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Effects of Global Climate Change on Nigerian Agriculture: An Empirical Analysis

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Abstract
This paper presents an empirical analysis of the effects of global warming on Nigerian agriculture and estimation of the determinants of adaptation to climate change. Data used for this study are from both secondary and primary sources. The set of secondary sources of data helped to examine the coverage of the three scenarios (1971-1980; 1981-1990 and 1991-2000). The primary data set consists of 1500 respondents' but only 1250 cases were useful. This study analyzed determinants of farm-level climate adaptation measures using a Multinomial choice and stochastic-simulation model to investigate the effects of rapid climatic change on grain production and the human population in Nigeria. The model calculates the production, consumption and storage of grains under different climate scenarios over a 10-year scenery. In most scenarios, either an optimistic baseline annual increase of agricultural output of 1.85% or a more pessimistic appraisal of 0.75% was used. The rate of natural increase of the human population exclusive of excess hunger-related deaths was set at 1.65% per year. Results indicated that hunger-related deaths could double if grain productions do not keep pace with population growth in an unfavourable climatic environment. However, Climate change adaptations have significant impact on farm productivity.

Key words: Climate change · Adaptation · Economic consequences · Farm level productivity, Average Rainfall, Nigeria

JEL Classification
D6, D91, E21, O13, Q01, Q2

1. Introduction

There is a growing consensus in the scientific literature that in the coming decades the world will witness higher temperatures and changing precipitation levels. The effects of this will lead to low/poor agricultural products. Evidence has shown that changing in climate has already affecting crop yields in many countries (IPCC, 2007; Deresa *et al*, 2008; BNRCC, 2008). This is particularly true in low-income countries, where climate is the primary determinant of agricultural productivity and adaptive capacities are low (SPORE, 2008; Apata *et a*l, 2009). Many African countries, which have their economies largely based on weather-sensitive agricultural productions systems like Nigeria, are particularly vulnerable to climate change (Dinar *et al*, 2006). This vulnerability has been demonstrated by the devastating effects of recent flooding in the Niger Delta region of the country and the various prolonged droughts that are currently witnessing in some parts of Northern region. Thus, for many poor countries like Nigeria that are highly vulnerable to effects of climate change, understanding farmers' responses to climatic variation is crucial, as this will help in designing appropriate coping strategies.

Evidence from literature and past studies has revealed that the recent global warming has influenced agricultural productivity leading to declining food production (Kurukulasuriya & Mendelsohn, 2006; IISD, 2007; Lobell *et al*, 2008). In order to support humanity growing population, they now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources (Abrahamson, 1989; Ehrlich & Ehrlich, 1990). This resource depletion was linked with other human pressures on the environment. Possibly the most serious of human impacts is the injection of greenhouse gases into the atmosphere. The reality of the impact of climate change on agricultural development has started showing signs (Adams *et al*, 1988; Fischer *et al*, 2002; Spore, 2008). A substantial body of research has documented these wide-ranging effects on many facets of human societies (Wolfe *et al*, 2005; ODI, 2007; Apata *et al*, 2009.).

Rough estimates suggest that over the next 50 years or so, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008). Specifically, population, income, and economic growth could all affect the severity of climate change impacts in terms of food security, hunger, and nutritional adequacy. If climate change adversely affects agriculture negatively, human effects are likely to be more severe in a poorer world. Wolfe *et al* (2005); Stige, (2006), and Orindi *et al*, (2006) worry that rising demand for food over the next century, due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries.

Recently, international tensions and concerns are heightening over what the impact of climate will have on the environment and agricultural produce (NEST, 2004; BNRCC, 2008; Apata, *et al* 2009). Also, how agricultural and food-distribution systems will be further stressed up by the shifting of temperatures and precipitating belts, especially if changes are rapid and not planned for (NEST, 2004). The crucial issue in this study is whether agricultural output supply can keep pace with population increase under this climate variability. This will actually depends; both on the scope for raising agricultural productivity (including reducing waste during distribution), availability of inputs used in the agricultural sector (land, labour, machinery, water resources, fertilizers, etc.) and having sufficient information on climatic variables for possible effective adaptation and mitigation strategies.

