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Original Research

Effect of Climate Variability on Rice Production in North-Central, Nigeria from 1980– 2020

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ABSTRACT: The impacts of climate variability on rice production in Nigeria's North Central were investigated in this study (1980 – 2020). Respondents were sampled using a multi-stage sampling technique. Data was collected from 450 rice farmers using a standardized questionnaire. Descriptive statistics, conventional least squares, Generalized Autoregressive Conditional Heteroskedasticity (GARCH), and the Augmented Dickey-Fuller test and t-test were used to examine the variables for stationarity and significance. The majority of responders (70.2%) believe that climatic fluctuation happens naturally. The normality test revealed that the variables were positively skewed; several of the variables had kurtosis values more than 3; and the Jarque-Bera test revealed that the variables were not normally distributed, i.e. the error term did not follow normal distribution. The regression study revealed that rainfall, temperature, relative humidity, and production capacity all had a substantial influence on farmer output in Benue and Nasarawa States, but only average temperature and production capacity did in Niger State. The factor analysis for the study area's constraint to rice farmers' awareness and resilience to climatic variability found that the two main components accounted 42.786% of the variance in the analysis. Furthermore, the variables that defined component 1 were a lack of technical know-how (0.694), a religious inclination (0.672), a cultural barrier (0.642), and a language barrier (0.640), whereas the variables that defined component 2 were finance (0.707), insufficient extension contact (0.681), and a lack of appropriate knowledge of climate change and its effects (0.640). (0.528).

Keywords: Rice, climate, production, variability, crop

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INTRODUCTION

Climate change had serious negative effects on rice production, including decreased crop yield and grain quality, flood destruction of farm land, a high incidence of weeds, pests, and diseases, an increase in infectious human diseases such as meningitis, malaria, and cholera, a decrease in soil fertility, and more floods and droughts in rice fields. Sufiyan et al. (2020) investigated the Rainfall and Crop Yield Simulation in Nasarawa, Nasarawa State, Nigeria. Agricultural yield is defined as crop growth per unit area.

This study calculates crop yields for 20 years and uses simulation to generate crop yields for 18 years at various places in Nasarawa Local Government Area, Nasarawa State, Nigeria. The goal is to demonstrate the relationship between rainfall variability and crop yield, as well as to simulate crop output based on rainfall intensity. To determine agricultural yield, the study employs time series analysis of linear, quadratic, and growth curve models. The results show that there was a lot of rain in the previous year from 2020 to 2038, with a rainfall pattern of more than 2200mm-2300mm every year. The agricultural production simulation predicts a faster growth curve and a bumper harvest in the next years.

Romilly (2005) investigated the application of global mean temperature time series modelling for managerial decision-making. The study employed Univariate data series approaches to model the properties of a data set of global mean temperatures in order to construct a sparse forecasting model for management decision-making in the short term.

Although the process might be used with temperature data at a more localized level, the model is estimated using global temperature data. Seasonal and non-seasonal unit root testing with and without structural discontinuities, as well as ARIMA and GARCH modeling, are among the statistical techniques used. A forecasting analysis reveals that the selected model outperforms competitors. The estimation results support a number of previous research' findings that the 20th century saw a considerable rise in global mean temperatures. By using GARCH modeling, it is also possible to see that there is volatility clustering in the temperature data and that there is a strong correlation between volatility and the average world temperature.

Sufiyan (2020) examined rainfall trend and it impact in Keffi Nasarawa State. This study focus on the rainfall trend between 2010 -2018 as it affects crop production in Keffi Nasarawa State, Nigeria. The time series analysis was conducted by using appropriate techniques of data collection and analysis. The linear integration model, quadratic trend model, growth curve model and regression analysis was applied to show the correlation between the rainfall and crop production in the study area. It was discovered that the period of rainy months have high correction and significantly fitted the model which indication high crop yields per harvest.

