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The Potential Impact of Climate Change on Nigerian Agriculture

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Table of Contents

Abstract

This report examines how extreme weather conditions have affected the mean and variance of the yield of 18 food crops in Nigeria over a period of 42 years (1971-2012). The analysis at the State level was reduced to five Agricultural Transformation Agenda (ATA) priority crops and covered 22 years (1991-2012) due to data scarcity. The framework for the analysis consists of a stochastic production function suggested by Just and Pope (1978, 1979). The results show that the productivity of more than half of the staple crops in Nigeria is threatened by increase in total annual rainfall and extreme temperature nationally and across states in Nigeria. However, such increase is found to have beneficial effects on the productivity of a few crops grown in Northern Nigeria. The economic impact shows that extreme temperature will cause a considerable annual loss in value for most crops except few that are are grown mainly in Northern Nigeria (Borno, Yobe, Kaduna, Kano and Sokoto states) such as millet, melon, and sugarcane.

Résumé

Ce rapport examine comment les conditions météorologiques extrêmes ont affecté la moyenne et la variance des rendements de 18 cultures vivrières au Nigeria sur une période de 42 ans (1971-2012). Du fait de l'absence de donnees, l'analyse au niveau des Etats s'est limitée aux cinq cultures prioritaires identifiees par l'Agenda de Transformation Agricole (ATA) et couvre une periode de 22 ans (1991-2012). Le cadre de l'analyse consiste en une fonction de production stochastique proposée par Just et Pope (1978, 1979). Les résultats montrent que la productivité de plus de la moitié des cultures de base au Nigeria est menacée par l'augmentation de la pluviométrie annuelle totale et les températures extrêmes à l'échelle nationale et à travers les Etats au Nigeria. Cependant, cette augmentation se trouve avoir des effets bénéfiques sur la productivité de quelques plantes cultivées dans le nord du Nigeria. L'impact économique montre que les températures extrêmes entraîneront une perte annuelle de valeur considérable pour la plupart des cultures, sauf quelques-unes qui sont cultivées principalement dans le nord du Nigeria (Borno, Yobe, Kaduna, Kano et Sokoto) telles que le mil, le melon et la canne à sucre.

1. Introduction

In both developing and developed countries, extreme weather events and climatic anomalies have serious implications for agriculture, affecting crop yields and disease patterns. For instance, when drought is followed by intense rain, it may increase the potential for flooding, thereby creating conditions that favor fungal infestations of leaves, roots, and tuber crops. Such sequential extremes, along with changing timing of seasons, may also decouple long-evolved relationships among species (e.g., predator/prey); these relationships are essential for controlling pests and pathogens, as well as plant pollinators (Epstein and Chilwenhee, 1994). Therefore, an objective assessment of the potential impacts of climate on agriculture should be based not only on the mean values of expected climatic parameters but also on the probability, frequency, and severity of possible extreme events. When user-focused weather and climate information are readily available and are used wisely by farmers and agricultural insurance corporations, the losses resulting from adverse weather and climatic conditions can be minimized.

In recent decades in Nigeria, major advances in short-term and seasonal weather forecasting, as well as in long-term climate modeling, have become available for use in early warnings and advisories. This new knowledge has brought to light the need to manage the risks posed to agriculture by extreme weather events and anomalies in climate conditions. Each year, a large amount of the Nigerian government's spending is devoted to two major program that help farmers manage risk: 1) subsidized premiums for agricultural risk-reducing insurance policies and 2) frequent ad-hoc disaster payments to reimburse farmers after natural disasters. It is expected that these costs will continue to increase due to climate change and increased occurrences of extreme weather events unless proper reform is put in place. Adequate knowledge regarding the effects of weather extremes on yields of the various crops grown in the nation is thus fundamental to such reform.

Traditionally, time series data of crop yields have been used to assess the influence of year-to-year weather fluctuations on crop yields, either for specific climatic regions or by relying on a panel (Rosenzweig and Parry, 1994; Deschenes and Greenstone, 2007; Schlenker and Robert, 2006; Soja and Soja, 2007; Palanisami et.al, 2011; Chalise and Ghimire, 2013). Rosenzweig and Parry (1994) use calibrated crop models to examine the effects of year-to-year weather fluctuations on crop yields and simulate farm adaptation options. Deschenes and Greenstone (2007) use a panel dataset to estimate the relation between profits and climatic variables in the United States; they regress profits in a county on climatic variables using county fixed effects. Chalise and Ghimire (2013) utilize historical data on yield, temperature, and precipitation in three adjacent agricultural districts of Georgia to assess the impacts of temperature and precipitation on mean yield of peanut production. The study finds that all temperature levels have a positive impact on peanut yield. Similarly, precipitation has a positive impact on yield, but only up to a certain limit; excessive precipitation has a negative effect. Schlenker and Robert (2006) employ a 55-year panel of crop yields in the United States paired with a weather dataset that incorporates the distribution of temperatures between the minimum and maximum within each day and across all days in the growing season to estimate the impacts of climatic factors on crop yield. The study shows that yields increase as temperature increases until about 29◦C for corn and soybeans and 33◦C for cotton, but temperatures above these thresholds quickly become harmful. Soja and Soja (2007) examine which kind of extreme weather causes bad harvests for seven agricultural crops in three regions of Austria. The data consists of area-based agro-statistical surveys and monthly means of meteorological parameters from 1869-2003. The results show that milder winters will be especially advantageous if no extreme temperatures occur in February, while dry weather in spring is especially disadvantageous for spring cereals. Dry, hot summers are unfavorable for sugar beet and corn and to a lesser extent for potato. Schlenker and Robert (2006) show that studies employing panel data contain a richer set of control variables and/or year fixed effects, thereby considerably reducing confounding.

Generally, the literature show that extreme temperatures have a negative impact on individual crop yield. Similarly, excessive precipitation has negative effect on yield for most crops. Luo (2011) provides a review of temperature thresholds for a range of crops, providing a basis for quantifying the probability of exceeding these temperature thresholds; this is a very important aspect of climate change risk assessment. This review also identifies the effects of extreme temperatures on yield and yield components. At present, little empirical evidence exists on crop yield variation in response to alterations in climatic conditions in sub-Sahara Africa. Further, none of the previous studies assess the effects of the major climatic factors (temperature and precipitation) on mean and variance of crop yield in Nigerian states, despite regular media reports of weather-based disasters affecting crop yields.

Specifically, empirical studies such as Zhang and Carter (1997) and Ajetomobi and Ajiboye (2010) take climate variables as normal inputs in production, whereas Nhemachema and Hassan (2007) and Mendelsohn (2009) study the impacts of climate variables on farmers' net revenues. However, the issues of production risk stemming from climate factors and standard physical inputs, as well as farmers' abilities to adapt to this risk, have not been systematically examined in the Nigerian context. Such knowledge is necessary to guide the nation's agricultural insurance corporation on how best to protect farmers in the face of climate-related risks. Thus, this study is an attempt to assess the potential impacts of extreme weather events on the productivity of agricultural commodities in Nigeria and the risks associated with such extreme events. The main research questions guiding this study include:

1 Are extreme weather conditions important to crop production in Nigeria?

2 Are extreme weather conditions a source of crop production risk in Nigeria?

Our objectives are to:

1. estimate the effect of extreme daily temperatures and rainfall during the growing season on the mean of yields of Nigerian staple crops and
2. estimate the effect of extreme daily temperatures and rainfall during the growing season on yield variability of Nigerian staple crops.

2. Materials and Methods

2.1 Description of the Model and Data

In order to account for the effects of the weather variables on both the mean and variability of crop yield, a stochastic production function approach suggested by Just and Pope (1978, 1979) is estimated. The basic idea involves decomposition of the production into a deterministic one related to the output level and a second one related to the variability of the same output. In a general sense, the model is:

$$Y = f(X,\beta) + h(\sqrt{X,\alpha})\varepsilon \qquad (1)$$

where Y is a specific crop yield and f() is an average production function (deterministic component of output) which relates X (set of independent explanatory variables such as climate, location, and time period) to mean yield with β as the vector of estimated parameters. The error term ε is an explicit form for heteroskedastic error term with zero mean. The functional form h is the variance function (stochastic component of output) which relates X to the standard deviation of yield with α as the vector of parameter estimates and ε is a random error term with zero mean and variance σ^2. Estimates of the parameters of f () give the average effect of the independent variables on yield, while h gives the effect of each independent variable on the standard deviation of yield.

$$E(Y) = f(X,\beta) \qquad (2)$$

and $\mathrm{var}(Y) = h^2(X,\alpha)$ *(3)*

The interpretation of the signs on the parameters of h() are straightforward. If the marginal effect on yield standard deviation of any independent variable is positive, then increases in that variable increase the yield risk (risk-increasing), while a negative sign implies increases in that variable reduces yield risk (risk-decreasing). With this formulation, climate and other variables can independently influence average and variance of crop yield.

2.2 Econometric Model Specification

Cobb Douglas and linear production forms are chosen for the average yield function, f(X). The functional forms are consistent with the Just and Pope postulate, which is an additive interaction between the average and variance functions. The basic model in linear form is specified as:

$$Y_{it} = \exp(\alpha_0 + \sum_{k=1}^{k} \alpha_k X_{kit}) + \alpha_t Trend + \varepsilon_{it} \sqrt{\beta_0 + \sum_{m=1}^{m} \beta_m X_{mit}} \tag{4}$$

where Y_{it} is the crop output in region i at time t, X_{kit} is the input quantity of factor k in region i at time t, and $\alpha_j, j = 0,1........k$,, are the parameters to be estimated. X_{mit} denotes a factor which can influence the risk level and β_m is the corresponding coefficient. ε is a stochastic disturbance term following the standard normal distribution. Thus, the expected output (often called the mean output) and the variance of output are determined by separate functions, which can algebraically be denoted as

$$E(Y_{it}) = \exp(\alpha_0 + \alpha_t Trend + \sum_{k=1}^{k} \alpha_k X_{kit}) \quad and \quad V(Y_{it}) = \beta_0 + \beta_t Trend + \sum_{m=1}^{m} \beta_m X_{mit} \tag{5}$$

Given the assumption that production risk in this framework takes the form of heteroskedasticity in the production function, the second term on the right-hand side of equation (4) can be interpreted as a heteroskedastic error term for the purpose of estimation. The difference between the linear and the Cobb Douglas functional forms is that the variables in the latter are expressed in logarithmic form. The better functional form for each crop depends on the results of the diagnostic tests, namely, Wald chi square, log-likelihood, Akaike Information Criteria (AIC), and Bayesian Information Criteria.

The two most commonly used approaches for estimating equation (5) are (i) the Feasible Generalized Least Square (FGLS) which involves three stages suggested by Just and Pope (1979) and (ii) the Maximum Likelihood Estimation (MLE) introduced by Saha et al. (1997). Under a small sample, the MLE has been proven to provide more efficient estimates when compared with FGLS (Saha et al., 1997). The log-likelihood function is

$$\ln L = -\frac{1}{2}\left[n\ln(2\pi) + \sum_{i=1}^{n} \ln h^2(X,\alpha) + \sum_{i=1}^{n} \frac{Y_i - f(X,\beta))^2}{h^2(X,\alpha)} \right] \tag{6}$$

Due to the relatively large sample in this study, the three stage estimation procedure as described in Judge et al. (1985) is employed. At the first stage, the yield is regressed on $f(X,\beta)$ with the least squares residuals, $\varepsilon(\varepsilon = y - f(X,\beta))$, as a consistent estimator of the error term. Since σ^2 is unobservable, the least square residuals obtained from the first stage are used to estimate the marginal effects of independent variables on the output variance in the second stage. Therefore, in the second stage, the square of error term, ε , is regressed on its asymptotic expectation $h(X,\alpha)$. The third and final stage uses the predictor error terms from the second stage as weights for generating the FGLS estimates for the mean yield equation. Just and Pope (1978) show that the β in the final stage is consistent and asymptotically efficient and corrects for the heteroscedastic error term. The FGLS model is estimated using STATA 12.0.

Another important stage of the analysis involves the calculation of the costs or benefits of climate change. From equation 4, the shadow prices of climate variables can be computed as follows:

$$wc = \frac{\partial E(y)}{\partial c} p_y = \alpha_c \frac{p_y * E(y)}{c} \tag{7}$$

where wc , is the shadow price of climate variable c (e.g. extreme temperatures), $E(y)$ is the expected output, and p_y is the output price. α_c represents the estimated output elasticity with respect to the climate factor c , which will be obtained from the mean production function of the Just and Pope (1979) procedure. Equation 7 thus quantifies the economic impacts of a marginal change in climate.

The model has been developed for each of the major staple crops in Nigeria. In order to evaluate the impact of crop yield changes on regional production, land use, and welfare distribution, as well as the potentials for agriculture to adapt to climate change, a price-endogenous spatial equilibrium model (TASM) was used.