Consequently, attempt is being made in this study to investigate the effects of climate change on food demand and production as well as population increase in Nigeria. Though some attempts have been made to estimate the impact of climate change on food production at the country, regional, or global scale (Pearce *et al*. 1996; McCarthy *et al*. 2001; Parry *et al*. 2004; Nkomo *et al*, 2006; Stern 2007; Deresa, *et al*, 2008; BNRCC, 2008; Apata *et al*, 2009). However, these attempts fail to provide critical insights in terms of effective and future adaptation strategies, insights from these studies help to appreciate the extent of the problem.

Studies on the impact of climate change (particularly rainfall and temperature) and climate-related adaptation measures on crop yield are very scanty. Studies of Liu *et al*, (2004); Mendelsoln *et al*, 2004; De-wit *et al* (2006); Kurukulasuriya & Mendelsohn, 2006; Deresa (2007), Yesuf *et al* (2009) and Apata *et al* (2009) are some of the economic studies that attempt to measure the impact of climate change on farm productivity. These studies imputed the cost of climate change as a proxy for capitalized land value and which are captured from farm net revenue. However, while these studies were conducted using sub-regional agricultural data as well as household-level it did not identify the determinants of effective adaptation methods to predict efficient adaptive measures. Also, its likely future effects on food production and population growth were not assessed too. Consequently, the objectives of this study are to examine global impact of key climatic variables on food production and how its likely effect on population increases. Also, to identify the determinants of effective adaptation methods to predict efficient adaptive measures in a typical developing country, using household-specific survey data from Nigeria.

2. Methodology

2.1 Area of Study

Nigeria has a population of about 140 million and an area of 923.000 square kilometres. Nigeria has a variety of ecosystems; from mangroves and rainforests on the Atlantic coast in the south to the savannah in the north. Whether dry or wet, these ecosystems are being battered by global warming. While excessive flooding during the past decade has hurt farming in coastal communities, desertification is ravaging the Sahel. Traditionally, desertification in the Sahel has been blamed on overgrazing practices of the local population. But it has been discovered that the real problem is climate change. Peoples' livelihoods are being harmed, and people who are already poor are becoming even more impoverished. Climate refugees are being created.

2.2 Method of Data Collection

Both primary and secondary data were used for this study. Secondary data came from National Core Welfare Indicator (NCWI)/National living Standard Survey (NLSS)/National Consumer Survey/Demographic/Health Survey (DHS)/National Population Commission (NPC), and National Bureau of Statistics. These set of secondary sources of data helped to examine the coverage of the three climate scenarios (1971-1980/1981-1990/1991-2000) used for this study. The primary data consists of 1500 respondents' but only 1250 responses were useful. In addition weather alerts, forecast and measurements over these periods were examined. This study analyzed determinants of farm-level climate adaptation measures in Nigeria using a Multinomial choice model in all the six zones in Nigeria. Also, a simple, nationally aggregated, stochastic-simulation model was constructed to investigate the effects of rapid climatic change on agriculture (grain production) and the human population in Nigeria. Based on monthly/annually meteorological weather related data collected from the Nigerian Meteorological station/Unit and Central Bank of Nigeria (CBN) annual reports, the model calculates the production, consumption and storage of crops (grains) under different climate scenarios over a 30-year period. In most scenarios, either an optimistic baseline annual increase of agricultural output of 1.85% or a more pessimistic appraisal of 0.75% was used. The rate of natural increase of the human population exclusive of excess hunger-related deaths was set at 1.65% per year.

2.3 Analytical Procedures

2.3.1 Model of Effect of Stochastic Perturbations in Food Production and Population Size

The model simulates the effect of stochastic perturbations in food production on population size. In yearly increments, the model calculates human population size, number of hunger related deaths, and the production, consumption and storage of grain under different climatic scenarios. Parameters that may vary in each run of the model include the initial population size, the initial level of grain production and grain stores, and the rate of change in population size. It is hypothesised that climate change will have unfavourable impact on agricultural production. Therefore, there is the need to capture the frequency and magnitude of changes in the harvest. The climate scenarios are described in terms of two parameters: the frequency and the magnitude of changes in grain production caused by changing weather patterns. All of the parameters in the model represent aggregates for the whole.

