wu [3] and Chang [4] 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 [1] 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 [5]. Ontoyin[6] and Stephens [1] 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[7].

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[8] 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 [9]. 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 [10]. 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 [11] 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. MATERIALS 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 [12] 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: $\overline{\chi}_{2i} = \overline{\chi}_{1i}$

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

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

The t-calculated is given as

$$t - calculated = \frac{\overline{\chi}_{2i} - \overline{\chi}_{1i}}{SE_i} \tag{1}$$

Where $\overline{\chi}_{2i}$ and $\overline{\chi}_{1i}$ 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 [13], Lobell et al. [14] and Chang [4] 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 [4] 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 [14]. According to Chang [4], rice yield response (production) function is given as:

$$\text{Yield} = f\ (\text{Climate, Technology, Management, Land}) \tag{2}$$

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 [15]. Chen and Chang [13] 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.,*[14], 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[16] 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 [4], 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 [4]. These variables also capture the extreme event on rice yield. According to Mendelsohn et al., [17], 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:

$$Y_t^R = \delta_o + \delta_t Y_{t-1}^R + \delta_1 T_t + \delta_2 T_t^2 + \delta_3 R_t + \delta_4 R_t^2 + \delta_5 VarT_t + \delta_6 VarR_t + \xi_t \tag{3}$$

whereδ_{t-1}, δ_1,δ_2, δ_3, δ_4, δ_5, and δ_6 are the slope coefficients of the explanatory variables Y^R_{t-1}, T_t, T_t^2, R_t, R_t^2, $VarT_t$and $VarR_t$respectively. Y_t^R, Y^R_{t-1}, 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 (^{0}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 (^{0}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 [4] 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 and climatic values. The a priori expectations for the explanatory variables used in equation (5) are summarized in table 1 below.

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

Table 1. Apriori expectations of rice yield response model

Variables	Parameters	A priori Expectations
Previous years rice yield (Y_{t-1}^R)	δ_t	Positive
Temperature (T_t)	δ_1	Negative
Extremely high temperature (T_t^2)	δ_2	Negative
Rainfall (R_t)	δ_3	Positive
Rainfall Square/extremely high rainfall (R_t^2)	δ_4	Negative
Maximum - minimum temperature; extreme ($VarT_t$)	δ_5	Negative
Maximum - minimum rainfall; extreme ($VarR_t$)	δ_6	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 [4] 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

Fig. 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.

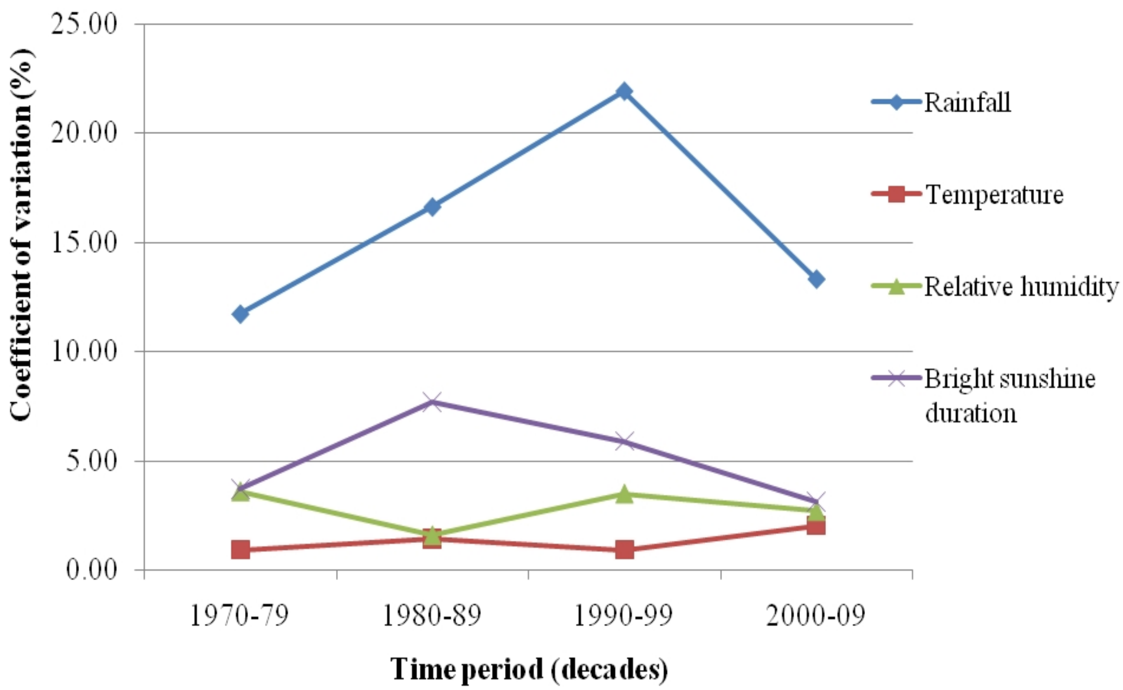

Fig. 1. Variability in climatic variables

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				0.4768
1980–89	1062.76	10	9	-0.0599	1.8331	
1970–79	1065.77	10				
1990–99	1119.92	10	9	0.8235	1.8331	0.2157
1970–79	1065.77	10		-0.0829	1.8331	0.4679
2000–09	1060.07	10	9			
1980–89	1062.76	10			1.8331	0.2616
1990–99	1119.92	10	9	0.6642		
1980–89	1062.76	10		-0.0322	1.8331	
2000–09	1060.07	10	9			0.4875
1990–99	1119.92	10		-0.5814		
2000–09	1060.07	10	9		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^{0}C and 28.07^{0}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^{0}C and 2000–09 mean value of 28.66^{0}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	9	1.8349		0.0523*
1980–89	28.2658	10			1.8331	
1970–79	28.0658	10		4.9202	1.8331	0.0004***
1990–99	28.5983	10	9			
1970–79	28.0658	10		2.9861	1.8331	0.0077***
2000–09	28.6559	10	9			
1980–89	28.2658	10		2.5272	1.8331	0.0162**
1990–99	28.5983	10	9			
1980–89	28.2658	10		1.8335	1.8331	0.0585*
2000–09	28.6559	10	9			
1990–99	28.5983	10		0.3011	1.8331	0.3851
2000–09	28.6559	10	9			

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^{0}C from 1980–89 and that of 28.27^{0}C from 1990–99. Additionally, the mean value of 28.27^{0}C obtained from 1990–99 and 28.67^{0}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.

3.2.3 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	9			
2000–09	76.0772	10		-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)
1970 – 79	7.4299	10				0.0365**
1980 – 89	7.0083	10	9	-2.0296	1.8331	
1970 – 79	7.4299	10		-1.2294	1.8331	0.1250
1990 – 99	7.2047	10	9			
1970 – 79	7.4299	10		-0.9564	1.8331	0.1819
2000 – 09	7.3558	10	9			
1980 – 89	7.0083	10		0.9115	1.8331	
1990 – 99	7.2047	10	9			0.1929
1980 – 89	7.0083	10		2.2050	1.8331	0.0275**
2000 – 09	7.3558	10	9			
1990 – 99	7.2047	10		1.0343		
2000 – 09	7.3558	10	9		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
Non-climate	
Rice yield (Mt/ha)	1.65
Lag rice yield (Mt/ha)	1.63
Climate	
Temperature (0C)	30.36
Rainfall (mm)	90.08
Climate variations	
Temperature (0C)	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 muticolinearity). 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	Coefficients	Std. Error	t-Statistic	Prob.	Marginaleffects
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 1^0C, 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 1^0C 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.

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