2.3 Sources and Measurement of Production and Climate Variables

The dependent variable for the analysis is yield measured in tonnes per hectare for each of the 18 food crops considered in this study. A number of temperature-related variables were used in this analysis, such as daily minimum and maximum temperature, average seasonal/monthly temperature, growing degree days (GDD), and Harmful Degree Days (HDD). The traditional way to calculate GDD is to measure the difference between mean daily temperature and a predetermined threshold (Robertson, 2012). If T_h is maximum temperature, T_i the minimum temperature, T_b a given baseline temperature (usually between 8 and 10°C), and Tm a given upper bound (typically 30-32°C), then over all days, growing degree days can be calculated as

$$GDD = \left\{ \frac{T_{h+}T_i}{2}, T_m \right\} - T_b \tag{8}$$

In this study, the baseline was assumed to be 10°C and the upper bound was set at 32°C. The use of mean daily temperature alone does not account for the fluctuation between daily maximum and minimum temperature. For example, 35° and 25° have the same mean temperature (30°) as 40° and 20°, which is within the optimal temperature range (Le, 2011). This study follows Schlenker and Robert (2008) and Le (2011) in order to account for harmful growing degree days (HDD). In defining HDD, the lower bound is assumed to be 34°C and no upper bound is defined. In multiple regression analysis, GDD is expected to influence yield positively, while the coefficient of HDD is expected to be negative. Precipitation (P) was measured as the accumulated total over the crop-growing season (in centimeters).

Crop yield and price data were obtained from the official records of each state's Agricultural Development Programme. The data are available for all states from 1991-2012. For the national aggregate (1971-2012), the yield and price data were obtained from FAOSTAT. Climate data were purchased from National Meteorological Agency in Lagos Nigeria for all 32 weather stations across the country. The data consist of daily observations of maximum temperature (Tmax), minimum temperature (Tmin), and precipitation from January 1, 1971 to December 31, 2012.

3. Results and Discussion

3.1 Results of Analysis at the National Level

The crops selected for this study are grown in at least one-quarter of the states in Nigeria. With the exception of rice and wheat, the yields of all grain crops have gradually increased over the past 42 years. For instance, the yield of maize increased from 0.57 tons ha^{-1} to a peak of 2.2 tons ha^{-1}, while that of sorghum rose from 0.6 to 1.63 tons ha^{-1}. These increases could be attributed to a combination of price incentives via structural adjustment programmes (SAPs) and improved technology. Nevertheless, the growth in yield has yet to catch up with the expectations of researchers and policymakers. According to IITA (2009), the average maize yield in developed countries has the potential to reach up to 8.6 tons ha^{-1}. This report attributes relative low yields to irregular rainfall, drought, declining soil fertility, and prevalence of parasitic weeds, insect pests, and diseases*.

Over the four decades considered in the analysis, yields of the following root and tuber crops – cassava, yam, and sweet potatoes – increased steadily. It should be noted that the rate of increase is generally higher post-SAP (1995-2012) than in other periods. Another reason for the increase might be increased government interest in promoting value chain development through the on-going Agricultural Transformation Agenda. In contrast, yields of cocoyam, sweet potatoes, and sugarcane declined over the period. For spices and vegetables, the yield trend varied across crops. While okra and ginger showed an increase, onion and tomatoes showed a decline and melon recorded no significant change.

Plants can be severely damaged if the daily temperature exceeds a certain temperature threshold at a certain developmental stage (Porter and Gawith, 1999). In addition, different processes can have

* old.iita.org/cms/details/maize_project_details.aspx?zoneid=63&articleid=273

different temperature thresholds (Wheeler et al., 1996). The temperature threshold used to construct the heat index for various crops is 34ºC (Luo, 2011). The trend of the extreme climate variables was constructed to coincide with the growing seasons of the crops considered for this study. Trends for temperature- and rainfall-related indices are shown in Appendix E, while those for harmful degree days are presented in Appendix F. Over the past 40 years, the number of days with temperatures above 34ºC rose for all the crop-growing seasons. The number of days with 95-percentiles of the daily precipitation also increased across the crop-growing seasons. With these trends, crop damage due to heat stress and flooding is expected to rise. The harmful degree days for each of the crop-growing seasons have also shown rising trends. Possible implications for Nigeria's ad-hoc disaster fund can be imagined if no adaptation and mitigation measures are put in place; this conclusion is presented graphically in Appendix F.

3.1.1 The Mean Yield Regression Results

Table 1 shows the summary of the regression coefficients for the mean yield function from stage three of the Just and Pope stochastic production function for each crop. A logarithmic transformation function is assumed for the mean yield function. Empirically, such a model has been found to be reasonable for defining the Just and Pope stochastic production process. The coefficients of determination show that the lowest adjusted R-squared value from the first stage of the estimation procedure is 0.30 for melon. Apart from cocoyam, the R-square values for root and tuber crops are generally higher than other crops. The overall significance of the model is supported by the significance of the F-values for all crops. This implies that the regression model fits the data well.

The results show that the yields of more than half of the crops are significantly affected by rainfall. There is a strong, positive, and significant relationship between rainfall and the yields of cassava, groundnut, cotton, sugarcane, and tomatoes. This implies that increased availability of water is beneficial to these crops. In contrast, an increase in rainfall is associated with significant declines in the yield of yam, sweet potatoes, ginger, maize, and melon. This means that the productivity of several major crops in Nigeria is vulnerable to flooding arising from an increase in cumulative rainfall over the analysis period. Extreme temperatures measured with Harmful Degree Days (HDD) have a negative association with yields of about two-thirds of the crops. For a few crops predominantly grown in Northern Nigeria, such as millet, onion, tomatoes and melon, HDD has a positive and significant relationship with yields.

Time trend in the mean production model is positive and significantly related to the yields of more than 60 percent of the crops. This shows that technological advances have increased the average yield of crops, as expected. This is significant given the keen interest of the on-going Agricultural Transformation Agenda (ATA) in technological progress.

Table 1: Mean Yield Function

Crop	Rain	GDD	HDD	Trend	Constant	F	R_2
Cassava	0.073** (2.51)	1.424* (1.82)	-0.346*** (-5.45)	0.009*** (5.44)	-13.458 (-1.40)	16954.48***	0.99
Cocoyam	-0.071 (-0.48)	1.141** (2.64)	-1.127 (-1.51)	-0.005 (-1.28)	-11.24*** (-2.19)	3.15**	0.30
Yam	-0.276** (-2.24)	1.254 (0.44)	-0.190 (-0.95)	0.016*** (5.51)	-9.053 (-0.26)	1690.09***	0.99
Sweet potato	-0.081** (-1.84)	5.817*** (3.44)	-0.542*** (-4.55)	-0.0264*** (-12.82)	-58.850*** (-3.22)	8943.97***	0.99
Ground nut	0.397** (2.69)	0.097 (0.03)	0.109 (0.57)	0.0126** (2.45)	-6.002 (-0.18)	13.24***	0.64
Cotton	0.367* (1.72)	6.154** (2.19)	-0.6281** (-2.79)	0.0461*** (12.11)	-73.641** (-2.30)	70.89***	0.90
Cowpea	0.0142 (0.40)	0.1203 (0.11)	-0.0574 (-0.39)	0.0255*** (7.47)	-2.390 (-0.19)	119.54***	0.94
Ginger	-0.245** (-1.69)	8.297*** (3.61)	-0.726** (-2.28)	0.037*** (5.24)	-94.027*** (-3.43)	58.46***	0.88
Maize	-0.408*** (-4.17)	1.016 (1.02)	-0.085 (-0.90)	0.025*** (8.19)	-7.480 (-0.65)	192.52***	0.96
Melon	-0.300* (-1.84)	-7.689 (-1.40)	0.687** (2.17)	-0.00254 (-0.37)	85.842 (1.36)	3.12**	0.30
Millet	0.0850 (1.01)	0.099 (0.08)	0.439*** (2.68)	0.006** (2.34)	-5.005 (-0.39)	21.51***	0.74
Okra	-0.067 (-0.97)	0.645 (0.41)	-0.116 (-1.42)	0.012*** (4.91)	-5.005 (-0.30)	615.43***	0.98
Onion	-0.0226 (-1.52)	-1.909 (-2.05)	0.271** (2.88)	-0.006*** (-3.22)	22.456** (2.14)	50080***	0.99
Rice	-0.0214 (-0.47)	-0.548 (-0.36)	-0.336*** (-3.06)	0.002 (0.86)	9.835 (0.57)	232.19***	0.96
Sorghum	-0.141 (-1.40)	-0.695 (-0.36)	0.062 (0.60)	0.0361*** (8.49)	-56.2455 (-1.58)	18.04***	0.70
Soya bean	-0.038 (-0.24)	4.656 (1.57)	-0.1360 (-0.48)	0.0362*** (8.49)	-56.246 (-1.58)	120.75***	0.94
Sugar cane	0.145** (1.88)	-3.741** (-2.57)	0.0920 (0.83)	-0.0237*** (-12.06)	47.862** (2.66)	13439.84***	0.99
Tomato	3.562** (2.62)	-32.532 (-1.29)	-1.289 (-0.89)	0.035 (0.83)	326.292 (1.20)	60.36***	0.89

Note: In parenthesis are the student's t values, *, **, *** indicate significance at 10, 5 and 1% respectively

3.1.2 Economic Impact Analysis

From a policy perspective, this study quantifies the change in agricultural output following a marginal change in climate. Drawing on the mean yield function, the change in mean yield following a 1°C increase in annual average temperatures or a 1 mm increase in total annual precipitation is calculated. The results are multiplied by the total area under grain cultivation and by the average price of grain products, as shown in equation 7, to quantify the market value of the total change in output. The results of the analysis are shown in Table 2. A 1ºC increase in HDD will cause considerable annual loss in value for most of the crops studied. For cassava and maize, these losses are 112,968.37 and 128,636.20 USD, respectively. For some crops that are resistant to drought and are grown mainly in Northern

Nigeria, such as millet, melon, and sugarcane, a 1oC increase in extreme temperatures will lead to some gains in value of production per hectare.

Table 2: Economic Impact Analysis

Crop	HDD coefficient	Average yield	Average HDD	Average area	Output price	HDD Marginal Product	loss in naira due to extreme temperature	Loss in US dollar due to extreme temperature
Cassava	-0.35	10.70	2701.00	2287162.57	7207.00	0.001371	22593673.56	112968.37
Cocoyam	-1.13	1.15	851.72	307259.55	10079.38	0.001522	4712640.26	23563.20
Yam	-0.19	9.79	2448.54	1735617.86	19512.37	0.00076	25727239.34	128636.20
Sweet potato	-0.54	5.62	598.97	370457.14	10510.04	0.005086	19801303.49	99006.52
Ground nut	0.11	1.13	803.57	1509751.38	17020.68	0.000153	3927981.06	19639.91
Cotton	-0.63	0.56	1495.78	469730.79	10199.17	0.000233	1118023.91	5590.12
Cowpea	-0.06	0.53	1370.38	2778335.00	25353.18	2.22E-05	1560999.65	7805.00
Ginger	-0.73	0.92	2066.50	72900.00	19567.68	0.000324	462819.23	2314.10
Maize	-0.09	1.36	1422.43	2948279.52	15055.21	8.1E-05	3594638.32	17973.19
Melon	0.69	0.85	1404.52	340982.86	42660.03	0.000417	6066196.97	30330.98
Millet	0.44	1.13	1428.19	4098640.24	13709.05	0.000349	19601501.91	98007.51
Rice	0.34	1.75	1845.44	1397672.62	17290.47	0.000318	7682131.01	38410.66
Sorghum	0.06	1.10	724.86	5199793.10	13813.66	9.58E-05	6881721.69	34408.61
Soya bean	0.14	0.53	2256.70	428572.38	19297.84	3.2E-05	264675.13	1323.38
Sugarcane	0.09	32.53	2701.29	30854.36	154.90	0.001108	5295.37	26.48

3.1.3 Changes in Yield Variance

The regression results for yield variance obtained from the estimation of the second stage of the Just and Pope stochastic production function are presented in Table 3. Like the mean function, a logarithmic function is also assumed. The Adjusted R-square varies from 0.80 for millet to 0.99 for tomatoes. The overall significance of the model captured with F-test shows that the model fits the data well for all crops. Rainfall is found to be risk-increasing for sweet potatoes, sugarcane, and rice and risk-decreasing for cotton. The corresponding coefficients are 3.168, 2.736, and 1.133 for the three crops that experience increased risk respectively. The risk-reducing effect of rainfall on cotton might be due to this crop's higher resilience to environmental stress. The GDD is found to reduce yield risk for most of the crops. HDD, however, would increase the yield risk of most of the crops.