The model is adapted from the study of Daily and Ehrlich, 1990 and was modified to capture the scope of the study.

$N_{t+1} = (1 + 0.01 \times \Delta N) \times \Delta N t'$ (1)

Where N = Population size,

ΔN = annual percentage rate of increase of grain production

$Gp,t_{+1} = (1+0.01\Delta G) \times Gp,t'$ (2)

$Gnf, t_{+1} = Gp,t_{+1} + 0.01 \times v \times Gp,t_{+1}$ (3)

$Ga,t_{+1} = Gnf, t_{+1} + 0.01 \times m \times Gnf, t_{+1}$ (4)

where G_p = potential grain production and ΔG = annual percentage rate of increase of grain production; G_{nf} = potential grain production modified by 'normal fluctuations';

v is a number selected randomly (and uniformly) from the set (-4.0, -2.0, 0, 2.0, 4.0) to produce an expected variance of 7.5%;

G_a. = actual production for the given year;

m = the amount by which grain production is enhanced or reduced in years where climatic events affect agriculture (determined stochastically).

Grain consumption (C) is calculated as

$C_t = (0.33 \text{ T per capita}) \times N_t$.

Grain stock (S) is calculated as follows, has a lower bound of zero T: $S_{t+1} = S_t + G_{a,t+1} - C_{t+1}$

The number of hunger-related deaths (D) occurring in a year is assumed in this study as a function of grain stocks and distribution. In the case of a huge grain surplus, where stocks constitute greater than 40% of consumption (i.e. $S \times 100/C\Delta$ 40), it is reported that about 25, 605 death occurs between 1991-2000 (Demographic and Health Survey(DHS), 2003), 21, 819 deaths were reported, 1981-1990 (DHS, 1990) and 35,003 deaths from 1971-1980 (National Population Commission, 1983). It is estimated that 82427 deaths were recorded during the 3 scenarios covered. If there is a grain surplus (i.e. $S > 0$) but stocks constitute no more than 40% of consumption (i.e. $S \times 100/C \Delta 40$), then $D_t = 2 \times 10^6 + d - (d/40) \times x$, where d = number of deaths per year when stocks equal zero, and is set at 35,003 here; $x = 5 \times 100/C$. If there is a grain deficit, then D_t, $= 2 \times 10^6 + d + 2x$ (deficit).

The model has several important limitations. First, it accounts for local heterogeneity only by including deaths caused by mal-distribution. This is a crude approximation because inequitable distribution of food (and wealth in general) and extreme heterogeneity in population density, in agricultural productivity (over space and time), in climate regimes, and in the variability of weather patterns are key factors in generating regional famine. Secondly, the model does not include mechanisms whereby compensation for imminent food shortages could be made.

Thirdly, the model implicitly assumes that the underlying ' trend' (rate of change) in grain production will remain constant even in the face of the social and economic turmoil. Furthermore, maintaining a growth rate in agricultural output of 1.7% per year embodies a series of optimistic assumptions of success in the development and implementations of better agricultural practices and technologies. In addition, the effects of climate change are assumed to be constant. These assumptions would all have the effect of underestimating the number of deaths that may result from the impacts of deleterious climate change. Finally, a few comments relative to our validation of the model must be made. It is very difficult to quantify the actual number of people that have starved to death over the past two decades. Aside from poor censoring in famine-stricken areas, malnutrition compromises the immune system and the immediate cause of death of severely malnourished people is thus usually reported as disease. The rough estimate of over 82 thousand deaths is considerably lower. The numbers of deaths produced by the distributional aspects of the model are therefore probably conservative. Despite these limitations, however, the model still captured the scope of the study

2.3.2. Choice of the Multinomial Logit Model: The analytical framework

The analyses presented in this study identify the important determinants of adoption of various adaptation measures for policy direction. The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the Multinomial Logit (MNL) and Multinomial Probit (MNP) models. Both the MNL and MNP are important for analyzing farmer adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies. This study uses a MNL logit model to analyze the determinants of farmers' decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative, the MNP (Hausman & Wise, 1978; Wu & Babcock, 1998). MNL has computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). The main limitation of the model is the Independence of Irrelevant Alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Hausman & McFadden, 1984; Hassan & Nhemachena, 2008).