Ekwe *et al.* (2014) studied mathematical study of monthly and annual rainfall trends in Nasarawa State, Nigeria. The paper critically examines the monthly and annual rainfall patterns in Nasarawa State for 20 years (1993-2012) using data obtained from the archives of Meteorological Observatory at the College of Agriculture, Lafia, Nasarawa State. Statistical techniques like time series analysis, mean and standard deviation were employed to depict the temporal distribution of rainfall over the area. The study shows that 1996 is the wettest year, while 2010 shows a year with the lowest negative rainfall deviation. In analyzing the months for the period, it was noticed that August recorded the highest rainfall value of 2498mm which is the month where clouds pervades the sky.

Onah *et al.* (2016) reviewed mitigating climate change in Nigeria: African traditional religious values in focus. Climate change affects various countries in varying degree. Human activities have been observed to be a major contributor to climate change. Consequently, excessive heat, variation in rainfall pattern, rise in sea level, flooding, drought, erosion among others are been experienced in different countries of the world. In Nigeria climate change is obvious and the government has been battling to meet the challenges of mitigating this without much success. The search for more sustainable climate change mitigation strategies becomes necessary. The option of traditional religious practices and values in this regard has not been adequately explored. This is what the study sets out to achieve. Drawing data from literature and in-depth interviews, the study argues that some useful African traditional religious values and practices such as respect for the land divinity, maintenance of sacred groves and forest among others offer good and alternative strategies for climate change mitigation in Nigeria.

Olaniyi *et al.* (2019) studied the impact of climate change on the Nigerian Ecosystem. The topic of climate change and its effects on the environment are examined in the essay. On global warming, climate change, and the environment, the impacts of human activity as well as those of natural events are presented and addressed. The choices that are accessible as a response to global warming are described, including possible human suffering as a result of any effects that cannot be averted by adaptation and mitigation. A summary of Nigeria's environmental situation, readiness for the effects of global warming, and associated issues are also provided. They show and discuss the current state of environmental data, the need for an environmental baseline assessment, and the development of a comprehensive database for the nation using a GIS. The report then emphasizes the necessity for governments at all levels to appropriately fund geo-information generation and promote its utilization in order to adequately and promptly respond to global warming, promote sustainable environmental management, and advance national development..

Stueeker *et al.* (2018) carried out a study on climate change variability impacts on rice production. The study revealed that changes in crop yield and production overtime are driven by a combination of genetics agronomics and climate disentangling the role of these various influences helps us to understand the capacity of Agriculture to adapt to change. They explore the impact of climate variability on yield and production in the Philippines from 1987-2016 both irrigated and rainfed production systems at various scales. Over this period, rice production is affected by variations in soil moisture which are largely driven by the El-Nino Southern Oscillation (ENSO). They discovered that climate impacts on rice production are substantially seasonally modulated and vary significantly by region. As expected, rain-fed upland rice production systems are more sensitive to soil moisture variability than irrigated paddy rice, accounting for 10% of the variance in national rice production anomalies, which are strongly negatively linked with an index capturing ENSO variability. While temperature is currently of minimal consequence in the Philippines, future climate estimates indicate that by the end of the century, temperatures may routinely surpass established limits to rice production if warming continues unabated. As a result, accurate seasonal forecasting will likely become increasingly important in providing the required information to guild agriculture management in order to mitigate the cumulative effects of soil moisture fluctuation and temperature stress. These and other detailed case studies supplement global yield research by providing vital local views that might aid in food policy decisions. Oyamakin *et al.* (2010) carried out a time series analysis of rainfall and temperature in South West Nigeria. In order to give an objective explanation to the effect of some natural phenomenon in the study of climate change, especially global warming, monthly recorded agro-meteorological data was collected from the Forestry Research Institute of Nigeria's (FRIN) agro-meteorological station. Least square method was used to estimate the trend in the series and the trend equation for rainfall and temperature. The time series method with an additive model for the deterministic approach was used to estimate seasonal variation/index and to create basic forecasts of future temperature and rainfall values. The monthly time plot for temperature and rainfall showed that the series are stationary and that the trends are variable. As a result, the temperature and rainfall forecasts made using probability forecast demonstrate that temperature grows slowly with time and rainfall falls averagely with time. As a result, the overarching goal of this study was to investigate the impact of climate variability on rice production in North Central Nigeria from 1980 to 2020. Hence, the specific objectives of this study are to:

(a) describe the socio-economic characteristics of rice farmers in the North-Central, Nigeria
(b) examine rice farmers' awareness of and resilience to climate variability in North-Central
(c) analyze the effects of climate variables on rice output in North-Central, Nigeria from 1980-2020

MATERIALS AND METHODS

Study area

North central

The study area is some selected states in North-Central region, Nigeria. The region has seven states namely Federal Capital Territory, Benue, Kwara, Kogi, Nasarawa, Niger, and Plateau. It is between arid north and moist south with temperature ranging from 18^{o}C – 37^{o}C yearly and rainfall of ranging from 1000mm to 1500mm per annum (Areola and Mamman 1999). The natives' occupation is predominantly rain-fed agriculture. It is known as the nation's flourishing agricultural produce area. The notable crops are rice, beans, maize, soybeans, sorghum, millet, Irish potatoes, grapes, wheat and barley. The area has longest stretches of river with great promising fishing industry, dry season farming and inland water way. The vegetation in southern is characterized by forests producing trees for timber and suitable habitat for animals. Three (3) selected states are Benue, Nasarawa and Niger States in the North-Central zone are known as lowland rice ecologies with rice farmers' clusters cultivating FARO 44 variety mainly.

Benue State

Benue State has estimated population of about 5,553,243 (Nigeria.com) and the 9th most populous state in Nigeria according to 2006 census. However, the Local government areas of the State include Guma, Gwer East, Ohimini, Katsina-Ala, Apa, Logo and Agatu, Vandeikya, Okpokwu, Ogbadibo, Obi, Gboko and Makurdi LGA.
Food production in Benue State is the main stay of its economy, employing more than 70 per cent of the working population (National Bureau of Statistics 2009). Agro-mechanization and plantation and forestry are developing areas in the State. Production of crops involves the use of fertilizers, improved seed, insecticides and external methods. Given the climate variation in the State, the available income generating crops include soybeans, rice, peanuts, mango varieties, citrus, palm oil, melon, pear, chili pepper, tomatoes, yam, cassava, sweet potato, beans, maize, millet, guinea corn and vegetables. The animal production comprises cattle, pork, poultry and goat. The Zaki Ibiam International Yam Market is the biggest market for a single product in Nigeria (NBS, 2009).

Nasarawa State

Nasarawa State is located in the central part of Nigeria otherwise known as the middle belt. The state lies between Latitude 7 0 45I and 9 0 251 'N of the Equator and between Longitude 7 0 and 9 0 37'E of the Greenwich meridian. It has a total landmass of about 27, 137.8 km2. Nasarawa State has a total of 13 Local Government Areas which are; Akwanga, Awe, Obi, Karu, Nasarawa, Nasarawa Eggon, Keffi, Wamba, Doma, Lafia, Kokona, Toto and Keana. The State Shares boundary with Kaduna State in the North, Plateau State in the East, Benue State in the East and Kogi State and FCT bounded the state in the West (Kalra *et al.,* 2008).

Nasarawa State's soil is the result of the interaction of several different variables, including rock, climate, organic matter, geography, and time. The state is incredibly blessed with rich, fertile soils, ranging from the loosed soil materials of alluvial deposits in the majority of the southern part of the state to the well-structured and developed oxisols and ferrisols in the northern part of the state and the undeveloped soils on hill slopes and entrenched river valleys like Binbol et al (2006). The vegetation of Nasarawa State lies within the guinea savanna, which is a derivative of the tropical deciduous forest that existed centuries ago. In the rainy season, the grasses and leaves are green and fresh, while in the dry season they die through withering or bush fire. Three distinct vegetation types can be seen in the state according to (Binbol *et al.,* 2006). Agriculture employs the larger percentage of the working population in the LGAs, but agricultural landholdings are generally small. The average number of farm plots per household ranges between 3 and 30 plots and between 0.4 and 4.0 ha (Nasarawa State Agricultural Development Program NADP, 2010).

Niger State

With 3.9 million residents, Niger state is the largest state in Nigeria and is situated along the Middle Belt (Alamu, 2013). With a total land area of about 86,000 km2, 80% of which is suitable for agricultural, it is one of the largest states in the nation (Tologbonse, 2008). Niger state, which makes up 9.30% of the nation's total land area, is not only split into three agricultural zones under climatic characteristics that encompass almost all classes of soil in the savannah regions of West Africa (Tologbonse, 2008).