Table 3: Yield Variance Function

Crop	rain	GDD	HDD	Trend	Constant	F	R_2
Cassava	1.087 (0.89)	-1.110 (-0.05)	-2.255 (-1.05)	0.079* (1.88)	11.254 (0.04)	104.59***	0.93
Cocoyam	-0.414 (-0.30)	52.065** (2.69)	-6.364*** (-3.31)	0.0160 (0.31)	-554.583** (-2.57)	41.44***	0.84
Sweet potato	3.168** (2.74)	-51.990** (-1.80)	3.271 (1.52)	-0.0236 (-0.52)	525.456** (1.68)	80.37***	0.91
Yam	-0.453 (-0.40)	-50.376* (-1.89)	2.333 (1.14)	-0.0295 (-0.78)	600.782* (1.87)	47.48***	0.86
G nut	-1.385 (-1.11)	5.685 (0.19)	-1.231 (-0.75)	0.040 (0.95)	-48.513 (-0.15)	39.27***	0.84
Soya bean	1.148 (1.31)	-9.181 (-0.63)	2.924* (1.68)	-0.074** (-2.31)	74.476 (0.42)	49.36***	0.86
Sugarcane	2.736** (2.78)	8.312 (0.43)	3.201* (1.86)	-0.107*** (-3.16)	-160.045 (-0.69)	95.51***	0.92
Cotton	-2.478*** (-2.12)	-47.556** (-2.66)	1.831 (0.88)	-0.030 (-0.71)	570.328** (2.77)	38.12***	0.83
Cowpea	0.664 (1.21)	7.134 (0.44)	-4.703* (-1.93)	-0.000886 (-0.02)	-60.515 (-0.34)	36.36***	0.83
Ginger	-0.375 (-0.35)	36.832* (1.88)	-1.050 (-0.57)	0.055 (1.48)	-440.584* (-1.88)	32.07***	0.84
Maize	1.1306 (1.03)	19.456 (0.98)	-4.838** (-2.88)	0.0134 (0.33)	-214.787 (-0.92)	73.89***	0.90
Melon	1.343 (1.71)	35.033 (1.62)	-2.210 (-1.67)	-0.00894 (-0.32)	-401.471 (-1.62)	36.04***	0.82
Millet	-0.294 (-0.44)	-12.71 (-0.71)	6.018** (2.08)	-0.151** (-2.56)	105.895 (0.54)	31.26***	0.80
Okra	1.434 (0.96)	-41.981 (-1.61)	3.829** (2.23)	-0.0534 (-1.13)	403.882 (1.48)	58.29***	0.88
Onion	-0.930 (-0.83)	-33.526 (-1.50)	4.455 (1.66)	0.131*** (2.94)	344.778 (1.15)	58.06***	0.88
Rice	1.133** (2.14)	-19.381 (-1.21)	1.112 (0.63)	-0.077** (-2.07)	210.1879 (1.15)	67.30***	0.90
Sorghum	-1.392 (-0.88)	-15.362 (-0.35)	1.014 (0.39)	-0.046 (-0.83)	179.406 (0.37)	34.49***	0.82
Wheat	0.301 (0.78)	-8.260 (-0.53)	0.757 (0.42)	0.015 (0.45)	87.824 (0.48)	38.44***	0.83
Tomato	0.045 (0.60)	0.341 (0.20)	0.093 (1.40)	-0.0159 (-7.04)	-2.244 (-0.13)	4237.81***	0.99

Note: In parenthesis are the student's t values, *, **, *** indicate significance at 10, 5 and 1% respectively

3.2 Results of Analysis at the State Level

This section describes the yield and weather data (temperature and rainfall) used in the analysis of state-level data. The weather data in each state are matched with the yield of each crop over the particular crop-growing season. The state-level analysis is limited to 1991-2012 because of data availability.

3.2.1 Crop Yields

Annual crop yields for five major crops including maize, sorghum, cotton, rice, and cassava were obtained from the official records of each state's Agricultural Development Programme. These crops were selected because they constitute priority staple food commodities under the nation's ATA action plan (FMARD, 2013). The data are available for all states from 1991-2012. The records include information on total production, land area, number of farmers growing each crop, and each crop's market price. Each state-average yield is derived as total production divided by total harvested hectarage. In all, there are 37 state-by-year observations for cassava, maize, and rice, 12 for cotton, and 21 for sorghum.

The average yield by various states over the entire analysis period is shown in Table 4. The results show that Abia, Borno, Kebbi, Delta, and Zamfara states have the highest yield for cassava, cotton, maize, rice, and sorghum, respectively.

Table 4: Average Yield (Tonnes/Hectare) of Selected Crops by State

State	Cassava	Cotton	Maize	Rice	Sorghum
Abia	19.18		1.65	1.89	
Adamawa	3.60	1.25	1.27	1.58	1.25
Akwa ibom	9.46		1.28	3.30	
Anambra	14.04		1.91	2.28	
Bauchi	7.88	1.56	1.85	1.60	1.00
Bayelsa	11.05		1.39	1.50	
Benue	12.37		1.29	2.06	1.55
Borno	3.60	4.65	1.20	1.18	1.34
Cross river	13.64		1.97	1.41	
Delta	12.71		1.74	4.98	
Ebonyi	12.27		1.38	2.47	
Edo	11.59		1.72	2.69	
Ekiti	17.68		2.40	2.28	
Enugu	10.69		1.71	3.13	
F.c.t.	6.08		2.63	1.07	0.66
Gombe	2.53	1.46	1.70	2.22	1.12
Imo	15.21		2.23	0.62	
Jigawa	2.60		0.81	1.16	0.59
Kaduna	11.83	3.18	2.68	2.68	1.90
Kano	2.60	1.38	1.72	1.61	1.50
Katsina	11.00	1.17	0.95	1.39	0.92
Kebbi	18.15	0.75	4.65	1.71	1.03
Kogi	15.47		1.68	2.02	1.10
Kwara	13.13		1.28	2.45	1.34
Lagos	12.59		2.34	1.73	
Nassarawa	14.76		1.73	2.03	1.43
Niger	10.32	0.79	1.46	1.67	0.93
Ogun	13.93		2.29	1.40	
Ondo	18.26		2.93	2.33	
Osun	16.90		1.86	1.37	
Oyo	9.98		2.35	1.37	1.31
Plateau	11.53	0.64	2.06	2.55	1.70
Rivers	10.34		1.59	3.30	
Sokoto	3.09		1.25	0.95	0.60
Taraba	9.27	1.08	3.46	2.07	1.47
Yobe	3.60		0.52	1.09	1.21
Zamfara	3.09	1.69	1.62	1.09	1.79
National	10.70	1.63	1.85	56.01	1.23

Source: FAOSTAT Statistical Database

3.2.2 Mean Yield Regression using State Level Data

Table 5 shows the summary of the regression coefficients for the mean yield function using state-level data. As with national data, a logarithmic transformation function is assumed for the mean yield function. The coefficient of determination varies from 0.12 for sorghum to 0.97 for cassava. The overall significance of the model is supported by the significance of the F-values for all crops, implying that the regression model fits the data well.

The results show that cassava and rice yields are positively and significantly affected by rainfall, implying that increased availability of water is beneficial to these crops at state level. Extreme temperatures measured with HDD have a negative association with yields of all the crops except cotton. The time trend in the mean production model is positive and significantly related to the yields of all crops except cotton. These results show that technological advances have increased the average yield of crops, as expected. This is significant because the crops selected are those given priority by the on-going ATA.

Table 5: Mean Yield Function Using State Level Data

Crop	Rain	GDD	HDD	Trend	Constant	F	R^2
Cassava	0.199*** (4.07)	0.585** (2.92)	-0.076*** (-5.26)	0.013*** (5.09)	-4.10** (-2.70)	4525.65***	0.97
Cotton	-0.200 (-1.27)	-0.98* (-1.60)	0.069 (1.00)	0.003 (0.40)	9.608* (1.96)	10.27**	0.16
Maize	0.069 (1.57)	0.090 (0.80)	-0.028** (-2.71)	0.010*** (4.46)	-0.732 -0.85)	283.85***	0.65
Rice	0.354*** (3.76)	-0.106 (-0.40)	-0.107*** -4.08)	0.008* (1.63)	-0.735 (-0.36)	79.03***	0.34
Sorghum	0.097 (1.48)	0.105 (1.23)	-0.057*** (-3.72)	0.005* (1.64)	-1.247** (-2.02)	12.35**	0.12

Note: In parenthesis are the student's t values, *, **, *** indicate significance at 10, 5 and 1% respectively

The regression results at the state level for cassava are shown in Table 6. The most significant results from the effects of GDD are found for states in Southern Nigeria, namely, Ondo, Edo, Enugu, and Ebonyi states. Apart from Edo state, the coefficients are positive, with the highest value evident in Ondo state. This means that an increase of one GDD unit induces a yield increase in these states. The effect of increased annual rainfall on cassava yield is negative and significant for Imo, Bayelsa, and Rivers states (all in Southern Nigeria). One possible explanation for this result is that rainfall is so abundant in these states that it leads to excess soil moisture. It should be noted that these states are located in the coastal part of Southern Nigeria, which is prone to flooding. Another reason for the inverse relationship between cassava yield and rainfall could be a result of a positive correlation between increased rainfall and cloud cover, leading to reduced radiation from the sun. Such an occurrence could reduce photosynthesis and hence reduce yield. On the other hand, positive coefficients for GDD are found in Enugu, Kebbi, Kogi, and Ogun state, as expected a priori.

As expected theoretically, the effect of increased extreme temperatures measured with HDD on cassava yield is negative in Ekiti, Kano, Jigawa, Ondo, and Sokoto states. These results reinforce the hypothesis that extreme weather is an important limiting factor for crop growth, particularly in Northern Nigeria. The coefficient of time trend is positive and significant in 27 percent of the states producing cassava, including Cross River, Delta, Ebonyi, Gombe, Imo, Katsina, Kogi, Lagos, Nassarawa, and Sokoto states. The positive trend can be attributed to long-term productivity gains in cassava agriculture; these improvements might be due to structural changes, improved cassava varieties, improved farming techniques and technologies, and more efficient fertilizer use. On the other hand, a negative time trend is found in Benue, Ogun, and Enugu states. This might be due to state-level structural changes relating to government policies in cassava agriculture that negatively affect productivity.

Table 6: Cassava Regression Results at the State Level

State	Rain	GDD	HDD	Trend	Cons.	R^2 Square	F
Abia	-.02 (-0.01)	10.98 (0.57)	-.58 (-0.72)	.15 (1.66)	-100.72 (-0.59)	0.82	15.91
Adamawa	1.72 (0.80)	5.22 (0.33)	-.82 (-0.37)	.01 (0.13)	-55.47 (-0.45)	0.6984	7.87
Akwa Ibom	.81 (0.87)	-3.82 (-0.30)	-.22 (-0.47)	.06 (0.58)	19.79 (0.19)	0.94	27.43
Anambra	-.61 (-0.42)	-7.03 (-0.34)	.66 (1.15)	-.14 (-1.46)	60.22 (0.33)	0.87	23.50
Bauchi	-.69 (-0.22)	.73 (0.13)	-.41 (-0.28)	-.04 (-0.48)	-4.02 (-0.10)	0.86	21.28
Bayelsa	-5.43** (-2.14)	1.58 (0.15)	.25 (0.36)	.01 (0.06)	20.98 (0.26)	0.86	21.45
Benue	2.42 (0.78)	-23.12 (-0.38)	1.56 (0.35)	-.31*** (-3.55)	177.08 (0.34)	0.88	25.64
Borno	2.17 (1.20)	9.66 (1.06)	-.46 (-0.24)	-.03 (-0.52)	-97.85 (-1.27)	0.72	9.07
Cross River	-.44 (-0.19)	-3.57 (-0.37)	.42 (1.15)	.18*** (3.64)	27.01 (0.31)	0.94	57.35
Delta	4.07 (1.26)	30.56 (1.39)	-.36 (-0.53)	.40 (3.97)	-309.92 (-1.52)	0.92	39.97
Ebonyi	.57 (0.55)	25.25** (2.81)	-.24 (-0.81)	.22*** (4.58)	-232.8** (-2.83)	0.97	95.38
Edo	3.38 (0.76)	-108.5** (-2.56)	-.03 (-0.04)	.06 (0.82)	918.29** (2.60)	0.91	36.56
Ekiti	-.25 (-0.09)	1.73 (0.09)	-2.1** (-2.12)	-.08 (-0.69)	-12.18 (-0.07)	0.91	33.88
Enugu	2.55** (2.01)	24.37* (1.80)	-.05 (-0.10)	-.13* (-1.82)	-234.2** (-2.01)	0.89	27.68
F.C.T	2.59 (0.62)	-33.92 (-1.04)	2.80 (0.93)	.03 (0.25)	263.30 (0.99)	0.60	5.14
Gombe	1.31 (0.51)	6.34 (1.38)	-1.92 (-1.62)	.13* (1.90)	-62.37** (-1.83)	0.92	41.28
Imo	-5.52*** (-3.44)	11.41 (0.62)	-.47 (-0.69)	.11* (1.86)	-62.87 (-0.41)	0.96	73.90
Jigawa	-2.68 (-1.63)	7.66 (0.88)	-4.51** (-1.92)	.02 (0.24)	-32.79 (-0.46)	0.94	54.04
Kaduna	-3.54 (-1.11)	8.58 (0.62)	-2.04 (-1.42)	-.02 (-0.20)	-43.99 (-0.41)	0.77	11.61
Kano	-2.68 (-1.63)	7.66 (0.88)	-4.51** (-1.92)	.02 (0.24)	-32.79 (-0.46)	0.94	54.04
Katsina	-.38 (-0.18)	7.06 (0.65)	.44 (0.17)	.16** (2.26)	-69.100 (-0.71)	0.93	48.81
Kebbi	4.28** (2.24)	16.17 (1.22)	-1.21 (-0.47)	.17 (1.59)	-168.09 (-1.51)	0.69	7.63
Kogi	5.35** (2.39)	-9.35 (-0.82)	.03 (0.04)	.12 (1.72)	37.57 (0.39)	0.93	46.32
Kwara	-.25 (-0.11)	6.89 (0.31)	-1.31 (-0.84)	-.01 (-0.14)	-58.45 (-0.31)	0.87	22.67
Lagos	-3.48 (-1.11)	21.74 (0.93)	-.60 (-0.56)	.15 (1.70)	-168.07 (-0.91)	0.82	15.19
Nassarawa	-.62 (-0.27)	-10.06 (-0.72)	.54 (0.48)	.22*** (4.45)	83.89 (0.73)	0.91	34.81