2.4 Model Specification

Let *i A* be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probabilities of choosing option *i A* and the set of explanatory variables X as (Greene, 2003):

$$\text{Prob}(A_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{j} e^{\beta_k' x_i}}, j = 0, 1 \ldots J \quad (5)$$

A 'universal' logit model avoids the IIA property while maintaining the multinomial logit form by making each ratio of probabilities a function of the attributes of all the alternatives. After considering all the economic model and interpretation, the effects of explanatory variables on the probabilities, marginal effects are usually derived as:

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j \left[\beta_j - \sum_{k=0}^{J} P_k \beta_k \right] = P_j \left(\beta_j - \bar{\beta} \right) \qquad (6)$$

The marginal effects measure the expected change in probability of a particular choice being made in respect to a unit change in an explanatory variable (Long, 1997; Greene, 2000). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

The explanatory variables used in the Multinomial Logit Models and hypothesized as determinants of respondents poor in the level of perception and adaptation to climate change (that is specialized in only (mono) cropping)are:, 1 for mono and 0 otherwise. Increased temperature (X_1), fall temperature (X_2), altered climate range (X_3), changed timing of rains (X_4), frequency of droughts (X_5), noticed climate change (X_6), cereal/legume intercropping (X_7), mulching (X_8), practiced zero tillage (X_9), making ridges across farms (X_{10}), farm size (X_{11}), own heavy machines (X_{12}), household size (X_{13}), farming experience (X_{14}), education (X_{15}), age of farmers (X_{16}) access to extension facilities (ACEXT) (X_{17}) Dummy, if access 1, otherwise 0, access to credit facilities (ACCRE) (X_{18}) and Sex (X_{19}).

3 Results and Discussions (Econometrics Estimation)

3.1 The Simulations Run Model of the climate scenarios (1971-2000)

To generate the output presented here, the model was iterated three-times per simulation (i.e., 3 scenarios), a run is a set of simulations done under the same initial conditions. The annual rate of natural increase of the population size (ΔN) is a constant percentage. For most runs, the initial population size and growth rate were set at 45576200 and 1.7% per scenario, respectively. Population size may be sharply reduced by grain shortages (which might likely cause rapid increases in deaths by starvation). These periods of population increase are assumed to be instantaneous. Following such scenarios, the constant rate of increase is applied to the new lower population size.

For most scenarios, initial production was set at 2374 metric tons (T) grain. The underlying rate of change in grain production (the ' trend ') also remains constant. For reference, the average value of the trend was 2.6 % per scenario from 1981 to 1990, and 1.4% per year from 1991 to 2000 (ANAP, 2006). To simulate normal stochastic fluctuations in production, the amount harvested in a given year is caused to deviate from the trend by one of five values (0.0, +2.0, -2.0, +4.0, or -4.0%) selected at random each year. These values were selected to create a pattern resembling a relatively favourable decade for local agriculture. The fluctuations in grain production generated by the model (expected variance 8.0%) are roughly comparable to those that actually occurred over the decade 1971-80 (observed variance 8.5%) a decade with little variation in the upward production trend. By contrast, the observed variances in grain production in the preceding (1981-1990) and following (1991-2000) decades were 51.0% and 20.4%, respectively. Thus the choice of the magnitude of 'normal' fluctuations was conservative

The level of grain consumption in each year to the scenario is calculated as the product of the current population size and the average consumption per person per year. Our estimate of average consumption, 0.35 T grain per person-year, is equal to the average global per-capita production level over 1955-88 (FAO 1956, 89; PRB 1988; UN 1987). Grain lost to wastage estimated to be 40% between production and consumption; (ANAP, 2006 and Akinyosoye, 2006), diverted to livestock, and otherwise not consumed directly. The grain carry-over stock is set at the beginning of each simulation. For most runs, the initial stock was set at 35,003T, an intermediate level equal to 21 % of consumption for the initial year.

