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Effects of climate change on grain productivity in Nigeria (1970-2014)

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Abstract. This study examines the effect of climate change on the yield for four main grain crops in Nigeria (sorghum, maize, millet and rice) over the period 1970-2014. Cobb Douglas and Maximum Likelihood Estimation were explored to obtain reliable estimates. Results suggests that climate have diversified effects on grain yield and variability which shows that as the climate becomes warmer, higher yield variability can be observed on these selected crops. In addition more rainfall increases the yield variability on sorghum, maize, millet and rice. The increasing variation on rainfall also increased crop yield variability on rice. Based on the empirical findings it can be concluded that climate change, through an increase in actual average temperature and changing rainfall pattern has resulted to a decline in productivity of most food grain crops. This effect varies within crops and there is need to adapt different policies for various crops to mitigate the adverse effect of climate change in Nigeria.

1. Introduction

Agrarian economies from ages past and till now, have been bedeviled with many challenges such as lack of storage facilities, financial wherewithal to pursue laudable ideas and goals. Currently, they are being confronted with climate change, which is termed as one of the greatest challenges of the 21st century, due to its magnitude effect on productivity of crops and animals vis-à-vis the contributions of agriculture to the gross domestic product (GDP) of agricultural dependent economies. Its contribution is significant part of GDP, which was 22% in 2013 [1]. It has been forecasted that Nigeria will loose 2-11% of GDP in 2020 and as high as 20-50% of her GDP due to its high vulnerability to climate change [2].

The climate change and its effects is global however, that is being felt in both developed and developing economies, however, the effects is more severe in developing economies due to failure of farmers to adopt climate smart agriculture. Small scale farmers, who constitute the bulk of the poor in Africa, face prospects of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases as a result of climate change [3]. It is projected that crop yield in Africa may fall by 10 – 20% by the year 2050 or even up to 50% due to climate change [4,5]. The fundamental effect of climate change on agriculture is its direct impact on food production. Almost all sectors in agriculture depend on vagaries of weather and climate whose variability subject rural farmers to production and financial risk [6, 7]. The risk from climate in Africa, and the rest of the world, includes, rising temperatures and heat waves, shortfalls in water supply/increasing floods arising from



shortage/excessive rainfalls, sea level rise, increasing likelihood of conflict and induced environmental and vector borne diseases. These conditions emanating from climate change are bound to compromise agricultural productions (crop, livestock, forest and fishery resources), nutritional and health statuses, trading in agricultural commodities, human settlements (especially of agricultural communities), tourism and recreation among others [8].

The variability of temperature, air humidity and total rainfall shows negative signs to agricultural production. These problems have contributed to major loss of production and increase in socio-economic and income vulnerability among farmers. Climate change requires the development of natural resources management strategies that ensures the sustainable use of soil and water, halt biodiversity decline and deal with emerging issues such as demand for renewable energy.

Several studies on climate and agriculture have been carried out in Nigeria. Some of them focused on the effect of climatic variables on agricultural production [1,9-14] while some reported farmers' perception of climate change and adaptation strategies [15]. The findings of these studies indicated that climate change is real with significant impact on agricultural production in Nigeria. This study therefore examined the trend of grain production and the effects of climate change on the production of four major grains in Nigeria.

2. Methodology

The study made use of secondary data on grain production in Nigeria for 41 years (1970-2011). Nigeria has a tropical climate with variable rainy and dry seasons, depending on location. Near the coast temperatures rarely exceed 32°C (90°F), but humidity is very high and nights are very hot. Inland there are two different seasons. A wet season from April to October, with lower monthly temperatures and the wettest month being June. Also a dry season from November to March, with midday temperatures that rise above 38°C (100°F) but relatively cool nights, dropping as low as 12°C (54°F). Average rainfall along the coast varies from about 180 cm (70 in) in the west to about 430 cm (170 in) in certain parts of the east. Inland, it decreases to around 130 cm (50 inch) over most of central Nigeria and only 50 cm (20 in) in the extreme north. The hot Harmattan wind from the Sahara sweeps across the northeastern areas which. The Harmattan wind is hot and dry and carries a reddish dust from the desert. The southwest wind brings cloudy and rainy weather. It is hot and wet most of the year in the southeast but dries in the southwest and farther inland. A savanna climate, with marked wet and dry seasons, prevails in the north and west, while a steppe climate with little precipitation is found in the far north.