Niger	.57 (0.14)	9.5 (0.39)	-4.36 (-1.09)	.08 (0.85)	-70.29 (-0.34)	0.70	7.91
Ogun	5.2** (2.23)	-7.65 (-0.48)	.53 (0.77)	-.14** (-1.84)	26.15 (0.20)	0.88	24.53
Ondo	-2.45 (-1.29)	57.01** (4.04)	-2.2*** (-3.19)	.05 (0.58)	-481.0*** (-4.03)	0.95	71.15
Osun	3.96 (1.43)	-13.100 (-0.86)	1.73 (1.44)	.06 (0.51)	82.80 (0.60)	0.88	23.97
Oyo	3.10 (0.64)	5.00 (0.14)	.84 (0.39)	-.15 (-1.27)	-72.44 (-0.24)	0.84	17.62
Plateau	-.23 (-0.05)	-.35 (-0.03)	.35 (0.84)	-.06 (-0.78)	2.23 (0.02)	0.87	12.06
Rivers	-2.71* (-1.91)	-4.03 (-0.69)	.31 (0.79)	.07 (1.04)	50.23 (1.10)	0.90	29.92
Sokoto	-.28 (-0.17)	41.23 (1.60)	-6.7** (-2.17)	.09** (2.07)	-332.02 (-1.58)	0.96	78.54
Taraba	-.15 (-0.05)	27.82 (1.25)	-2.14 (-0.69)	-.00 (-0.02)	-237.36 (-1.35)	0.81	14.26
Yobe	-.03 (-0.02)	-24.24** (-2.07)	2.39 (1.23)	-.11 (-1.34)	199.44** (2.07)	0.76	10.50
Zamfara	-1.81 (-1.06)	-10.58 (-0.86)	-.59 (-0.55)	.04 (0.51)	102.60 (0.96)	0.93	48.16

Note: In parenthesis are the student’s t values, *, **, *** indicate significance at 10, 5 and 1% respectively

The regression results at the state level for maize are shown in Table 7. The most important results for the effect of growing degree days are found in Bayelsa and Kano states. A 1 percent increase in growing degree days will lead to about a 9.3 percent yield increase in yield in Bayelsa and about a 19.2 percent decline in yield in Kano. The most significant results for the effect of extreme temperature (HDD) are found in Adamawa, Bauchi, Bayelsa, Imo, Osun, Borno, Edo, Katsina, Niger, and Zamfara states, with the first five states showing negative effects and the second five showing positive effects. This means that an increase in HDD induces a yield decrease in half of the states where the variable is significant. The effect of increased annual rainfall on maize yield is positive and significant in Anambra, Bauchi, Ebonyi, Jigawa, Katsina, Kogi and Taraba and negative for Delta, Rivers and Enugu states.

As with cassava, the coefficient of time trend is positive and significant in more than one-quarter of the states producing maize in Nigeria. The states include Cross River, Ekiti, Bayelsa, Borno, Jigawa, Katsina, Ogun, Oyo, and Zamfara. The positive trend can be attributed to long-term productivity gains in maize agriculture, largely due to improved maize varieties, especially from the International Institute of Tropical Agriculture (IITA), improved farming techniques and technologies, and more efficient fertilizer use.

Table 7: Maize regression results at state level

State	Rain	GDD	HDD	Trend	Constant	R^2	F
Abia	2.82 (0.95)	46.16 (1.38)	-.023 (-0.03)	.01 (0.09)	-411.83 (-1.51)	0.79	17.21
Adamawa	.61 (0.26)	14.01 (1.20)	-3.47** (-2.10)	-.04 (-0.54)	-108.08 (-1.21)	0.82	20.88
Akwa-Ibom	3.62 (1.00)	67.68 (1.27)	-.91 (-1.13)	-.28 (-0.63)	-543.02 (-1.27)	0.54 (2.62)	2.62
Anambra	3.19** (2.71)	25.80 (1.34)	-.05 (-0.11)	.05 (0.79)	-242.99 (-1.47)	0.80	18.38
Bauchi	5.31* (1.83)	7.92 (1.49)	-2.61** (-2.24)	-.03 (-0.44)	-95.12** (-2.75)	0.80	18.54
Bayelsa	.07 (0.05)	9.31* (1.63)	-.93** (-2.90)	.15** (2.94)	-84.13** (-2.11)	0.95	77.48
Benue	-2.50 (-0.66)	-88.52 (-1.31)	4.87 (1.16)	.04 (0.41)	737.41 (1.31)	0.71	11.67
Borno	-1.27 (-1.33)	-3.65 (-1.00)	1.83** (2.33)	.09*** (3.32)	26.41 (0.86)	0.90	38.50
Cross Rivers	-3.29 (-0.61)	-29.22 (-0.57)	.15 (0.20)	.32** (2.74)	260.74 (0.58)	0.76	12.96
Delta	-5.26** (-1.96)	-6.71 (-0.24)	.01 (0.03)	.01 (0.08)	91.61 (0.39)	0.82	21.63
Ebonyi	3.39** (2.18)	14.79 (0.58)	.06 (0.10)	.01 (0.13)	-152.45 (-0.70)	0.69	10.99
Edo	1.05 (0.51)	-41.33 (-1.54)	1.00** (2.78)	.06 (1.28)	330.62 (1.50)	0.92	54.66
Ekiti	-1.99 (-1.13)	9.08 (0.38)	-1.17 (-1.27)	.18** (2.35)	-65.82 (-0.35)	0.93	61.28
Enugu	2.64* (1.64)	5.27 (0.14)	.41 (0.57)	-.14** (-1.90)	-66.35 (-0.22)	0.82	18.82
F. C. T.	1.04 (0.89)	5.00 (0.30)	-.35 (-0.32)	.15*** (3.40)	-50.48 (-0.37)	0.62	8.17
Gombe	-4.68 (-1.20)	10.96 (1.53)	-2.33 (-1.49)	.08 (0.87)	-56.24 (-1.21)	0.86	28.54
Imo	-4.74 (-1.22)	29.99 (0.99)	-1.29* (-1.81)	-.31** (-2.83)	-213.73 (-0.88)	0.78	16.59
Jigawa	3.51** (2.19)	-7.56 (-0.60)	1.69 (0.67)	.13** (2.18)	25.83 (0.25)	0.83	22.91
Kaduna	-4.02 (-1.24)	-11.79 (-0.51)	1.07 (0.67)	-.19** (-2.23)	120.20 (0.67)	0.83	22.22
Kano	-.89 (-0.68)	-19.24* (-1.86)	3.47* (1.68)	-.04 (-0.85)	146.03* (1.74)	0.95	85.24
Kastina	3.62*** (3.30)	-11.02 (-1.43)	6.31*** (4.31)	.19*** (4.20)	31.06 (0.49)	0.94	70.45
Kebbi	-1.25 (-0.56)	10.76 (0.89)	-.56 (-0.27)	-.17 (-1.93)	-81.43 (-0.80)	0.77	15.50
Kogi	3.72 (2.63)	-.39 (-0.05)	.08 (0.24)	.03 (0.67)	-26.70 (-0.39)	0.90	42.31
Kwara	.99 (0.40)	-12.23 (-0.77)	1.62 (1.47)	-.00 (-0.01)	84.29 (0.66)	0.83	22.45
Lagos	2.00 (0.48)	-47.72 (-0.87)	1.11 (0.91)	-.28** (-2.01)	379.16 (0.87)	0.81	19.43
Nassarawa	-.22 (-0.04)	-24.84 (-1.07)	-.64 (-0.90)	-.09 (-0.68)	196.47 (1.13)	0.81	19.43

Niger	-2.51 (-0.98)	-23.38 (-0.98)	3.12** (3.12)	-.03 (-0.64)	197.97 (0.86)	0.84	24.16
Ogun	.61 (1.13)	-.67 (-0.12)	-.06 (-0.53)	.09*** (4.02)	-1.77 (-0.04)	0.96	98.54
Ondo	.60 (0.56)	3.58 (0.25)	-.55 (-0.98)	-.01 (-0.13)	-35.37 (-0.31)	0.91	46.03
Osun	2.22 (1.13)	19.63 (0.72)	-1.59** (-2.43)	.07 (0.87)	-181.35 (-0.82)	0.90	40.47
Oyo	-.71 (-0.35)	14.48 (1.32)	-.87 (-1.36)	.14*** (3.23)	-117.86 (-1.32)	0.83	23.13
Plateau	.69 (0.08)	-13.34 (-0.37)	.39 (0.36)	.13 (0.63)	95.82 (0.35)	0.53	4.17
Rivers	-5.91** (-2.44)	14.71 (1.36)	-.46 (-0.75)	-.00 (-0.02)	-81.80 (-1.09)	0.78	15.41
Sokoto	-3.95 (-0.81)	-9.75 (-0.08)	-6.77 (-0.55)	-.13 (-0.93)	140.91 (0.13)	0.67	10.05
Taraba	3.69* (1.78)	-3.73 (-0.36)	.46 (0.31)	-.24*** (-4.13)	4.01*** (0.05)	0.84	23.99
Yobe	1.53 (0.85)	-41.83* (-1.90)	2.54 (0.96)	.02 (0.20)	329.76* (1.81)	0.66	9.37
Zamfara	.44 (0.68)	-14.25 (-1.53)	1.97** (2.93)	.10*** (3.82)	104.62 (1.36)	0.92	48.34

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

The regression results at the state level for rice are presented in Table 8. GDD produces positive and significant effects on the mean yield of rice in Ekiti, but negative effects for Yobe and Kaduna states. It is expected that temperatures between 10ºC and 32ºC would enhance rice yields in these geographical locations. On the other hand, increased GDD induces a decline in rice yield in Yobe and Kaduna states. Rainfall has a negative effect on mean rice yield in Bauchi, Bayelsa, and Cross Rivers states. Historical evidence suggests that there can be great reduction in rice yields due to excessive rainfall during the production season in these areas; thus our result is consistent with farmers' experience. On the other hand, the relationship between rainfall and mean rice yield is positive in Borno and Ebonyi states. Extreme temperatures (HDD) negatively influences rice yield in Adamawa, Gombe, and Nassarawa states in Northern Nigeria. The coefficients are 2.09, 2.16, and 0.94, respectively.

Like other crops promoted by the nation's ATA, the coefficient of time trend is positive and significant in more than one-quarter of the states producing rice in Nigeria, including Zamfara, Oyo, Osun, Ogun, Niger, and Enugu. The positive trend can be attributed to long-term productivity gains, due largely to improved rice varieties, especially from the IITA and AFRICARICE institutions, improved farming and extension services, and more efficient fertilizer use.