The model iterates a set of equations describing this system for a projection time of ten years for each scenario. We consider that period sufficiently long to reflect trends, but not so long that agricultural and economic systems are likely to change fundamentally. The mean and the standard deviation of several statistics are recorded on the completion of each run: the total number of deficits, the total number of deaths and maximum that occurred, and the final population size were study. To determine the number of simulations required per run, we produced multiple sets of runs consisting of 100 and 1000 simulations each using initial conditions with high variance in output parameters (run E, table 1). The coefficient of variation of the mean number of deaths was 2.4, 1.3 and 0.3 respectively. We therefore considered 1000 simulations per run sufficient to produce reasonably consistent results.

The output of the model under a variety of scenario' is displayed in tables 1-3. In most cases we contrast the output under different scenarios with reference to the average number of deaths produced in a run, a figure that reflects both the frequency and magnitude of changes in grain stocks. Generally, in what follows 'deaths' here refers to hunger-related deaths in excess of those subsumed in the natural rate of increase. The model was ran in the absence of unfavourable climatic events and under the assumption that annual growth in grain production (ΔG) would keep pace with that of the population (ΔN), which was 1.7% in 1981-1990 scenarios (ΔN is now 1.8%). Over the 10-year projection time under this scenario (run A, Table1), although there are no grain deficits (0.0 ± 0.0), 31 ± 14 thousand deaths occur because of mal-distribution of food. The variance in the output statistics is quite high, as indicated by the occurrence of over 35 thousand hunger related deaths in one of the 1000 simulations. Thus, there will be increase in the population size at a constant growth rate of 1.7%, with no hunger-related reductions.

The model was run under several climatic scenarios with negative changes in harvest ranging from 3 to 10% per event. These seem reasonable values, because a reduction of about 5% (from the 1971-80 trend of 2.1% growth per annum) can be attributed to weather-caused harvest failure during 1961-1970 scenarios. The first set of the following runs assumes that ΔN = ΔG = 1.7% and that the initial carry-over stocks totalled 35,003 T (table 1). Under these growth rates, a 5% reduction in harvest every five years (on average; probability of event, P_e = 20% causes 0.1 (Δ0.3). Current trends in agriculture suggest that assuming grain production levels can increase by 1.7% annually is very optimistic. Growth averaged just 1.4% annually from 1981-90. Achieving either of these growth rates (1.7 or 0.9%) could well require substantial technological innovation, and maintaining productivity in the long run will clearly require major changes in farming practices.

Therefore, we repeated the set of runs presented in table 1 under the assumption that ΔG = 0.9 % over the 10 year projection time. Table 2 displays the output of these simulations. Even in the absence of unfavourable climatic conditions (run J, table 2), the imbalance between ΔN (1.7%) and ΔG (0.9%) leads to a staggering 82, 427 thousand deaths over the 30-year projection time. Under each scenario with climate-induced reductions (runs K-R), over 20 thousand people die on average. However, imposing various deleterious climatic regimes (runs K-R) on grain production does not increase the resulting average number of deaths as much as when ΔG equals ΔN runs

To test the sensitivity of the model to different rates of increase in grain production relative to those of population growth, we ran an identical set of climate scenarios on both the conditions that ΔN = 1.7% and ΔG = 1.3% (runs S-U, table 3), and that ΔN = 1.7% and ΔG = 2.4% (runs V-X, table 3). The number of deaths that occur with ΔG = 1.3 is appreciably less than under the comparable scenarios with ΔG = 0.9 (runs K, M, and L, table 2). The number of deaths that occur when Δ*G* = 2.4% (runs V-X, table 3) is roughly comparable to that where Δ*N* = Δ*G* = 1.7 and no unfavourable weather patterns occur (run A, table 1). The number of deaths produced with Δ*N* = Δ*G* = 0 9 % is only slightly less (7%, on average) than under the same climatic scenarios with Δ*N* =Δ*G* = 1.7% (runs B, D and C, Table 1).

