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Scientific Note

The effects of rainfall and other weather parameters on cocoa production in Nigeria

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Abstract

Cocoa (*Theobroma cacao*) is an important crop to Nigeria, as significant as it is, the climatic factors affecting it's production cannot be controlled by human efforts. The effect of changing climate all over the world is also affecting the yield of cocoa in Nigeria. This study determines the effects of rainfall, temperature and relative humidity on Cocoa yield in Nigeria by analyzing the trend over three decades 1980-2011. The study employed the use of the annual readings of the three climatic parameters in question and the cocoa yield recorded over these periods. Data were subjected to inferential statistics and regression analysis in Stata. The results showed that the mean rainfall value over the three decades ranged from 1148.84± 438.59mm, 1245.25±209.59 mm and 1186.27± 175.02mm for period between 1980-1990, 1991-2000 and 2001-2011 respectively. While the yield ranged from 13.85 tons, 10.53 tons and 14.21 tons; the temperature ranged from 24.64, 25.91 and 25.1°C, while relative humidity also ranged between 74.91, 74.18 and 75.1%, respectively in the decades. Regression of yield against rainfall shows negative correlation of 0.0067852, with temperature and relative humidity exhibiting positive correlations of 1.092 and 0.7346 respectively. The study concluded that excessive rainfall decreases yield of cocoa, while increases in temperature and relative humidity boosts some physiological processes for pod production in Cocoa. The study recommends that farmers should adopt newly developed Cocoa varieties from Cocoa Research Institute of Nigeria which are well adapted to beat the vagaries of weather changes being experienced for improved income and livelihood.

Keywords: *Theobroma cacao*, bioclimatology, fruit production

Os efeitos dos parâmetros de chuva e outras condições meteorológicas na produção de cacau na Nigéria

Resumo

Cacau (Theobroma cacao) é uma importante cultura para a Nigéria, tão importante como é, os fatores climáticos afetando sua produção não pode ser controlado por esforços humanos. O efeito da mudança do clima em todo o mundo também está afetando o rendimento do cacau na Nigéria. Este estudo determina os efeitos de chuva, temperatura e umidade relativa do ar no rendimento de cacau na Nigéria, analisando a tendência ao longo de três décadas 1980-2011. O estudo empregou o uso das leituras anuais dos três parâmetros climáticos em questão e o rendimento de cacau registada ao longo desses períodos. Os dados foram submetidos à estatística inferencial e análise de regressão em Stata. Os resultados mostraram que a média de chuvas ao longo das três décadas variou de 1.148,84 ± 438,59 milímetros, 1.245,25 ± 209,59 milímetros e 1186,27 ± 175,02 milímetros por período entre 1980-1990, 1991-2000 e 2001-2011, respectivamente. Enquanto o rendimento variou de 13,85 toneladas, 10,53 toneladas e 14,21 mil toneladas; a temperatura variou de 24,64, 25,91 e 25.1oC, enquanto a umidade relativa também variou entre 74,91, 74,18 e 75,1%, respectivamente, nas décadas. Regressão de rendimento contra chuvas apresentou correlação negativa de 0.0067852, com temperatura e umidade relativa apresentando correlações positivas de 1,092 e 0,7346, respectivamente. O estudo concluiu que o excesso de chuvas diminui produção de cacau, enquanto os aumentos de temperatura e umidade relativa do ar aumenta a alguns processos fisiológicos para a produção de vagem em Cocoa. O estudo recomenda que os agricultores devem adotar variedades de cacau recentemente desenvolvidos pelo Instituto de Pesquisas do Cacau da Nigéria, que estão bem adaptadas para vencer os caprichos de mudanças climáticas que está sendo experimentado para melhoria da renda e sustento.