Table 8 Rice mean yield regression results

State	Rain	GDD	HDD	trend	Cons	R2	F
Abia	-.32 (-0.26)	-8.96 (-0.98)	-.12 (-0.43)	.18 (-1.48)	72.13 (0.92)	0.89	39.94
Adamawa	-1.85 (-1.35)	10.92 (1.12)	-2.09* (-1.77)	.05 (1.37)	-73.13 (-0.98)	0.79	18.09
Akwa_Ibom	1.02 (0.54)	28.09 (1.47)	-.41 (-0.70)	.16 (0.86)	-239.87 (-1.51)	0.81	9.72
Anambra	.15 (0.14)	-12.79 (-1.60)	.17 (0.47)	-.02 (-0.43)	101.74 (1.43)	0.92	42.06
Bauchi	-2.31** (-1.71)	2.36 (0.48)	-.08 (-0.25)	.02 (0.43)	-8.90 (-0.24)	0.77	15.98
Bayelsa	-2.31* (-1.71)	2.36 (0.48)	-0.87 (-1.25)	.03 (0.43)	-8.90 (-0.24)	0.94	66.92
Benue	-6.39* (-1.69)	-15.29 (-0.35)	-1.82 (-1.12)	.07 (0.72)	173.75 (0.46)	0.79	18.31
Borno	4.07* (1.82)	1.64 (0.16)	-1.18 (-0.59)	-.39** (-5.95)	-32.53 (-0.38)	0.79	18.46
Cross River	-1.91 (-0.93)	1.65 (0.20)	-.10 (-0.16)	.07 (1.09)	-2.16 (-0.03)	0.79	12.48
Delta	.57 (0.61)	2.84 (0.62)	-.05 (-0.45)	-.02 (-0.78)	-28.88 (-0.70)	0.56	6.01
Ebonyi	4.08** (3.20)	-5.54 (-0.58)	1.50** (3.28)	-.01 (-0.21)	10.93 (0.13)	0.84	18.85
Edo	-1.55 (-1.46)	-3.82 (-0.33)	-.15 (-1.35)	-.08** (-3.79)	40.32 (0.43)	0.98	293.37
Ekiti	-2.13 (-0.94)	44.29*** (3.18)	-.75 (-1.55)	.11 (0.92)	-365.30** (-3.16)	0.92	48.13
Enugu	-.83 (-0.34)	-2.35 (-0.11)	.73 (0.93)	.34** (2.64)	14.88 (0.08)	0.78	17.19
F.C. T.	-.03 (-0.02)	-16.68 (-1.01)	.59 (0.49)	.04 (0.68)	137.32 (1.05)	0.44	4.46
Gombe	1.28 (0.36)	11.7** (2.33)	-2.16** (-2.32)	-.18* (-1.81)	-103.31*** (-3.08)	0.86	30.20
Imo	.44 (0.20)	31.70* (1.63)	-.60 (-1.51)	.09 (1.60)	-275.23* (-1.67)	0.76	14.86
Jigawa	-2.21 (-1.22)	-13.59 (-1.54)	-1.44 (-0.63)	.02 (0.31)	133.38** (1.79)	0.75	14.89
Kaduna	-3.95 (-0.88)	-40.01** (-2.11)	.84 (0.74)	-.14 (-1.24)	361.32** (2.40)	0.64	8.90
Kano	-.08 (-0.05)	-1.52 (-0.19)	.89 (0.42)	-.26*** (-3.99)	8.49 (0.12)	0.82	21.96
Kastina	-1.40 (-0.47)	-19.28 (-1.15)	-.84 (-0.30)	-.04 (-0.54)	176.09 (1.19)	0.61	7.98
Kebbi	.80 (0.37)	-4.90 (-0.38)	2.06 (0.95)	-.00 (-0.04)	23.01 (0.21)	0.72	12.33
Kogi	-1.47 (-0.62)	6.33 (0.68)	-.38 (-1.03)	-.22** (-2.81)	-44.87 (-0.55)	0.90	40.67
Kwara	-1.20 (-0.46)	14.94 (0.80)	.44 (0.50)	-.18** (-1.97)	-120.41 (-0.79)	0.68	10.78
Lagos	-2.44 (-1.58)	-8.18 (-0.79)	.40 (1.46)	-.12** (-2.00)	83.86 (1.03)	0.91	46.89
Nassarawa	-3.34 (-1.39)	21.06** (2.29)	-.94** (-2.59)	.01 (0.19)	-152.71** (-2.21)	0.95	51.46
Niger	2.99	15.52	-.80	.16**	-153.75	0.72	12.79

	(1.11)	(1.31)	(-0.71)	(2.89)	(-1.44)		
Ogun	-2.26 (-1.10)	-2.03 (-0.19)	-.26 (-0.75)	.45 (6.66)	23.51 (0.30)	0.96	100.68
Ondo	.73 (0.29)	25.26* (1.65)	-.85 (-1.61)	-.04 (-0.33)	-222.25* (-1.75)	0.87	29.79
Osun	-.10 (-0.07)	-7.83 (-0.82)	.19 (0.69)	.36*** (5.05)	58.14 (0.74)	0.90	42.63
Oyo	-.08 (-0.05)	-4.97 (-0.51)	.39 (1.11)	.30*** (6.39)	34.64 (0.41)	0.92	52.87
Plateau	.31 (0.15)	1.71 (0.21)	.50 (1.56)	.06 (1.07)	-19.15 (-0.31)	0.89	19.53
Rivers	-.99 (-0.41)	-3.39 (-0.39)	.70 (1.16)	.05 (0.43)	32.07 (0.49)	0.56	5.94
Sokoto	-2.31 (-1.16)	-4.09 (-0.12)	1.25 (0.34)	-.08 (-1.58)	41.79 (0.15)	0.80	18.93
Taraba	-2.81 (-0.65)	3.59 (0.12)	-1.04 (-0.28)	.06 (0.49)	-12.9 (-0.05)	0.75	14.71
YOBE	2.57 (0.81)	-50.05** (-2.59)	-4.76 (-1.34)	-.42** (-2.92)	436.15** (2.76)	0.64	9.07
Zamfara	.20 (0.25)	-9.93 (-1.26)	.56 (1.17)	.12*** (3.31)	75.27 (1.18)	0.95	98.97

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

The regression results at the state level for sorghum are shown in Table 9. The coefficient of GDD is significant in FCT, Kaduna, Gombe, Taraba, and Nassarawa states, but apart from Nassarawa state, these coefficients are negative. This means that an increase of one GDD unit induces a yield decrease in FCT, Kaduna, and Taraba states. On the other hand, positive coefficients for GDD are found in Katsina state, as expected a priori. The effect of increased annual rainfall on sorghum yield is negative and significant for Adamawa, Oyo, and Zamfara states. This means that as rainfall becomes abundant in theses, it leads to excessive soil moisture.

As expected theoretically, the effect of increased extreme temperature measured with HDD on sorghum yield is negative in Gombe, Kano, Oyo, and Taraba states. The results reinforce the hypothesis that extreme weather is an important limiting factor for crop growth, particularly in Northern Nigeria, where warmer environments exist.

The coefficient of time trend is positive and significant in just two of the states producing sorghum in Nigeria: Kwara and Nassarawa. This positive trend can be attributed to technological progress in sorghum production in those states. On the hand, a negative time trend is found in FCT, Kaduna, Kogi, and Niger states, perhaps due to state-level structural changes relating to government policies in sorghum agriculture that negatively affect productivity.

Table 9: Sorghum Regression Results at the state level

State	Rain	GDD	HDD	Trend	Constant	R	F
Adamawa	-3.83* (-1.70)	5.15 (0.32)	-2.50 (-1.06)	.11 (1.53)	-8.37 (-0.07)	0.76	15.68
Bauchi	-.54 (-0.20)	1.74 (0.80)	-.67 (-1.09)	-.05 (-0.76)	-11.28 (-0.71)	0.85	27.28
Benue	-1.97 (-0.88)	-53.08 (-1.44)	.86 (0.77)	-.06 (-1.11)	428.48 (1.47)	0.83	22.97
Borno	1.12 (0.65)	-6.50 (-0.86)	1.46 (0.91)	.03 (.05)	32.49 (0.54)	0.92	53.99
F. C. T	2.80 (1.59)	38.73* (1.90)	-1.57 (-1.41)	-.17** (-2.52)	-323.85** (-2.05)	0.87	30.46
Gombe	-5.11* (-1.68)	6.14** (2.50)	-1.21* (-1.73)	.03 (0.47)	-15.26** (-15.26)	0.90	44.75
Jigawa	-1.25 (-0.33)	3.60 (0.22)	-.20 (-0.06)	-.13 (-1.02)	-21.05 (-0.17)	0.31	3.04
Kaduna	1.07 (0.44)	6.05 (0.49)	.04 (0.10)	-.16** (-2.30)	-57.98 (-0.60)	0.84	24.57
Kano	-2.02 (-1.62)	7.27 (1.10)	-4.30*** (-3.02)	.02 (0.52)	-27.67 (-0.54)	0.82	21.10
Kastina	4.32** (2.32)	3.55 (0.26)	3.04* (1.64)	.09* (1.64)	-77.25 (-0.70)	0.87	31.58
Kebbi	.37 (0.16)	3.57 (0.30)	-1.05 (-0.49)	-.01 (-0.17)	-29.77 (-0.32)	0.75	14.77
Kogi	-.86 (-0.52)	3.58 (0.35)	-.27 (-0.62)	-.18** (-2.67)	-24.82 (-0.30)	0.93	58.79
Kwara	-1.13 (-0.51)	-13.44 (-0.59)	.08 (0.07)	.16** (2.09)	2.09 (0.60)	0.78	16.65
Nassarawa	1.94 (1.43)	-8.93** (-2.58)	-.13 (-0.58)	.11** (2.55)	48.78** (2.37)	0.96	58.41
Niger	-2.56 (-0.80)	-38.01 (-1.38)	1.83 (1.54)	-.16** (-2.46)	309.72 (1.40)	0.87	32.00
Oyo	-5.08** (-2.22)	27.76 (1.42)	-1.29** (-2.58)	.02 (0.38)	-184.91 (-1.25)	0.78	16.42
Plateau	-.57 (-0.20)	6.76 (1.33)	1.05** (2.19)	.05 (0.71)	-50.99 (-1.27)	0.88	17.95
Sokoto	-6.03** (-1.68)	-27.38 (-0.41)	.79 (0.10)	-.08 (-0.88)	253.56 (0.50)	0.62	8.45
Taraba	.52 (0.42)	29.38*** (3.06)	-4.76*** (-3.32)	.06 (1.30)	-220.11*** (-3.21)	0.87	32.02
Yobe	-.62 (-0.31)	-6.95 (-0.31)	2.03 (0.67)	.13 (1.47)	45.12 (0.27)	0.78	17.12
Zamfara	-2.89** (-2.70)	-9.05 (-0.68)	.89 (1.13)	.00 (0.03)	85.29 (0.82)	0.85	25.93

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

The regression results at the state level for cotton are shown in Table 10. Significant results for the effect of GDD are found in Adamawa, Sokoto, Zamfara, and Katsina states. Apart from Katsina state, these coefficients are positive, with the highest value found in the Zamfara State. This means that an increase of in GDD unit induces a yield increase in those states. The effect of increased annual rainfall on cotton yield is negative and significant for Katsina state, possibly due to a positive correlation between increased rainfall and cloud cover, leading to reduced radiation from the sun. Such an occurrence could reduce photosynthesis and hence reduce yield.

As expected theoretically, the effect of increased extreme temperatures measured with HDD on cotton yield is negative for Adamawa, Sokoto, and Zamfara states. The results further reinforce the hypothesis that extreme weather is an important limiting factor for crop growth, particularly in Northern Nigeria. The coefficient of time trend is positive and significant in Katsina state but negative for Adamawa and Zamfara states.

Table 10 Cotton regression results at the state level

State	Rain	GDD	HDD	TREND	Constant	R^2	F
Adamawa	1.75** (2.08)	14.97** (2.34)	-.92** (-2.45)	-.15* (-1.93)	17.05** (2.54)	0.66	6.29
Bauchi	.01 (0.45)	.18 (0.89)	-.01 (-0.85)	-.01*** (-3.66)	.04 (0.31)	0.100	360.77
Borno	.13 (0.29)	.00 (0.00)	.00 (0.01)	.00 (0.02)	-.02 (-0.01)	0.93	43.59
Gombe	.11 (0.48)	-1.33 (-0.93)	.10 (1.30)	.03** (2.47)	-.42 (-0.46)	0.59	4.56
Kaduna	-.26 (-0.30)	-3.72*** (-0.70)	.32 (1.17)	.04 (0.70)	-3.23 (-0.71)	0.47	2.87
Kano	.20 (0.23)	-2.51** (-0.54)	-.21 (-0.72)	-.07 (-1.06)	1.79 (0.37)	0.43	2.41
Katsina	-2.36** (-4.21)	-16*** (-4.09)	.84*** (4.07)	.19*** (4.04)	-8.2*** (-4.80)	0.82	14.61
Kebbi	.06 (0.19)	-.72 (-0.17)	.27 (0.66)	.01 (0.20)	.61 (0.27)	0.75	9.85
Niger	.18 (0.65)	3.10* (1.69)	-.08 (-0.67)	-.05** (-2.29)	3.62* (1.82)	0.50	3.16
Sokoto	.78 (0.79)	14.21* (1.72)	-1.6** (-2.84)	-.17** (-2.02)	9.61 (1.49)	0.69	7.24
Zamfara	1.16*** (4.71)	8.03*** (4.42)	-.3*** (-3.30)	-.05** (-2.99)	8.28*** (5.98)	0.80	13.08

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

3.2.3 Changes in Yield Variance Using State-Level Data

The regression results for yield variance obtained from the estimation of the second stage of the Just and Pope stochastic production function are presented in Table 11. Like the mean function, a logarithmic function is also assumed. The adjusted R-square varied from 0.54 for rice to 0.68 for maize. The overall significance of the model captured with F-test shows that the model fits the data well for all crops. Rainfall is found to be risk-increasing for rice and risk-decreasing for cassava, cotton, maize, and sorghum. The corresponding coefficients are 0.98, 1.41, 0.71, 0.74, and 0.99 for the five crops, respectively. The risk-reducing effect of rainfall on cassava and cotton might be due to their lower water demand. The GDD is found to increase yield risk for rice and sorghum, while HDD would decrease the yield risk of rice. Technological progress indicated by trend is positively associated with yield risk for maize, sorghum, and cotton but negatively related to yield risk for rice.

Table 11: Yield variance function using state-level data

CROP	Rain	GDD	HDD	Trend	Constant	F	R_2
Cassava	-0.98*** (-4.32)	-0.985 (-1.16)	0.305*** (3.91)	-0.002 (-0.14)	12.088* (1.90)	199.12***	0.56
Cotton	-1.41** (-2.70)	-1.041 (-0.56)	0.076 (0.31)	0.048** (2.22)	15.243 (1.06)	53***	0.52
Maize	-0.714** (-2.95)	0.970 (1.20)	0.139 (1.54)	0.096*** (7.64)	-7.714 (-1.28)	336.01***	0.68
Rice	0.737** (2.85)	1.503* (1.70)	-0.187** (-2.87)	-0.029** (-2.14)	-19.565** (-2.81)	178.17***	0.54
Sorghum	-0.986** (-2.58)	1.484* (1.65)	-0.122 (-1.18)	0.047** (2.60)	-8.525 (-1.22)	163***	0.65

The state-by-state regression results for yield variance are shown in Tables 12 to 16 for cassava, maize, rice, sorghum, and cotton, respectively.