Table 1

Each run represents 1,000 simulations of the same conditions: (1971-1980)

Run	Net p/n	Δ *N* *and* Δ *G*	Probab of event	Mag. of change	Initial stock ('000 tonnes)	No. of Deficit Per simulation mean ± s.d	Number of deaths per simulation ('000 tonnes) Mean ± s.d. MAX
A	*N*	1.7	0	0	35	0.0 ±0.0	31 ± 10 36
B	*N*	1.7	10	5	35	0.1 ±0.3	33 ± 19 42
C	*N*	1.7	10	10	35	0.6 ±0.8	41 ± 11 31
D	*N*	1.7	20	5	35	0.2 ±0.9	42 ± 16 41
E	*N*	1.7	20	10	35	1.2 ±1.1	71 ± 08 33
F	*N*	1.7	30	5	35	0.1 ±0.0	46 ± 10 48
G	*N*	1.7	30	10	35	0.8 ±1.0	38 ± 22 30
H	*N*	1.7	50	5	35	2.4 ±1.3	31 ± 14 45
I	*N*	1.7	50	10	35	3.3 ±1.1	43 ± 13 51

Source: Computer Output Results 2008

Table 2

Each run represents 1,000 simulations of the same conditions: (1981-1990)

J	*N*	1.7	0.9	0	0	35	2.4 ±1.9	43 ± 16 41
K	*N*	1.7	0.9	10	5	35	4.1 ±2.6	47 ± 21 35
L	*N*	1.7	0.9	10	10	35	1.6 ±1.8	51 ± 14 41
M	*N*	1.7	0.9	20	5	35	3.2 ±1.9	48 ± 10 38
N	*N*	1.7	0.9	20	10	35	4.7 ±2.2	32 ± 12 51
O	*N*	1.7	0.9	30	5	35	3.1 ±0.8	31 ± 12 45
P	*N*	1.7	0.9	30	10	35	2.1 ±2.1	44 ± 31 32
Q	*N*	1.7	0.9	50	5	35	3.4 ±1.3	45 ± 17 32
R	*N*	1.7	0.9	50	10	35	2.6 ±1.1	51 ± 23 41

Source: Computer Output Results 2008

Table 3

Each run represents 1,000 simulations of the same conditions: (1991-2000)

Run	Net p/n	Δ ***N***	Δ ***G***	Probab of event	Mag. of change	Initial stock ('000 tonnes)	No. of Deficit Per simulation mean ± s.d	Number of deaths per simulation ('000 tonnes) Mean ± s.d. MAX
S	*N*	1.7	1.3	10	5	35	2.1 ±1.1	31 ± 11 41
T	*N*	1.7	1.3	10	5	35	3.1 ±2.5	42 ± 10 33
U	*N*	1.7	1.3	20	10	35	1.6 ±1.2	32 ± 14 37
V	*N*	1.7	1.3	20	5	35	1.2 ±1.0	46 ± 15 30
W	*N*	1.7	1.3	30	5	35	1.2 ±1.1	41 ± 18 43
X	*N*	1.7	1.3	30	10	35	2.3 ±0.7	20 ± 12 46

Source: Computer Output Results 2008

3.2 Climate Change measurement (average rainfall) population growth and grain production

Tables 4 & 5 present the results of climate change (captured by average rainfall), population growth and food production (grain production). The climate change scenarios (1971-2000) analysis revealed that population growth during the 1st -2nd scenarios (1971-1980 & 1981-1990) increased by 58.04%, while food production during the same period increased by 68.69% (Table 4). However, in the 3rd scenario, analysis revealed a decline in food production by 76.92% as population continue to grow. This portrays an alarming situation that food production does not keep pace with population growth. Average rainfall according to the study maintains a fairly steady growth during these periods. This finding corroborated with other past studies that at this period, 1981-1990; poverty levels in the country recorded the highest (CBN 2006).

Table 5 presented the disaggregation analysis results. Results show that all the zones in Nigeria experienced about 23.04% population growth across the 3 scenarios. However, grains production and rainfall have been declining. For instance, in the Northern regions there is a decline in food production to about 178.37% with high deficit recorded in the North West zone of the country (339%). The Southern part shows a decline of about 20%, while the South-south recorded a high decline (281%) The impact of climate change or global warming (as captured by average rainfall) revealed that all the Northern region has been experiencing a decline (11.03%) during period under review (1971-2000), with North West region most affected (13.32%). The Southern region however, climate change (as captured by average rainfall) show a beneficial response with the exception of South east that recorded a decline (9.09%), while the South west show a high figure of 20.58% and South-south of 2.45%. Findings indicate that the agricultural impacts of climate change in Nigeria need a holistic and quickly interventions. The total average impact may be positive or negative depending on the climate scenarios and zones. They are positive in the South particularly in the Southwest in most scenarios, but negative in the North in some scenarios

Table 4

Frequency Distribution of Average Total Rainfall, Population and Food Production for all the Scenarios considered.