An integrated analysis of the combined effects of 1980 to 2014 climate change and trends on the production of four major grain crops which are maize (*Zea mays*), millet, sorghum (*Sorghum bicolor* (L.) Moench) and rice (*Oryza sativa*) in Nigeria was carried out. These crops were selected because they are the major grain crops grown in Nigeria and also based on historical observations and model projections which will help for a better and closer study of the effect of climate change.

This section presents the effects of climatic change on grains production in Nigeria between 1970-2014. The effect of climate change on grain productivity in Nigeria was estimated using pooled time-series cross-sectional data collected in the country from 1970 to 2014. The crop yields data were obtained from the crop production statistics of the Agricultural Development Programme (ADP) and Federal Ministry of Agriculture (FMA) in the country's head quarter, Abuja. The crop yield data includes time series average yields of each crop in Nigeria. The data on rainfall and temperature were acquired from Nigeria meteorological Station (NIMET). Temperature data contains daily minimum and maximum outcome over the growing season for each crop.

The summary statistics presented in table 1 shows the means of the grains in the year under review. The mean yield of rice is highest, which is closely followed by the mean yield of maize. The mean yield of millet which is the lowest is marginally lower than that of sorghum.

Table 1. Summary statistics

Variable	Mean	Std. Dev	Min.	Max.
Year	1992.5	12.84523	1971	2014
maize (ton)	1.363409	0.319643	0.57	2.2
Sorghum (ton)	1.116136	0.242057	0.6	1.63
Millet (ton)	1.107727	0.338374	0.44	1.85
Rice (ton)	1.748409	0.283794	1.27	2.39
Mean temp ($^{\circ}$ C)	33.44337	1.967527	30.16472	36.43876
Mintemp ($^{\circ}$ C)	21.63636	0.706149	20	22.3
Mean Rainfall (mm)	209.4775	164.3373	11.31	1156.33

2.1 *Trend of grains production in Nigeria (1970-2014)*

Figure 1 shows the trend of the yield of maize, millet, sorghum and rice in years under review. The lowest yields for maize, millet, sorghum and rice were observed in the year 1972, 2011, 1973 and 1976 to be 0.57 tonnes/ha, 0.44 tonnes/ha, 0.60 tonnes/ha, 1.27 tonnes/ha respectively while the highest yields for the same set of crops were observed in the year 2009, 2008, 1982, 1987 to be 2.20 tonnes/ha, 1.85 tonnes/ha, 1.63 tonnes/ha and 2.39 tonnes/ha respectively.

Millet and sorghum (59% of total grain production by volume) yields have either stagnated or progressed at a very slow pace, putting the average yield for these two crops at 1-1.5 tonnes/ha over the 2000-2006 period. Production increased by a factor of 3.8 (millet) and 3.4 (sorghum) between 1980 and 2008, and now stands at approximately 9 million tonnes for each of these two crops. But the yield of sorghum declined in 2014 to 6.5 million tonnes. Rice and maize attained yields of close to 2 t/ha. However, while maize yields have risen from about 1 t/ha in the early 1990s to about 2 t/ha in 2009, rice yields stagnated at around 2 t/ha for a period of 10 years (1980 and 1990).

Maize has performed well in Nigeria, and its production volume has risen from about 1 million tonnes in 1980 to over 7.5 million tonnes in 2008 to 7.6 million tonnes in 2013 increasing to 7.7 million tonnes in 2014. Unlike rice which production volume has risen from 2.4 million tonnes in 2013 to 2.8 million tonnes in 2014. The volume of rice produced increased by a factor of 3.4 between 1980 and 2008, reaching 4.2 million tonnes of rice in 2010.