For cassava, rainfall is found not to be risk-increasing across all states; this effect is most critical in Kaduna state, with a coefficient of 1.33, and least critical in Lagos state. The risk-reducing effects of rainfall are evident in the following cassavaproducing states, namely, Abia, Anambra, Ebonyi, Enugu and Taraba. GDD is found to increase the yield risk of cassava in Abia, Ekiti, Nassarawa, Niger, Ogun, Osun, Taraba, and Zamfara. States. Extreme temperatures (HDD) would increase the yield risk in most states growing cassava in Northern Nigeria, namely, Borno, Kano, Niger, and Zamfara. Extreme temperatures are, however, beneficial in Adamawa, Bauchi, and Katsina states. Technological progress is positively correlated with cassava yield risk in about 20 percent of cassava-producing states, including include Bayelsa, Ekiti, Jigawa, Katsina Ogun, Oyo, and Zamfara. It is negatively related in Enugu, Imo, Kaduna, Lagos, and Taraba states.

Table 12: Cassava yield risk function at the state level

State	Rain	GDD	HDD	Trend	constant	R^2	F
Abia	2.82 (0.95)	46.16 (1.38)	-.023 (-0.03)	.01 (0.09)	-411.83 (-1.51)	0.79	17.21
Adamawa	.61 (0.26)	14.01 (1.20)	-3.47** (-2.10)	-.04 (-0.54)	-108.08 (-1.21)	0.82	20.88
Akwa-Ibom	3.62 (1.00)	67.68 (1.27)	-.91 (-1.13)	-.28 (-0.63)	-543.02 (-1.27)	0.54 (2.62)	2.62
Anambra	3.19 (2.71)	25.80 (1.34)	-.05 (-0.11)	.05 (0.79)	-242.99 (-1.47)	0.80	18.38
Bauchi	5.31 (1.83)	7.92 (1.49)	-2.61** (-2.24)	-.03 (-0.44)	-95.12 (-2.75)	0.80	18.54
Bayelsa	.07 (0.05)	9.31 (1.63)	-.93** (-2.90)	.15** (2.94)	-84.13 (-2.11)	0.95	77.48
Benue	-2.50 (-0.66)	-88.52 (-1.31)	4.87 (1.16)	.04 (0.41)	737.41 (1.31)	0.71	11.67
Borno	-1.27 (-1.33)	-3.65 (-1.00)	1.83** (2.33)	.09*** (3.32)	26.41 (0.86)	0.90	38.50
Cross Rivers	-3.29 (-0.61)	-29.22 (-0.57)	.15 (0.20)	.32** (2.74)	260.74 (0.58)	0.76	12.96
Delta	-5.26 (-1.96)	-6.71 (-0.24)	.01 (0.03)	.01 (0.08)	91.61 (0.39)	0.82	21.63
Ebonyi	3.39 (2.18)	14.79 (0.58)	.06 (0.10)	.01 (0.13)	-152.45 (-0.70)	0.69	10.99
Edo	1.05 (0.51)	-41.33 (-1.54)	1.00** (2.78)	.06 (1.28)	330.62 (1.50)	0.92	54.66
Ekiti	-1.99 (-1.13)	9.08 (0.38)	-1.17 (-1.27)	.18** (2.35)	-65.82 (-0.35)	0.93	61.28
Enugu	2.64 (1.64)	5.27 (0.14)	.41 (0.57)	-.14* (-1.90)	-66.35 (-0.22)	0.82	18.82
F. C. T.	1.04 (0.89)	5.00 (0.30)	-.35 (-0.32)	.15*** (3.40)	-50.48 (-0.37)	0.62	8.17
Gombe	-4.68 (-1.20)	10.96 (1.53)	-2.33 (-1.49)	.08 (0.87)	-56.24 (-1.21)	0.86	28.54
Imo	-4.74 (-1.22)	29.99 (0.99)	-1.29* (-1.81)	-.31** (-2.83)	-213.73 (-0.88)	0.78	16.59
Jigawa	3.51 (2.19)	-7.56 (-0.60)	1.69 (0.67)	.13** (2.18)	25.83 (0.25)	0.83	22.91
Kaduna	-4.02 (-1.24)	-11.79 (-0.51)	1.07 (0.67)	-.19** (-2.23)	120.20 (0.67)	0.83	22.22
Kano	-.89 (-0.68)	-19.24 (-1.86)	3.47* (1.68)	-.04 (-0.85)	146.03 (1.74)	0.95	85.24
Kastina	3.62 (3.30)	-11.02 (-1.43)	6.31*** (4.31)	.19*** (4.20)	31.06 (0.49)	0.94	70.45
Kebbi	-1.25 (-0.56)	10.76 (0.89)	-.56 (-0.27)	-.17 (-1.93)	-81.43 (-0.80)	0.77	15.50
Kogi	3.72 (2.63)	-.39 (-0.05)	.08 (0.24)	.03 (0.67)	-26.70 (-0.39)	0.90	42.31
Kwara	.99 (0.40)	-12.23 (-0.77)	1.62 (1.47)	-.00 (-0.01)	84.29 (0.66)	0.83	22.45
Lagos	2.00 (0.48)	-47.72 (-0.87)	1.11 (0.91)	-.28** (-2.01)	379.16 (0.87)	0.81	19.43
Nassarawa	-.22 (-0.04)	-24.84 (-1.07)	-.64 (-0.90)	-.09 (-0.68)	196.47 (1.13)	0.81	19.43

Niger	-2.51 (-0.98)	-23.38 (-0.98)	3.12*** (3.12)	-.03 (-0.64)	197.97 (0.86)	0.84	24.16
Ogun	.61 (1.13)	-.67 (-0.12)	-.06 (-0.53)	.09*** (4.02)	-1.77 (-0.04)	0.96	98.54
Ondo	.60 (0.56)	3.58 (0.25)	-.55 (-0.98)	-.01 (-0.13)	-35.37 (-0.31)	0.91	46.03
Osun	2.22 (1.13)	19.63 (0.72)	-1.59** (-2.43)	.07 (0.87)	-181.35 (-0.82)	0.90	40.47
Oyo	-.71 (-0.35)	14.48 (1.32)	-.87 (-1.36)	.14*** (3.23)	-117.86 (-1.32)	0.83	23.13
Plateau	.69 (0.08)	-13.34 (-0.37)	.39 (0.36)	.13 (0.63)	95.82 (0.35)	0.53	4.17
Rivers	-5.91 (-2.44)	14.71 (1.36)	-.46 (-0.75)	-.00 (-0.02)	-81.80 (-1.09)	0.78	15.41
Sokoto	-3.95 (-0.81)	-9.75 (-0.08)	-6.77 (-0.55)	-.13 (-0.93)	140.91 (0.13)	0.67	10.05
Taraba	3.69 (1.78)	-3.73 (-0.36)	.46 (0.31)	-.24*** (-4.13)	4.01 (0.05)	0.84	23.99
Yobe	1.53 (0.85)	-41.83 (-1.90)	2.54 (0.96)	.02 (0.20)	329.76 (1.81)	0.66	9.37
Zamfara	.44 (0.68)	-14.25 (-1.53)	1.97** (2.93)	.10*** (3.82)	104.62 (1.36)	0.92	48.34

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

In the case of maize, rainfall is found to be risk-increasing in Bauchi, Borno, Delta, Ekiti, Kaduna, Kastina, Kebbi, Kogi, Kwara, Lagos, Ondo, Sokoto, and Yobe states. The most affected state is Yobe, with a coefficient of 1.33; the least affected is Kogi. Rainfall is risk-reducing in Abia, Anambra, Ebonyi, Enugu, F.C.T., and Taraba states. GDD is found to increase the yield risk of maize in Abia, Ekiti, Kogi, Nassaawa, Niger, Ogun, Osun, Taraba, and Zamfara States. HDD would increase the yield risk in Kastina, Kwara, Lagos, Sokoto, and Yobe states. Technological progress is positively correlated with maize yield risk in Bauchi, Bayelsa, Enugu, Gombe, Imo, Kastina, Kogi, Kwara, Ogun, Ondo, Plateau, Sokoto, and Yobe, but is negatively related in Akwa-Ibom, Anambra, Ebonyi, Edo, Nassarawa, Niger, Rivers, and Taraba states.

Table 13 Maize yield risk function at the state level

State	Rain	GDD	HDD	Trend	Constant	R^2	F
Abia	-.56* (-2.44)	7.73** (2.25)	-.29** (-2.72)	.00 (0.17)	-59.71** (-2.15)	0.94	69.62
Adamawa	.01 (0.02)	-6.05 (-1.37)	.74 (1.21)	-.02 (-0.77)	48.13 (1.39)	0.68	10.09
Akwa-Ibom	.67 (1.15)	9.31 (1.63)	-.49** (-2.31)	-.26*** (-3.35)	-74.01 (-1.59)	0.99	269.28
Anambra	-.39** (-3.23)	-3.47* (-1.87)	-.09* (-1.66)	-.04*** (-8.45)	32.83* (2.03)	0.99	355.59
Bauchi	.42* (1.80)	.09 (0.05)	-.23 (-1.40)	.03*** (3.86)	-2.50 (-0.17)	0.87	30.18
Bayelsa	-.09 (-1.20)	.27 (0.93)	.00 (0.05)	.02*** (5.06)	-1.39 (-0.62)	0.95	69.46
Benue	.07 (0.19)	1.49 (0.14)	.02 (0.02)	-.05 (-0.91)	-12.74 (-0.14)	0.40	3.82
Borno	.57** (2.33)	-4.04 (-1.20)	.47 (1.05)	-.02 (-1.35)	29.00 (1.08)	0.76	14.47
Cross Rivers	.03 (0.05)	.69 (0.11)	-.21** (-1.98)	-.01 (-1.25)	-5.53 (-0.10)	0.92	43.87
Delta	.46** (2.99)	.86 (0.29)	.01 (0.30)	-.01 (-1.33)	-10.11 (0.12)	0.98	225.25
Ebonyi	-.14* (-1.77)	-1.36 (-1.13)	-.15*** (-4.58)	-.15*** (-4.58)	13.03 (1.24)	0.99	507.31
Edo	-.15 (-1.20)	3.43 (1.37)	-.00 (-0.07)	-.01 (-1.76)	-26.78 (-1.28)	0.98	223.63
Ekiti	.49 (2.00)	6.46 (1.85)	-.23 (-1.18)	-.00 (-0.29)	-55.99 (-1.95)	0.96	113.33
Enugu	-.39 (-3.28)	-2.25 (-1.33)	.07 (0.95)	.07 (7.22)	21.49 (-0.44)	0.98	335.09
F. C. T.	-1.09* (-1.69)	7.78 (0.71)	-1.19 (-1.32)	.03 (0.96)	-54.02 (-0.61)	0.38	3.67
Gombe	.17 (0.80)	1.20 (0.71)	-.29** (-1.85)	.02* (1.92)	-9.79 (-0.69)	0.85	24.88
Imo	-.52 (-1.08)	3.65 (0.76)	.08 (.09)	.04*** (3.03)	-26.28 (-0.65)	0.98	180.42
Jigawa	-.16 (-0.69)	-9.14 (-1.10)	.89 (0.90)	.07 (1.49)	73.98 (1.11)	0.52	5.49
Kaduna	.76** (2.02)	-.89 (-0.25)	.05 (0.14)	.03 (1.02)	2.56 (0.09)	0.80	18.10
Kano	-.07 (-1.00)	.76 (0.33)	-.18 (-0.67)	.01 (0.36)	-4.85 (-0.26)	0.81	0.09
Kastina	.39** (2.53)	-6.83** (-2.45)	.98** (2.45)	.05** (2.70)	50.66** (2.38)	0.22	2.18
Kebbi	.56** (2.01)	2.45 (0.51)	-.51 (-0.83)	-.03 (-1.37)	-20.19 (-0.54)	0.95	75.77
Kogi	.27** (2.25)	2.29* (1.88)	-.00 (-0.82)	.06*** (13.90)	-21.36** (-2.07)	0.95	84.18
Kwara	.34** (1.97)	-4.21** (-2.23)	.28** (2.37)	.02 (2.09)**	32.16** (2.13)	0.51	5.36
Lagos	1.18 (3.23)	-14.95** (-2.37)	.79*** (4.53)	.03 (1.48)	116.10** (2.29)	0.91	43.41
Nassarawa	-.57 (-1.61)	3.81*** (3.45)	-.08 (-1.31)	-.02*** (-5.61)	-25.94*** (-3.52)	0.99	288.96