Palavras-chave: cacau, bioclimatologia, produção de frutos

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According to Intergovernmental Panel on Climate Change (IPCC, 2007), agriculture in many regions of the world will be severely hit by global warming, climate disruption, and extreme weather events. The negative effects of climate change on agriculture include increased crop damage from extreme heat, planning problems due to fewer reliable forecasts (uncertainty), increased soil erosion, increased moisture stress, and severe floods. Seasonal changes in rainfall and temperature could also alter growing seasons, planting and harvesting calendars. In addition, water availability for irrigation and drinking will be less predictable because rainfall will be more variable.

Climate change will affect agricultural productivity and food availability through two different channels. First, soil fertility will decline as the hydraulic conductivity of soil in the surface layer will be affected by climate-induced water stress. Indeed, water is vital to plant growth and historically, many of the largest falls in crop productivity have been attributed to sudden low precipitation events. Second, the variability in weather conditions could be a cause of low productivity as uncertainty inhibits innovation and imitation. Moreover, uncertainty about agricultural production will increase as extreme climate events, such as droughts and floods, are expected to be more frequent and cause more damage. As risky environment is pervasive in its effect on farming practices and farm performance, increasing uncertainty could discourage farmers upgrading production technology and therefore, affect productivity (IPCC, 2001).

The impact of climate conditions on agricultural productivity is confirmed by many recent studies (Tao et al., 2003, 2008; Parry et al., 2004; Xiong et al., 2007; Schlenker & Lobell, 2010). They show that a decrease in growing period water availability and water stress could play a major role in reducing agricultural productivity. FAO (2001) examined the effects of rainfall on food production and concluded that there are many interactions between climate variability and agriculture. Kumar et al. (2004) and Sivakumar et al. (2005) argued that varying precipitation patterns have a significant impact on agriculture. Das & Kalra (1995) evaluated the fertilizer and resource management for enhancing crop productivity under inter-annual variations in weather conditions. The results revealed sensitivity of crop yield to climatic variability.

As argued by Lobell & Burke (2008), estimates of climate change impacts on agricultural productivity are often complicated by our ignorance of the contribution of different factors to plant growth. According to Monteith (1981), the main factors contributing to yield variation are temperature and rainfall. Specifically, the IPCC (2001) points out that crop yield responds to three sources of climatic variability: change in annual mean temperature and precipitation; change in the distribution; a combination of changes of the mean condition and the variability.

This study explored the responses of Cocoa yield to the sources of climatic variability such as rainfall, temperature, relative humidity. The mean values of rainfall, temperature, relative humidity and cocoa yield in the three decades under study was used; the single effects of rainfall, temperature and relative humidity on cocoa yield was determined; while the combined effects of the weather parameters on yield of cocoa in the study area was compared

The study was conducted in Nigeria at Cocoa Research Institute of Nigeria (CRIN), Ibadan Headquarter. The data were sourced from CRIN records on the estate from 1980-2011. Data were cleaned and subjected to Descriptive, inferential statistics and regression analysis in STATA.

The table 1 above shows the trend of Cocoa yield (tons) and climatic parameters over the years under study between 1980- 2011 on CRIN estate in Ibadan, Oyo State, Nigeria.

The mean Cocoa yield recorded between 1980 and 1990 was 13.85 (± 6.58) tons with the minimum and maximum yield as 5.38 and 26.52 tons respectively; between year 1990 and 2000 mean Cocoa yield recorded was 10.53 (± 3.10)tons which showed a reduction compared to the previous decade the minimum and maximum yields were 4.62 and 13.99 tons respectively. This result may be owing to the sharp increase in rainfall to 1245.3mm from 1148.8mm from the previous decade. The yield of cocoa increased between year 2001 to 2011 to 14.21(±5.18)tons from 10.53(±3.10)tons of previous decade, this may be as a result of the increase in relative humidity to 75.1% from 74.18% of the previous decade and the reduction in the rainfall to 1186.3mm from 1245.3mm. And it is noticeable that in this decade, the mean temperature decreased with increase in relative humidity, which helped the yield of cocoa tremendously.