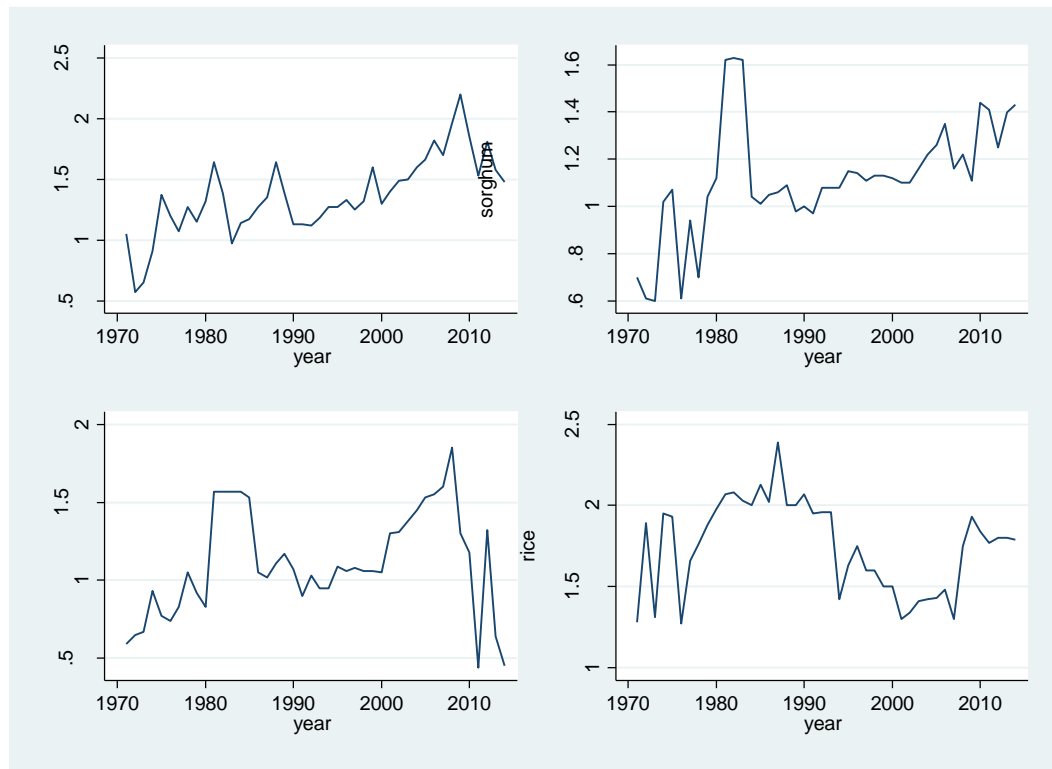


Figure 1. The trend of grain production

2.2 Trend Equations for Grain Crops in Nigeria

The estimated linear trend equation estimated for each grain crop (sorghum, millet, maize and rice) in Nigeria using available statistics on annual yield between 1970-2014 is presented in table 2. The trend equations show that there are positive trends in the outputs of all the grains in the years under review with the exception of rice which shows a downward trend. The coefficients of time for maize and sorghum are significant at 1% probability level while that of millet and rice are not significant. The result indicates that the yield of the major grain crops in Nigeria with the exception of rice increases with the years in the period under review.