Niger	-.31 (-0.78)	13.04** (2.29)	-1.51*** (-3.14)	-.10*** (-3.12)	-101.25** (-2.17)	0.76	14.64
Ogun	.29 (1.56)	3.72* (1.93)	.03 (1.02)	.06*** (6.19)	-32.77** (-2.14)	0.99	6256.90
Ondo	.34 (1.81)	-2.92 (-1.11)	-.16 (-1.10)	.04*** (3.05)	22.72 ()1.05	0.98	349.61
Osun	-.48 (-1.26)	11.62** (2.17)	-.23** (-2.07)	.01 (0.73)	-92.52** (-2.17)	0.97	130.04
Oyo	.15 (0.32)	.82 (0.17)	.10 (0.14)	.05 (1.58)	-7.80 (-0.20)	0.40	3.83
Plateau	-.25 (-0.26)	-2.65 (-0.88)	.19 (1.08)	.02** (2.78)	23.78 (1.18)	0.92	32.84
Rivers	.08 (1.18)	-.07 (-0.28)	-.03 (-0.67)	-.01*** (-5.31)	.56 (0.30)	0.99	794.31
Sokoto	.61** (2.96)	-13.29** (-2.05)	1.58** (2.44)	.13*** (3.73)	101.38* (1.95)	0.80	18.08
Taraba	-1.97 (-3.44)	35.06*** (3.56)	-4.65*** (-3.40)	-.16*** (-3.05)	-260.43*** (-3.38)	0.81	18.62
Yobe	1.33** (2.05)	-38.72*** (-4.53)	5.42*** (4.87)	.14** (2.20)	293.88 (4.44)	0.62	7.76
Zamfara	-.12 (-0.69)	16.41*** (4.16)	-1.64*** (-3.65)	-.03 (-1.38)	-130.58*** (-4.12)	0.61	7.57

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

The results for rice shows that rainfall is risk-decreasing in Bauchi, Bayelsa, and Benue states. The coefficients are 2.31, 2.31, and 6.39, respectively. Rainfall is risk-increasing in Borno and Ebonyi. GDD is found to decrease the yield risk of rice in Kaduna and Yobe states. HDD would decrease the yield risk in Bauchi, Bayelsa, Nassarawa, and Niger states. Technological progress is positively correlated with rice yield risk in Bauchi, Bayelsa, Borno, F.C.T., Kwara, Nassarawa, Niger, Oyo, Sokoto, and Taraba, but is negatively related in Benue, Cross-Rivers Kaduna, Kastina, and Zamfara states.

Table 14 Rice yield risk function at the state level

State	Rain	GDD	HDD	Trend	Cons	R^2	F
Abia	-.32 (-0.26)	-8.96 (-0.98)	-.12 (-0.43)	.18 (-1.48)	72.13 (0.92)	0.89	39.94
Adamawa	-1.85 (-1.35)	10.92 (1.12)	-2.09* (-1.77)	.05 (1.37)	-73.13 (-0.98)	0.79	18.09
Akwa_Ibom	1.02 (0.54)	28.09 (1.47)	-.41 (-0.70)	.16 (0.86)	-239.87 (-1.51)	0.81	9.72
Anambra	.15 (0.14)	-12.79 (-1.60)	.17 (0.47)	-.02 (-0.43)	101.74 (1.43)	0.92	42.06
Bauchi	-2.31* (-1.71)	2.36 (0.48)	-.08 (-0.25)	.02 (0.43)	-8.90 (-0.24)	0.77	15.98
Bayelsa	-2.31* (-1.71)	2.36 (0.48)	-0.87 (-1.25)	.03 (0.43)	-8.90 (-0.24)	0.94	66.92
Benue	-6.39* (-1.69)	-15.29 (-0.35)	-1.82 (-1.12)	.07 (0.72)	173.75 (0.46)	0.79	18.31
Borno	4.07* (1.82)	1.64 (0.16)	-1.18 (-0.59)	-.39*** (-5.95)	-32.53 (-0.38)	0.79	18.46
Cross River	-1.91 (-0.93)	1.65 (0.20)	-.10 (-0.16)	.07 (1.09)	-2.16 (-0.03)	0.79	12.48
Delta	.57 (0.61)	2.84 (0.62)	-.05 (-0.45)	-.02 (-0.78)	-28.88 (-0.70)	0.56	6.01
Ebonyi	4.08*** (3.20)	-5.54 (-0.58)	1.50*** (3.28)	-.01 (-0.21)	10.93 (0.13)	0.84	18.85
Edo	-1.55 (-1.46)	-3.82 (-0.33)	-.15 (-1.35)	-.08*** (-3.79)	40.32 (0.43)	0.98	293.37
Ekiti	-2.13 (-0.94)	44.29*** (3.18)	-.75 (-1.55)	.11 (0.92)	-365.30*** (-3.16)	0.92	48.13
Enugu	-.83 (-0.34)	-2.35 (-0.11)	.73 (0.93)	.34** (2.64)	14.88 (0.08)	0.78	17.19
F.C. T.	-.03 (-0.02)	-16.68 (-1.01)	.59 (0.49)	.04 (0.68)	137.32 (1.05)	0.44	4.46
Gombe	1.28 (0.36)	11.7** (2.33)	-2.16** (-2.32)	-.18* (-1.81)	-103.31*** (-3.08)	0.86	30.20
Imo	.44 (0.20)	31.70 (1.63)	-.60 (-1.51)	.09 (1.60)	-275.23* (-1.67)	0.76	14.86
Jigawa	-2.21 (-1.22)	-13.59 (-1.54)	-1.44 (-0.63)	.02 (0.31)	133.38* (1.79)	0.75	14.89
Kaduna	-3.95 (-0.88)	-40.01** (-2.11)	.84 (0.74)	-.14 (-1.24)	361.32** (2.40)	0.64	8.90
Kano	-.08 (-0.05)	-1.52 (-0.19)	.89 (0.42)	-.26*** (-3.99)	8.49 (0.12)	0.82	21.96
Kastina	-1.40 (-0.47)	-19.28 (-1.15)	-.84 (-0.30)	-.04 (-0.54)	176.09 (1.19)	0.61	7.98
Kebbi	.80 (0.37)	-4.90 (-0.38)	2.06 (0.95)	-.00 (-0.04)	23.01 (0.21)	0.72	12.33
Kogi	-1.47 (-0.62)	6.33 (0.68)	-.38 (-1.03)	-.22** (-2.81)	-44.87 (-0.55)	0.90	40.67
Kwara	-1.20 (-0.46)	14.94 (0.80)	.44 (0.50)	-.18** (-1.97)	-120.41 (-0.79)	0.68	10.78
Lagos	-2.44 (-1.58)	-8.18 (-0.79)	.40 (1.46)	-.12** (-2.00)	83.86 (1.03)	0.91	46.89
Nassarawa	-3.34 (-1.39)	21.06** (2.29)	-.94** (-2.59)	.01 (0.19)	-152.71** (-2.21)	0.95	51.46
Niger	2.99	15.52	-.80	.16**	-153.75	0.72	12.79

	(1.11)	(1.31)	(-0.71)	(2.89)	(-1.44)		
Ogun	-2.26 (-1.10)	-2.03 (-0.19)	-.26 (-0.75)	.45*** (6.66)	23.51 (0.30)	0.96	100.68
Ondo	.73 (0.29)	25.26 (1.65)	-.85 (-1.61)	-.04 (-0.33)	-222.25 (-1.75)	0.87	29.79
Osun	-.10 (-0.07)	-7.83 (-0.82)	.19 (0.69)	.36*** (5.05)	58.14 (0.74)	0.90	42.63
Oyo	-.08 (-0.05)	-4.97 (-0.51)	.39 (1.11)	.30*** (6.39)	34.64 (0.41)	0.92	52.87
Plateau	.31 (0.15)	1.71 (0.21)	.50 (1.56)	.06 (1.07)	-19.15 (-0.31)	0.89	19.53
Rivers	-.99 (-0.41)	-3.39 (-0.39)	.70 (1.16)	.05 (0.43)	32.07 (0.49)	0.56	5.94
Sokoto	-2.31 (-1.16)	-4.09 (-0.12)	1.25 (0.34)	-.08 (-1.58)	41.79 (0.15)	0.80	18.93
Taraba	-2.81 (-0.65)	3.59 (0.12)	-1.04 (-0.28)	.06 (0.49)	-12.9 (-0.05)	0.75	14.71
Yobe	2.57 (0.81)	-50.05* (-2.59)	-4.76 (-1.34)	-.42** (-2.92)	436.15** (2.76)	0.64	9.07
Zamfara	.20 (0.25)	-9.93 (-1.26)	.56 (1.17)	.12*** (3.31)	75.27 (1.18)	0.95	98.97

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

For sorghum, rainfall is found to be risk-increasing in Benue and Kastina states; these coefficients are 1.35 and 1.2, respectively. On the other hand, rainfall is risk-reducing in Kogi state. GDD is found to increase the yield risk of sorghum in Kastina states. Technological progress is positively correlated with sorghum yield risk in Banuchi, Benue, Borno, Gombe, Kano, Nassarawa, and Zamfara, but is negatively related in Adamawa, Kastina, Kwara, Plateau, Sokoto, and Taraba states.

Table 15 Sorghum yield risk function at the state level

State	Rain	GDD	HDD	Trend	Constant	R	F
Adamawa	-.34 (-0.24)	-3.12 (-0.61)	.51 (0.88)	-.05*** (-8.54)	25.96 (0.54)	0.80	18.37
Bauchi	.14 (0.64)	.51 (.94)	-.04 (-0.70)	.02*** (5.47)	-5.27 (-0.63)	17.19	17.19
Benue	1.35* (1.97)	2.60 (1.00)	-.31* (-1.82)	.02*** (5.54)	-29.87 (-1.29)	0.78	15.98
Borno	.01 (0.02)	.63 (0.24)	-.09 (-0.36)	.01** (2.12)	-4.63 (-0.18)	0.27	2.58
F. C. T	1.10 (0.53)	7.24 (1.14)	-.53 (-0.89)	.00 (0.09)	-64.41 (-1.02)	0.03	1.16
Gombe	.08 (0.54)	.88 (1.41)	-.12** (-3.26)	.00** (2.58)	-7.09 (-1.28)	0.88	33.91
Jigawa	-.88 (-0.79)	.91 (0.13)	1.11 (1.22)	-.00 (-0.21)	-7.43 (-0.13)	0.64	8.70
Kaduna	-.51 (-0.42)	.04 (0.01)	.08 (0.40)	.02 (1.25)	3.94 (0.14)	0.79	17.21
Kano	.91 (1.13)	6.61 (1.52)	-.15 (-0.37)	.05*** (7.25)	-59.39*** (-59.39)	0.75	14.02
Katsina	1.20** (2.40)	6.13** (2.99)	-.78*** (-3.23)	-.03*** (-6.65)	-54.09** (-2.99)	0.76	14.56
Kebbi	-.55 (-0.41)	-.62 (-0.12)	.43 (0.73)	-.00 (-0.13)	6.75 (0.14)	0.07	1.32
Kogi	-.23* (-1.89)	1.09 (1.19)	-.03 (-0.89)	.00 (1.62)	-7.00 (-0.95)	0.87	27.47
Kwara	-.04 (-0.05)	-2.88 (-1.07)	.08 (0.37)	-.02*** (-4.39)	23.26 (0.87)	0.62	8.08
Nassarawa	.24 (0.85)	.30 (.30)	-.01 (-0.21)	.02*** (3.61)	-4.08 (-1.00)	0.90	20.90
Niger	-.21 (-0.08)	4.42 (0.56)	.08 (0.12)	-.00 (-0.85)	-33.59 (-0.43)	-0.02	0.88
Oyo	-.95 (-0.75)	9.60* (1.67)	-.16 (-0.48)	.00 (0.19)	-68.20 (-1.35)	0.33	3.03
Plateau	.41 (1.03)	.82 (1.16)	-.10 (-1.21)	-.02*** (-3.91)	-8.59 (-1.15)	0.97	81.89
Sokoto	-3.22 (-0.97)	-10.50 (-0.94)	1.28 (1.02)	-.05*** (-4.53)	101.30 (0.99)	0.49	5.10
Taraba	-.13 (-0.29)	.58 (0.18)	-.06 (-0.18)	-.05*** (-7.84)	-2.51 (-0.09)	0.84	23.92
Yobe	-.28 (-0.33)	-5.99 (-1.45)	.66 (1.27)	.01 (1.29)	47.21 (1.32)	0.63	8.46
Zamfara	.47 (1.19)	2.18 (1.46)	-.08 (-0.69)	.04*** (4.97)	-20.59 (-1.57)	0.81	19.77

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

In the case of cotton, rainfall is found to be risk-increasing in Borno, with a coefficient of 0.61. Rainfall is risk-reducing in Sokoto. GDD is found to increase the yield risk of cotton in Borno state,while HDD would increase the yield risk in Adamawa state. Technological progress is positively correlated with cotton yield risk in Adamawa, Kastina, and Niger, but is negatively related in Borno and Kaduna states.