Scenarios	Average Total Rainfall (mm)	Population	Food Production (Grain) ('000 Tonnes)
1971-1980	1257.02	45576200	147.30
1981-1990	1415.88	78524000	214.60
1991-2000	1436.64	102081200	58.20

Table 5
Frequency Distribution of Average Total Rainfall, Population and Food Production (Grains) 1971-2000

Zone	**North Central (7) NC**	**North West (7) NW**	**North East (5) NE**	**South West (6)**	**South East (5)**	**South-South (6) SS**
			1971-1980			
Average Total Rainfall (mm)	1074.85	952.03	783.68	1696.41	-	3034.15
Population	7346380	11649891	5427094	8978946	-	12175889
Food production (Grain) ('000 Tonnes)	23.74	37.65	17.54	29.02	-	37.34
			1981-1990			
Average Total Rainfall (mm)	1173.43	762.50	762.52	1226.20	2194.50	2376.10
Population	12657202	20071793	9350432	15469976	9188059	11786539
Food production (Grain) ('000 Tonnes)	34.59	54.85	25.55	42.28	25.11	32.21
			1991-2000			
Average Total Rainfall (mm)	1087.43	840.15	701.06	1543.90	2011.70	2435.59
Population	16454363	26093331	12155561	20110969	11944476	15322500
Food production (Grain) ('000 Tonnes)	11.56	12.48	11.16	11.91	11.13	11.46

3.3 Farmer's Actual Adaptation Measures and Practises

Table 6 presents farmers' *actual* adaptation measures and practices actually followed, thus, grouped into ten categories. These strategies, however, are mostly followed in combination with other strategies. These are grouped into the following adaptation options: diversifying into multiple and mixed crop-livestock systems, and switching from crops to livestock and from dry land to irrigation, practicing zero tillage, making ridges across farms and cereal/legume intercropping. Table 6 reveals that making ridges across farms is the dominant system (18.75%). Multiple crops under dry land is the second most common strategy ((18.46%), and Multiple cropping mixed with livestock rearing under dry land conditions (15.41%) comes third. Change use of chemicals, fertilizers and pesticides is the most common adaptation practise (14.56%). The implication is that when necessary inputs are available at the right time and are utilized, it tends to improve productivity. The main adaptation strategic measures followed Food and Agriculture Organization (FAO) classification (Dixon et al., 2001) and were used to classify the strategic measures into thirteen.

Table 7 presents the estimated marginal effects and t-levels from the MNL model. The results show that most of the explanatory variables considered are statistically significant at 10%. This study uses specialized (mono) cropping as the base category for no adaptation and evaluates the other choices as alternatives to this option. The results show that altered climate change, frequency of droughts, age and sex all had no significance effect on adaptation. While the increased temperature, intercropping of cereal/legume, mulching, zero tillage making ridges, farm size, farming experience, educational status access to extension and credit facilities are factors influencing adaptation positively (Table 9). However, fall in temperature, change timing of rains, own heavy machines and household size are also significant factors that influence adaptation negatively. This result suggests that the larger the occurrence of these variables, the poorer the adaptation.

. Summary of the results revealed that fall in temperature influences the probability of switching away from mono-cropping more than changes in increased temperature. Similarly, the magnitudes of the marginal coefficients suggest that low outputs warming is a strong factor influencing the probability of switching to other systems that are better adapted to changes in temperature. Better access to extension and credit services seems to have a strong positive influence on adaptation. In addition, access to other farm assets such as heavy machinery is found to promote the use of large –scale farming. These results suggest that capital, land and labor serve as important factors for coping. The choice of the suitable adaptation measure depends on factor endowments (i.e. family size, land area and capital resources). The more experienced farmers are, the more likely to adapt. Sex of the farmer did not seem to be of significance in influencing adaptation, as the marginal effect coefficient was statistically insignificant and signs do not suggest any particular pattern. These results suggest that it is the experience rather than sex that matters for adaptation.