The soil types, however, range from the shallow soils found near rocky terrain to the deep soils found in valleys. Even though they appear difficult, the deeper soils of the alluvial type have remarkable potential for rain-fed and irrigation-based farming. In addition, the state has dry and wet seasons, with annual rainfall variations of 1,600 mm in the south and 1,100 mm in the north. The dry season lasts for 7 to 8 months, while the rainy season lasts for 5 to 6 months in each zone. The state's main crops are grown there because to the good environment, including rice, sorghum, maize, millet, groundnuts, cowpeas, soybeans, cotton, yam, cassava, vegetables, and others (Niger State of Nigeria, 2013). Rice yield increased in the state between 2006 and 2010 in some areas. The amount of farmland treated with fertilizer in the Niger state increased from 6325.80-6651.60 tons and 6977.40 to 7303.20 tons between 2006 and 2008 as a result of production levels throughout time. From 2008 to 2010, fertilizer applications continued at the same rate.

Research design

This study employed a historical and survey research design. The historical research design is unobtrusive; the act of research has no effect on the study's results. The historical method is ideal for trend analysis. History records can provide significant contextual context that is needed to completely comprehend and analyze a research problem. Survey study design entails using research instruments such as questionnaires. The survey entails meeting with respondents to gather information about the study via questionnaire.

Population of the study

The populations of the study comprised of all the rice farmers in North Central Zone of Nigeria.

Sampling procedures and sample size

Multi stage sampling techniques was applied in this study. In stage one, three (3) states (Benue, Nasarawa and Niger States) out of the seven (7) states in the North Central zone were purposively selected for this study because of the predominant lowland rice ecologies in those states and clusters of rice farmers cultivating FARO 44 varieties mainly. In stage two, the three (3) local government area and three (3) community one (1) each from a local government area known as predominant rice producing areas were purposeful selected because of the insecurity reports in the selected States. The third stage involved random selection of fifty (50) respondents from each of the communities. This gave a total of 450 respondents for the study (Table 1).

Table 1: Distribution of Rice Respondents by States, LGA.

Zone	States	LGA	Clusters	Sample size
A	Benue	Agatu	150	50
		Guma	150	50
		Naka	150	50
A	Nassarawa	Awe	150	50
		Doma	150	50
		Obi	150	50
A	Niger	Agaie	150	50
		Katcha	150	50
		Lapai	150	50
Total				450

Computed by the authors 2022.

Method of data collection

Both cross sectional data and annual time data series were used in order to accomplish the objectives of this research. Cross sectional data were generated through primary source (respondents). A structured questionnaire with open and close questions were prepared for data collection and data were collected using oral interview schedule, key informant interview and focus group discussions methods in the rice farmers' clusters in the Study area. Data entry was done by the field enumerators because they were selected based on their knowledge of use of GPIS and proficiency on computer fundamental. Familiarization visits to states offices Ministry of Agriculture/Agricultural Developmental Programme (ADP) was carried out in order to obtain relevant information.

Validity and reliability test

The draft of the questionnaire was vetted and modified by agricultural extension expert, climate change experts and statistician. After correction pre-test of the questionnaires was carried out in Municipal Area Council, FCT. The responses was collated and subjected to statistical test using Cronbach Alpha to ascertain the reliability.

Methods of data analysis

i. Descriptive statistic such as Tables, Frequency, Percentages and Mean (SD) is used to achieve objective (i) which required the cross-sectional data.
ii. Generalized Autoregressive Conditional Heteroscadascity (GARCH) is used to achieve objective (ii) which required the cross-sectional data.

However, Augmented Dickey-Fuller test and t-test were applied to test for stationarity and significant level of the variables respectively.

Normality test

The distribution of the data is tested with kurtosis and other descriptive statistics tools.

t-test

t =

$$t_{\bar{X}_1 - \bar{X}_2} = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}$$

t-test was applied to the hypotheses. This was used to test for the significant level.