Table 16 Cotton yield risk function at the state level

State	Rain	GDD	HDD	TREND	Constant	R^2	F
Adamawa	1.23 (0.79)	-19.65 (-1.65)	2.26** (1.98)	0.20*** (4.11)	144.26 (1.56)	0.83	23.04
Bauchi	-1.09 (-0.37)	-2.73 (-0.56)	0.03 (0.04)	0.10 (-1.14)	27.89 (0.86)	0.73	9.25
Borno	0.61** (2.24)	7.05*** (6.75)	-0.71** (-2.78)	-0.12*** (-12.75)	-59.12*** (-6.53)	0.94	58.25
Gombe	-5.16 (-1.28)	-3.67 (-0.54)	0.29 (0.27)	-0.07 (-0.57)	60.78 (1.34)	0.74	9.92
Kaduna	1.82 (1.14)	7.78 (1.19)	0.50 (0.84)	-0.19*** (-4.16)	-78.54 (-1.54)	0.77	11.15
Kano	-2.23 (-1.27)	0.63 (0.11)	-0.26 (-0.29)	0.07 (1.18)	8.82 (0.19)	0.47	3.04
Katsina	-1.53 (-0.72)	-3.97 (-0.46)	0.003 (0.00)	0.26*** (3.73)	38.32 (0.51)	0.74	9.87
Kebbi	-0.13 (-0.16)	-1.29 (-0.27)	-0.45 (-0.61)	0.10* (1.77)	11.90 (0.30)	0.59	4.92
Niger	0.40 (0.27)	-8.71 (-1.30)	0.88 (0.82)	0.23*** (7.22)	63.24 (1.13)	0.88	24.75
Plateau							
Sokoto	-2.57* (-1.75)	5.25 (0.27)	0.14 (0.08)	0.07** (1.95)	-30.46 (-0.20)	0.51	5.62
Zamfara	4.90 (1.54)	6.09 (0.29)	0.45 (0.31)	0.10 (0.65)	-91.66 (-0.52)	0.66	9.58

Note: The figures in brackets are the t-values; * means significant at 10%; ** means significant at 5% and *** means significant at 1% probability levels

4. Summary and Implications of the Results

This report examines the effects of mean climate and extreme climate on mean and variance of 18 food crops in Nigeria. The results indicate a clear level of variation in crops' production and risk response to extreme weather across states. The productivity of yam, maize, tomato, and melon is threatened by an increase in total annual rainfall, while such an increase will have a beneficial effect on the productivity of cassava and ginger. Extreme temperatures have a negative association with cassava and sweet potato yields; however, for crops predominantly grown in Northern Nigeria such as millet, onion, tomatoes, and melon, this association is positive. Given the importance of cassava in the Nigerian food basket and the increase in recent years in the number of days with temperatures above 34^{o}C, efforts should be made to further develop cassava cultivars that are more heat-resistant. Extreme temperatures (HDD) increase the yield risk of onion and okra, two major vegetable crops. This calls for increased attention to dry season irrigation in order to enhance the productivity of these important vegetables.

In conclusion, climate change is likely to affect agriculture in Nigeria, but the effect on yield will vary with geography and crop. Our results show that the productivity of more than half of Nigeria's staple crops is threatened by an increase in total annual rainfall; however, such an increase in water availability will have a beneficial effect on the productivity of a few crops grown in Northern Nigeria. Extreme temperatures have a negative association with about two-thirds of Nigeria's staple crops; again, however, the association is positive for crops predominantly grown in Northern Nigeria such as millet, onion, and melon. The state-level analysis shows that extreme temperatures are an important limiting factor for crop growth in more than one-quarter of the states in Nigeria. As expected, the worst affected are states located in Northern Nigeria. The results further show that increased temperatures affect not only the mean yield, but also the yield risk in several states. The most affected crop in this regard is maize.

Examples of potential adaptive measures that can be taken to mitigate potential negative effects include improved irrigation, introduction of weather-based insurance schemes, introduction of new crops and crop varieties, earlier sowing, use of ditches to drain more water from the soil, utilization of land that has previously been considered too marginal for agricultural cultivation, and pluriactivity. The overriding aim of Weather Index Insurance for Agriculture (WIIA) is to alleviate the negative impacts of extreme weather on farming households and village economies by compensating part of the damage caused to farming products. Such insurance products are already available in Japan, the U.S. and EU member countries. In the scheme, insurance claims are paid according to the number of days when temperature either falls below or exceeds certain agreed levels, in order to compensate the income loss caused by the cold or the extreme heat. An advantage of WIIA is that, actual damage to crops in individual farmers need not be measured and verified. Instead, compensation is automatically paid out when a certain set of conditions are satisfied. Other advantages of index insurance include rapid payout and low transaction costs. However, in order to utilize WIIA the following points should be kept in mind:

(1) WIIA does not eliminate the risk of extreme weather conditions. Hence, considerable priority should still be placed on how to reduce greenhouse gas (GHG) emissions through mitigation measures.

(2) The Insurance does not eliminate the need for infrastructure development. It should be seen as a supplemental option. In this context, it should be considered as a short term approach to alleviate impact of extreme weather until infrastructure is fully developed and weather conditions return to their prior stable state.

Appendix A

Table A1: Grains, Pulse and Oil Seed Crops Produced in Nigeria by States

Crop	States
Cereals	
Maize	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, borno, cross river, delta, ebonyi, edo, ekiti, enugu, f.c.t., gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, Ondo,osun, oyo, plateau, rivers, sokoto, taraba, yobe.
Sorghum	Adamawa, bauchi, benue, borno, f.c.t., gombe, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, nassarawa, niger, oyo, plateau, sokoto, taraba, yobe, zamfara.
Millet	Adamawa, bauchi, benue, borno, f.c.t., gombe, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, nassarawa, niger, plateau, sokoto, yobe, zamfara
Rice	Abia, adamawa, akwa ibom, anambra, bauchi, benue, borno, cross river, delta, ebonyi, edo, ekiti, enugu, f.c.t., gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, plateau, sokoto, taraba, yobe, zamfara
Wheat	Adamawa, bauchi, borno, jigawa, kaduna, kano, katsina, kebbi, sokoto, zamfara
Pulse	
Soya bean	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Beans	Abia, adamawa, akwa ibom, bauchi, benue, borno, cross river, edo, ekiti, enugu, f.c.t., gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara.
Oil seed	
Groundnut	Abia, adamawa, bauchi, benue, borno, cross river, delta, ebonyi, edo, enugu, f.c.t., gombe, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ondo, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara

Table A2: Root and Tuber, Sugar and Fibre Crops Produced in Nigeria by States

Crop	States
Root and Tuber	
Yam	Abia, adamawa, akwa ibom, anambra, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, f.c.t., imo, kaduna, kogi, kwara, lagos,nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, Taraba
Cassava	Abia, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, f.c.t., gombe, imo, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe
Cocoyam	Abia, adamawa, akwa ibom, anambra, bayelsa, cross river, delta, ebonyi, edo, ekiti, enugu, gombe, imo, kaduna, lagos, niger, ogun, ondo, osun, oyo, rivers
Sweet potato	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Sugar	
Sugarcane	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Fibre	
Cotton	Adamawa, bauchi, borno, gombe, kaduna, kano, katsina, kebbi, Niger, plateau, sokoto, zamfara

Table A3: Spices and Vegetable Crops Produced in Nigeria by States

Crops	State
Spices	
Ginger	Benue, kaduna, lagos, nassarawa
Onion	Adamawa, bauchi, benue, ekiti, gombe, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, plateau, sokoto, taraba, yobe, zamfara
Pepper	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Vegetable	
Tomato	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Okra	Abia, adamawa, akwa ibom, anambra, bauchi, bayelsa, benue, cross river, delta, ebonyi, edo, ekiti, enugu, fct, gombe, imo, jigawa, kaduna, kano, katsina, kebbi, kogi, kwara, lagos, nassarawa, niger, ogun, ondo, osun, oyo, plateau, rivers, sokoto, taraba, yobe, zamfara
Melon	Abia, akwa ibom, anambra, cross river, delta, ebonyi, edo, ekiti, enugu, f.c.t., imo, kwara, lagos, nassarawa, niger, ogun, ondo,s osun, oyo, rivers

Appendix B

Table B1: Cropping Calendar for Grains, Pulse and Oil Seed Crops in Nigeria

Agro-ecological zones	Crop	Planting period onset	Planting Period end	Planting rate	cropping cycle
Derived savannah	Maize	01/03	31/08	25-32	100-120 days
Humid forest	Maize	01/03	31/08	25-33	100-120 days
Northern guinean savannah	Maize	01/03	31/08	25-30	100-120 days
Derived savannah	Rice	01/04	31/05	65	6-8 months
Northern guinean savannah	Rice	01/08	31/07	65	6-8 months
Humid forest	Rice	01/04	31/05	65	6-8 months
Southern guinean savannah	Rice	01/04	31/05	65	6-8 months
Southern guinean savannah	Sorghum	01/08	30/09	7-10	70-120 days
Northern guinean savannah	Sorghum	01/04	30/06	7-10	70-120 days
Sudanese savannah	Sorghum	01/04	30/06	7-10	70-120 days
Derived savannah	Soybean	01/07	15/12	40-60	90-120 days
Humid forest	Soybean	01/07	15/12	40-60	90-120 days
Northern guinean savannah	Soybean	01/07	30/11	40-60	90-120 days
Southern guinean savannah	Soybean	01/07	15/12	40-60	90-120 days
Sudanese savannah	Soybean	01/07	30/11	40-60	90-120 days
Derived savannah	Cowpea	01/09	30/09	15-25	90-120 days
Northern guinean savannah	Cowpea	01/07	31/08	15-25	90-120 days
Southern guinean savannah	Cowpea	01/07	31/08	15-25	90-120 days
Sudanese savannah	Cowpea	01/07	31/08	15-25	90-120 days
Northern guinean savannah	Millet	01/07	31/08	8-11	70-150 days
Sudanese savannah	Millet	01/07	31/08	8-11	70-150 days
Northern guinean savannah	Wheat	01/04	01/05	150-200	50-200 days
Sudanese savannah	Wheat	01/04	01/05	150-200	50-200 days
Derived savannah	Groundnut	01/03	31/08	40-90	100-120 days
Humid forest	Groundnut	01/03	31/08	40-90	100-120 days
Northern guinean savannah	Groundnut	01/07	31/08	40-90	100-120 days
Southern guinean savannah	Groundnut	01/03	31/08	40-90	100-120 days
Sudanese savannah	Groundnut	01/07	31/08	40-90	100-120 days

Table B2: Cropping Calendar for Root and Tubers and Fibre Crops in Nigeria

Agro-ecological zones	Crop	Planting period onset	Planting Period end	Planting rate	cropping cycle
Derived savannah	Yam	01/11	30/04	3,000-5,000	8-10 months
Humid forest	Yam	01/11	30/04	3,000-5,000	8-10 months
Northern guinea savannah	Yam	01/11	30/04	3,000-5,000	8-10 months
Southern guinea savannah	Yam	01/11	30/04	3,000-5,000	8-10 months
Northern guinea savannah	Sweet potato	01/05	31/12	30,000-40,000	90-120 days
Derived savannah	Cassava	01/03	31/08	6.913-1.3580	18-24 months
Humid forest	Cassava	01/03	31/08	6.913-1.3580	18-24 months
Northern guinean savannah	Cassava	01/03	31/08	6.913-1.3580	18-24 months
Sahelian savannah	Cassava	01/07	31/08	6.913-1.3580	18-24 months
Southern guinean savannah	Cassava	01/03	31/08	6.913-1.3580	18-24 months
Southern guinea savannah	Cocoyam	01/05	01/06		120-150 days
Southern guinean savannah	Cotton	15/06	15/07	15	150-180 days
Northern guinean savannah	Cotton	01/07	15/07	15	150-185 days

Table B3: Cropping Calendar for Spices Vegetable and Sugar Crops in Nigeria

Agro-ecological zones	Crop	Planting period onset	Planting Period end	Planting rate	cropping cycle
Derived savannah	Melon	01/12	30/06	2.3	3-4 months
Northern guinean savannah	Melon	01/12	30/06	2.3	3-4 months
Derived savannah	Onion	01/11	31/12	4.5	90-120 days
Northern guinean savannah	Onion	01/11	31/12	4.5	90-120 days
Sahelian savannah	Onion	01/11	31/12	4.5	90-120 days
Southern guinean savannah	Onion	01/11	31/12	4.5	90-120 days
Sudanese savannah	Onion	01/11	31/12	4.5	90-120 days
Derived savannah	Pepper	01/02	31/05	0.2	90-150 days
Humid forest	Pepper	01/02	31/05	0.2	90-150 days
Northern guinean savannah	Pepper	01/02	31/05	0.2	90-150 days
Sahelian savannah	Pepper	01/04	30/06	0.2	90-150 days
Southern guinean savannah	Pepper	01/02	31/05	0.2	90-150 days
Sudanese savannah	Pepper	01/04	30/06	0.2	90-150 days
Derived savannah	Tomato	01/03	30/04	5-10	3 months
Humid forest	Tomato	01/03	30/04	5-10	3 months
Northern guinean savannah	Tomato	01/03	30/04	5-10	3 months
Southern guinean savannah	Tomato	01/03	30/04	5-10	3 months
Sudanese savannah	Tomato	01/09	31/10	5-10	3 months
Southern guinea savannah	Okra	01/03	01/04	3-4	30-60 days
Southern guinea savannah	Okra	01/07	01/08	3-4	30-60 days
Derived savannah	Ginger	01/03	31/12	2500	180-270 days
Sahelian savannah	Sugarcane	01/01	28/02	5,000-7,000	365 days

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