Table 6

Actual adaptation measures used by farmers (N= 1250)

Adaptation measures	**Respondents (%)**
Specialized crop under dry land	121 (8.97)
Specialized crop under irrigation	15 (1.11)
Specialized livestock under dryland	13 (0.96)
Specialized livestock under irrigation	5 (0.37)
Multiple crops under dryland	249 (18.46)
Multiple crops under irrigation	14 (1.04)
Mixed mono-crop/livestock under dryland	144 (10.67)
Mixed mono-crop/livestock under irrigation	25 (1.35)
Mixed multiple crops/livestock under dryland	208 (15.41)
Mixed multiple crops/livestock under irrigation	31 (2.30)
Practiced zero Tillage	47 (3.48)
Making ridges across farms	253 (18.75)
Cereal/legume intercropping	182 (13.49)
Number of observations	**1349***

*** Multiple Responses indicated**

Table 7
Marginal Effects of Explanatory Variables from Multinomial Logit Adaptation Model

Variable	Estimate	t-value
Increased Temperature (X_1)	.090E-02	5.107***
Fall in Temperature (X_2)	-.308E-01	-2.917**
Altered Climate Range (X_3)	.4211	0.128
Changed timing of rains (X_4)	-.161E-01	-3.427***
Frequency of Droughts (X_5)	-.8851	-0.315
Noticed Climate Change (X_6)	.6272	1.7061
Cereal/legume Intercropping (X_7)	.5783	2.408**
Mulching (X_8)	.22E-05	2.1371*
Zero Tillage (X_9)	933E-06	3.412***
Making Ridges across Farms (X_{10})	.717	2.762**
Farm size (X_{11})	.827E-07	2.1262*
Owned heavy machines (X_{12})	-.923E-01	- 4.4262***
Household size (X_{13})	-.135E+11	-4.4262***
Farming experience (X_{14})	.5196E-04	2.5931*
Educational status (X_{15})	.1162	5.011***
Age (X_{16})	.2364	.3472
Access to extension facilities (X_{17})	.3681	2.5272**
Access to credit facilities (ACCRE) (X_{18}).	.2606	1.9621*
Sex (X_{19})	-.5190	-.9428

Source: Computer Printout of Logit Regression Analysis
*** = Significant at p<0.01, ** = Significant at p<0.005, * Significant at p<0.001
Log-likelihood function: -201.44, Significance level: . (P<00001) Constant = 0.71

4 Policy Implications

Findings from this study indicate that the agricultural impacts of climate change in Nigeria are uncertain. The total average impact may be positive or negative depending on the climate scenario. But most scenarios show that climate change will have an overall positive impact on Nigeria's agriculture. Impacts also vary both quantitatively and qualitatively by zone and season. They are positive in the Southern region of Nigeria in most scenarios, but negative in some Northern part of the country in some scenario. Farmers appear to be abandoning mono-cropping for mixed and mixed crop-livestock systems, considering risky, mono-cropping practicing under dry land. Farming experience and access to education were found to promote adaptation. This implies that education to improve awareness of potential benefits of adaptation is an important policy measure for future adaptation and mitigation strategies.

Moreover, the study found out that lack of effective access to information on climate change. Thus, there is need for effective and reliable access to information on changing climate. In addition, empowerment (credit or grant facilities) is crucial in enhancing farmers' awareness. This is vital for adaptation decision making and planning. Combining access to extension and credit ensures that farmers have the information for decision making and the means to take up relevant adaptation measures.

It is evidenced from this study that grain crop farmers are experiencing change in climate and they have already devised a means to survive. It is from this point that policy of reliable and effective measures of adaptation need to be implemented and must be accessible to the end users.

People responses to the issue of climate change are at low pace. Thus, there is a need to design strategies that could help the farmers/rural communities' responses effectively to global warming through early warming alerts and interpretations in the language useful to farmers/rural communities.

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