RESULTS AND DISCUSSION

Rice farmers' socio-economic characteristics in North-Central, Nigeria

Table 2a shows that 85 (56.7%) of the respondents in Benue State are males; there are 91 (60.7%) male respondents in Nasarawa State while 130 (86.7%) respondents are males in Niger State. The male respondents consist of 306 (68%) in North-Central Nigeria. The results depict that rice farming in North-Central Nigeria is mainly practiced by male.

Table 2a further revealed that 102 (68%) of the respondents in Benue state are married; in Nasarawa State, there are 114 (76%) respondents that are married, likewise, 132 (88%) of the respondents in Niger state are married. Generally, 348 rice farmers in North-Central Nigeria are married. The results depict that rice farming in North-Central Nigeria is mainly practiced by married respondents. The household size as shown in (Table 2a) shows that average household size of the respondents is 6.7, 6.8 and 6.4 in Benue State, Nasarawa State and Niger State, respectively. So, the average household size of the respondents in North-Central Nigeria is 6.6.

The age of respondents as shown in (Table 2a) shows that average age of the respondents is 45.8, 44.4 and 51.3 in Benue State, Nasarawa State and Niger State, respectively. So, the average age of the respondents in North-Central Nigeria is 47.2. The results depict that rice farming in North-Central Nigeria is mainly practiced by mainly youth. The farming experience of respondents as shown in (Table 2a) shows that average farming experience of the respondents is 6.9 years, 7.8 years and 11.8 years in Benue State, Nasarawa State and Niger State, respectively. So, the average farming experience of the respondents in North-Central Nigeria is 8.8 years.

Table 2a shows that 68 (45.3%) of the respondents in Benue State attained secondary school; there are 81 (54%) of respondents that attained secondary school in Nasarawa State while 72 (48%) respondents attained secondary school in Niger State. The many of the respondents 221 (49.1%) attained secondary school in North-Central Nigeria. The results depict that rice farming in respondents in North-Central Nigeria has adaptive capacity which is in agreement with the views of Staal *et al.,* (2002); Hans-Martin and Richard, (2006).

The Table 2a further revealed that 94 (62.7%) of the respondents in Benue state do not belong to cooperative; in Nasarawa State, there are 87 (58%) respondents that belong to cooperative, likewise, 150 (100%) of the respondents in Niger state belong to cooperative. In general, many of the rice farmers 293 (65.1%) in North-Central Nigeria belong to cooperative. The results depict that rice farming in North-Central Nigeria has adaptive capacity which is in agreement with the views of Staal *et al.,* (2002); Hans-Martin and Richard (2006).Table 2b shows that the average size of farm of the respondents is 6.21, 7.21 and 6.14 hectares in Benue State, Nasarawa State and Niger State, respectively. So, the average size of farm of the respondents in North-Central Nigeria is 6.52 hectares. The results depict that rice farming in North-Central Nigeria is mainly on the medium scale of operation. Table 2b further revealed that Lowland rice farming is mainly practiced by the respondents in Benue state (125; 83.3%), Nasarawa State (137; 91.3%) and

Table 2a: Demographic characteristics of the respondents.

Items/States	Benue	Nasarawa	Niger	North-Central	
Gender	%	%	%	Freq.	%
Male	56.7	60.7	86.7	306	68
Female	43.3	39.3	13.3	144	32
Total	100.0	100.0	100.0	450	100
Marital Status					
Single	16.0	14.0	12.0	63	14
Married	68.0	76.0	88.0	348	77.3
Divorced	12.7	6.0	0	28	6.2
Widowed	3.3	4.0	0	11	2.4
Total	100.0	100.0	100.0	450	100
Household Size					
<4	0	0	22	33	7.3
4-6	48	87.3	71.3	310	68.9
7-9	48.7	8	2	88	19.6
9>	3.33	4.67	4.67	19	4.2
Total	100	100	100	450	100
Mean				6.62	
Age		0			
<31	6.67	11.3	7.33	38	8.4
31-40	24	32.7	18	112	22
41-50	42.7	33.3	17.33	140	31.1
50>	26.7	22.7	57.33	160	35.6
Total	100	100	100	450	100
Mean				47.17	
Farming Experience					
<6	5.33	54	10.7	105	23.3
6-10	87.3	36	51	267	59.3
11-15	7.33	2.67	10.7	31	6.89
15>	0	7.33	24	47	10.4
Total	100	100	100	450	100
Mean				8.84	
Educational level					
No schooling	12.0	13.3	1	45	10
Primary school	21.3	8.7	34.0	96	21.3
Secondary school	45.3	54.0	48.0	221	49.1
Tertiary institution	21.3	24.0	13.3	88	19.6
Total	100.0	100.0	100.0	450	100
Member of Association					
Non-member	62.7	42.0	0	157	32
Member	37.3	58.0	100.0	293	65.1
Total	100.0	100.0	100.0	450	100