Table 1. Mean values of weather parameters for three decades

Parameters	1980- 1990				1990-2000				2001- 2011			
	Yield (Tons)	Rainfall (mm)	Temp (°C)	R/ Hum (%)	Yield (Tons)	Rainfall (mm)	Temp (°C)	R/H (%)	Yield (Tons)	Rainfall (mm)	Temp (°C)	R/H (%)
	13.85	1148.8	24.64	74.91	10.53	1245.3	25.91	74.18	14.21	1186.3	25.1	75.1
STD D	6.58	438.59	1.29	3.14	3.10	209.59	1.81	1.66	5.18	175.02	1.97	2.18
MIN.	5.38	324.9	23	70	4.62	787.6	23	72	8.32	1024.9	23	71
MAX.	26.52	1571.9	29	80	13.99	1599.7	27	76	24.04	1605	28	77

Source: CRIN databank

The mean temperature was less than the optimal recommended in a study by Lawal & Emaku (2007) although it fluctuated along that range to support and balance the metabolic processes for cocoa yield. This result is also in line with the result of Mendelsohn et al. (2000) and Deressa et al. (2008) that reported increased intensity and duration of sunshine and rainfall variability on the African continent. The minimum temperature of 23°C was maintained, this showed why productivity was maintained, Boyer (1970) reported that a drop below 23˚C reduced flowering in Cocoa. This can also be seen in the growth rate of climatic variables as presented in the table.

The above result also showed that increase in relative humidity increased yield of cocoa, this is also in line with Lawal & Emaku (2007) that reported increases in cocoa yield and black pod disease incidences on cocoa with increased relative humidity (RH).

This is also visible in the table above that between 1980-90, RH was 74.91 and yield was 13.85tons; when it dropped to 74.18% with temperature increase between 1990-2000, the yield decreased to 10.53tons; and with increased RH between 2001- 2011 and reduced temperature and rainfall. The yield had a boost to 14.21tons. This shows the interrelationship between the climatic variables and also in consonance with the results of Das & Karla (1995) which reported sensitivity of crop yield to climatic variability.

The results of the regression results showed the strength of contribution of the climatic variables to cocoa yield (Table 2).

With 32 observations, the regression of rainfall against Cocoa yield showed a negative relationship with a coefficient of -0.00678 which indicates that as rainfall increases it leads to decrease of 0.00678 in the yield of cocoa. This relationship is significant at 5% level of probability.

Regression of temperature on Cocoa yield showed a positive relationship between the variables. As temperature increases, it leads to an increase of 1.0921; this relationship is significant at 5% level of probability.

The result of regression of RH and yield showed also a positive relationship with a coefficient of 0.7346; this means that an increase in RH will lead to 0.7346 in cocoa yield. This relationship is significant at 5% level of probability.

The regression showing the effects of each of the weather parameters (Rainfall, Temperature and Relative Humidity) on Cocoa yield shows that Rainfall has a negative significant relationship with Cocoa yield which means reduction by 0.00678 ton with unit increase in rainfall while Temperature and Relative Humidity have positive significant relationships with Cocoa yield but the effects they exhibit on the yield are different, temperature increases yield by 1.0921ton while relative humidity increases yield by 0.7346 tons.

The regression of RH and Temperature against yield (Table 3) showed both are positively related to yield and significant at 5% level of probability but at different rates, an increase in RH will increase the yield of cocoa by 0.71387 meaning that as RH increases cocoa yield also increase by 0.71387tons while with increase in Temperature, cocoa yield increases by 1.060tons.

This indicates that Cocoa requires more temperature for production to increase when compared with its requirements for relative humidity (RH).

Table 2. Regression results for single effects of rainfall, air temperature and relative humidity.