Table 2. Estimated Linear Trend Equation for Major Grain Crops in Nigeria

Variable	Regression Equation	R ² and Adjusted R ²	N
Maize	$Y_{ma} = -35.64879 + 0.08185758T$ (7.27)	0.5572/0.5467	44
Sorghum	$Y_{so} = -19.21747 + 0.0102051T$ (4.17)	0.2933/0.2765	44
Millet	$Y_{mi} = -11.79929 + 0.0064778T$ (1.64)	0.0605/0.0381	44
Rice	$Y_{ri} = 12.11812 - 0.0052044T$ (-1.57)	0.0555/0.0330	44

2.3 Effects of Climate Change on Grain Productivity

Two specifications of the production function, linear and Cobb- Douglas production functions were tested. The value of Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) Wald and Log likelihood are better in the Cobb Douglas result, hence the Cobb Douglass results are discussed. The estimated results, which show the effects of climate change on grain productivity in Nigeria are presented in the following order:

2.4 *Effects of Rainfall and Temperature on the Trends of Sorghum Production in Nigeria*

The result in table 3 shows that temperature has negative and statistically significant effects on sorghum. On the other hand contrary to *a priori* expectation, rainfall and sorghum production are directly related. These results imply that high temperature, low temperature and large amount of rainfall favour sorghum production. In numerical terms, a 1 percent increase in temperature resulted in 0.05% decrease in sorghum output while the same variation in rainfall would reduce sorghum production by 0.76%.

Table 3. Climate Change and Sorghum Production

Variable	Cobb Douglas Function			Linear Function		
	Coef.	std. err	Z	Coef.	std.err	Z
Mean						
Heat index	-0.050*	0.028	-2.15	0.043**	0.006	2.53
Rain index	-0.314	0.106	-1.2	0.001*	0.011	2.56
Rainfall	0.162*	0.914	4.95	-0.068	0.082	-3.27
Trend	0.001	0.013	1.31	0.044	0.041	2.38
_cons		1.149	-2.67	3.202**	0.669	8.14
Std. dev						
Heat index	0.143**	0.013	7.37	0.254**	0.214	13
Rain index	0.220*	0.089	2.84	-0.0009*	0.301	-1.77
Rainfall	-0.760**	0.167	-4.49	0.059	0.081	1.96
Trend	0.201	0.012	1.59	0.059**	0.042	4.95
_cons	4.59**	0.979	5.6	2.21**	0.589	5.96
Log likelihood	-65.37			64.8*		
Wald chi2	9.41**			6.88**		
AIC	36.747			5.605		
BIC	97.21			2.961		
No of Obs	44			44		

2.5 *Effects of Rainfall and Temperature on the Trends of Maize Production in Nigeria*

The results in table 4 indicates that there is inverse relationship between temperature and maize production. On the other hand contrary to *a priori* expectation, rainfall and maize production are directly related. These results imply that maize production was favoured by high temperature and large amount of rainfall.

Table 4. Climate Change and Maize Production

Variable	Cobb Douglas Function			Linear Function		
	Coef.	Std. err	Z	Coef.	std.err	Z
Heat index	-0.050**	0.005	-2.04	0.207**	0.081	3.8
Rain index	-0.116	0.025	-0.63	0.146	0.048	0.97
Rainfall	0.040	0.045	0.89	-0.007	0.043	-0.86

Trend	0.037**	0.002	2.82	0.012**	0.004	5.08
_cons	0.178	0.306	0.58	-2.29**	0.528	-4.41
Stddev						
Lh	0.019**	0.004	4.7	-0.071	0.011	-1.13
Lr	0.113**	0.043	6.33	-0.027	0.004	-0.77
Lrn	-0.162**	0.012	-4.83	-0.072**	0.063	-2.36
Trend	0.0124**	0.062	9.17	-0.008	0.013	-0.27
_cons	1.179**	0.273	5.01	1.345**	0.385	3.51
Log	-					
Likelihood	21.867**			-41.646**		
Wald chi2	17.66**			49.66**		
AIC	63.734			3.291		
BIC	110.467			0.951		
No of Obs	44			44		

2.6 Effects of Rainfall and Temperature on the Trends of Millet Production in Nigeria

Millet productivity as shown by the results in table 5 was significantly influenced by temperature while effect of rainfall is not significant on its yield in the year under review. The result indicates that a 1% increase in temperature will result to 0.04% decrease in millet output.