Rainfall					
Source	SS	df	MS		
Model	122.030279	1	122.030279		
Residual	716.484971	30	23.8828324		
Total	838.51525	31	27.048879		
Yield (tons)	Coef.	Std.Err	t	P>Itl	[95% Conf. Interval]
Rainfall mm	-.0067852	0.0030017	-2.26	0.031	-0.0129156 -0.0006548
_cons |	21.24644	3.671897	5.79	0.000	13.74743 28.74546
Number of obs 32 F(1, 30) = 5.11 Prob > F = 0.0312 R-squared = 0.1455 Adj R-squared = 0.1170 Root MSE = 4.887					
Temperature					
Model	110.28696	1		110.28696	
Residual	728.22829	30		24.2742763	
Total	838.51525	31		27.048879	
Yield (tons)	Coef.	Std.Err	t	P>Itl	[95% Conf. Interval]
temp 1	0.092105	0.5123605	2.13	0.041	0.0457257 2.138485
cons	-14.43042	12.98236	-1.11	0.275	-40.94394 12.0831
Number of obs = 32 F(1, 30) = 4.54 Prob > F = 0.0414 R-squared = 0.1315 Adj R-squared = 0.1026 Root MSE = 4.9269					
Relative humidity					
Model	114.117992	1		114.117992	
Residual	724.397258	30		24.1465753	
Total	838.51525	31		27.048879	
Yield (tons)	Coef.	Std.Err	t	P>Itl	[95% Conf. Interval]
relhumi |	0.7345509	0.3378879	2.17	0.038	0.0444918 1.42461
cons |	-41.82012	25.31426	-1.65	0.109	-93.51874 9.878499
Number of obs = 32 F(1, 30) = 4.73 Prob > F = 0.0377 R-squared = 0.1361 Adj R-squared = 0.1073 Root MSE = 4.9139					

Also the regression between Rainfall and RH (Table 3) shows that both have significant relationship at 5% level of probability. The coefficient for rainfall shows that an increase in rainfall will lead to 0.0065tons decrease in cocoa yield while an increase in RH will increase the yield of cocoa by 0.70589tons. This indicates that for cocoa production, cocoa desires more humid environment than rainfall. In the light of the observations and the results, increase in rainfall will decrease yield of cocoa while both temperature and relative humidity exhibits positive relationship for yield increase on Cocoa, and since these are natural occurrences which man cannot control, ways around beating these occurrences can be explored by shortening the maturity dates, planting early maturing varieties. This study recommends that cocoa farmers should adopt the eight newly developed cocoa varieties by CRIN because they have features such as high yielding potentials, early maturing, high butter fat content, superior chocolate quality, adaptability to different ecologies and the vagaries of climate, resistance to Phytophthora pod rot and Mirid attacks. The combination of these qualities on Nigerian cocoa can increase the income of cocoa farming households and improve their livelihood.

Table 3. Regression results for combined effects of relative humidity and temperature

Source		SS		df	MS
Model		217.976394		2	108.988197
Residual		620.538856		29	21.3978916
Total		838.51525		31	27.048879
Yield (tons)	Coef.	Std.Err	t	P>ltl	[95% Conf. Interval]
Relhumi	0.713872	0.318214	2.24	0.033	0.0630513 1.364693
tempo[c]	1.06026	0.4812569	2.20	0.036	0.0759789 2.044541
cons	-67.07649	26.44407	-2.54	0.017	-121.1607 -12.99228
Number of obs = 32 F(2, 29) = 5.09 Prob > F = 0.0127 R-squared = 0.2600 Adj R-squared = 0.2089 Root MSE = 4.6258					
Relative humidity and rainfall					
Model		227.250365	2	113.625182	
Residual		611.264885	29	21.0780995	
Total		838.51525	31	27.048879	
Yield (tons)	Coef.	Std.Err	t	P>ltl	[95% Conf. Interval]
relhumi	0.7058748	0.3159324	2.23	0.033	0.0597206 1.352029
rainfallmm	-0.0065382	0.0028221	-2.32	0.028	-0.0123101 -0.0007662
_cons	-31.89964	24.03572	-1.33	0.195	-81.0582 17.25892
Number of obs = 32 F(2, 29) = 5.39 Prob > F = 0.0102 R-squared = 0.2710 Adj R-squared = 0.2207 Root MSE = 4.5911					

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