Table 5. Climate Change and Millet Production

Variable	Cobb Douglas			Linear Function		
	Coef.	Std. err	Z	Coef.	Std.err	Z
Mean						
Heat index	-0.043	0.0463	-1	-0.013	0.086	-1.93
Rain index	-0.068	0.0319	-1.06	0.021	0.097	2.16
Rainfall	0.218	0.0793	2.07	-0.093	0.042	-1.34
Trend	0.041	0.0023	1.57	0.877	0.079	1.92
_cons	-0.025	0.4539	-1.91	0.975	0.033	11.12
Stddev						
Lh	-0.041	0.045	-6.06	-0.00146	0.014	-2.37
Lr	0.097	0.856	1.25	9.47E-05	0.005	1.34
Lrn	-0.109	0.573	-2.28	-0.00943	0.001	-3.49
Trend	0.716	0.858	4.1	0.009443	0.002	3.98
_cons	0.749	0.635	3.37	0.390337	0.071	5.24
Log						
Likelihood	-203.817			260.61		
Wald chi2	12.04			19.47		
AIC	27.6337			41.2191		
BIC	67.8923			51.5739		
No of Obs	44			44		

2.7 Effects of Rainfall and Temperature on the Trends of Rice Production in Nigeria

Both temperature and rainfall respectively have negative and positive significant effects on the trend of rice production in Nigeria in the period under review as shown in table 6. These results imply that low temperature and large amount of rainfall favoured rice production. Numerically, a 1 percent increase in temperature will result to 0.06% decrease in rice output while the same variation in rainfall would increase rice production by 0.04%.

Table 6. Climate Change and Rice Production

Variable	Cobb Douglas Function			Linear Function		
	Coef.	std. err	Z	Coef.	std. err	Z
Mean						
Heat index	-0.006	0.004	-2.96	-0.004	0.081	-4.92
Rain index	-0.159	0.037	-5.11	0.005	0.009	4.79
Rainfall	0.07	0.025	7.01	-0.017	0.008	-3.09
Trend	0.065	0.007	3.35	0.015	0.072	3.03
_cons	-0.117	0.164	-0.7	0.008	0.567	12.9
Stddev						
Lh	0.029	0.015	2.58	-0.047	0.053	-8.43
Lr	0.045	0.086	1.48	6.20E-02	0.024	6.97
Lrn	0.046	0.021	3.01	-0.092	0.027	-2.62
Trend	0.092	0.056	2.62	0.083	0.097	0.26
_cons	-0.068	0.125	-0.08	1.142	0.024	10.69
Log Likelihood	-53.68			-10.46		
Wald chi2	121.15			143.08		
AIC	98.335			46.913		
BIC	114.483			93.087		
No of Obs	44			44		

3. Conclusion

This study revealed that there is a relationship between climate change and the yields of maize, millet, sorghum and rice. Unfavorable climatic conditions or climate change impacted negatively on grain yields; if there is drought, excessive temperature, and low rainfall there will be a decline in yield resulting to a decline in productivity as well. If climatic conditions are favorable and other factors contributing to yields and development of grain are put in place, there will be an increase in yield. Therefore, it was inferred that climate change has a great effect on grain yields in Nigeria.

4. Recommendations

On the premise of result obtained in this study, the following recommendations is inevitable for a greater grain crop yield response despite the incidence of climate change and its risk. The government should understand that there is a great loss of crop yield as a result of climate change variability and should help

the crop farmers with effective adaptation strategies such as providing irrigation facilities to cope with the challenges of inadequate rainfall. There is also a need for better policies and investments on infrastructure to facilitate technology adoption and adaptation. These include investments on irrigation, roads, storage facilities and improved access to markets. Extension agent should provide vital information on crop varieties with increased tolerance to climate change and other climate-smart agricultural practices that will enable farmers mitigate against climate change.

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