Niger State (121; 80.7%) which is in agreement with the views of Staal *et al.,* (2002); Hans-Martin and Richard, (2006).

Table 2b further revealed that FARO44 is mainly cultivated by the respondents in Benue state (50; 33.3%) and Niger State (51; 34%) while FARO61 56 (37.3) is mainly cultivated by the respondents in Nasarawa State. Therefore, FARO44 128 (28.4%) is mainly cultivated by the respondents in the North-Central Nigeria. This agrees with Manasseh *et al.* (2018) who found in their study that Faro 44 was one of the most cultivated rice varieties. The results depict that means of communicating information on rice variety in North-Central Nigeria still need to be enhanced. The source of seed as shown in (Table 2b) shows that open markets are where many of the respondents sourced for their seeds for planting in Benue State (53; 35.3%), Nasarawa State (87; 58%) and Niger State (136; 90.7%), respectively. So, many of the respondents in North-Central Nigeria sourced their seeds from open market (276; 61.3%). The rice yield per hectare of the respondents as shown in (Table 2b) shows that average rice yield per hectare of the respondents is 676.0, 674.4 and 1748.0 in Benue State, Nasarawa State and Niger State, respectively. So, the average rice yield per hectare of the respondents in North-Central Nigeria is 1032.8. The results depict that rice farming in North-

Table 2b: Continuation of socioeconomic characteristics of the respondents.

Items/States	**Benue**	**Nasarawa**	**Niger**	**Freq.**	**North-Central**
Size of Farm	**%**	**%**	**%**		**%**
<4	69.33	59.33	48.67	266	59.11
4-6	18.67	15.33	46.67	121	26.89
7-9	6	12.67	4.67	35	7.78
9>	6	12.67	0	28	6.22
Total	100	100	100	450	100
Mean				6.52	
Type of Rice Farming					
Upland	16.7	8.7	19.3	67	14.89
Lowland	83.3	91.3	80.7	383	85.11
Total	100	100	100	450	100
Variety of rice					
CP	15.3	24	0	59	13.11
OC	26.7	27.3	0	81	18
FARO61	21	34	0	88	19.56
FARO47	0	0	1.3	2	0.444
FARO44	33.3	11	37.3	128	28.44
FARO41	0	0	1.3	2	0.444
FARO24	0	0	2	3	0.667
FARO22	0	0	2.7	4	0.889
FARO21	0	0	14	21	4.67
GAWALC1	0	0	3.3	5	1.11
GAWALC2	0	0	3.3	5	1.11
JAMILA	0	0	32	48	10.67
JAMILAV1	0	0	2.7	4	0.889
Total	100	100	100	450	100
Source of seed					
Open market	35.3	58	90.7	276	61.33
Company	30.7	21	9.3	97	21.56
Institute	34	17.3	0	77	17.11
Total	100	100	100	450	100
Rice yield per hectare					
<600	94.67	50	0	217	48.22
600-1000	5.3	48	10.67	96	21.33
1100-1500	0	0	28.67	43	9.56
1600-2000	0	2	22	36	8
2100-2500	0	0	38.67	58	12.89
2500>	0	0	0	0	0
Total	100	100	100	450	100
Mean				1032.8	
Source of Capital					
Equity	80	76.6	83.3	360	80
Formal Credit	1	14	2	31	6.9
Formal Grants	5.3	3.3	9.3	27	6
Informal Credit	2	2.7	1.3	9	2
Informal Grants	8	3.3	4	23	5.1
Total	100	100	100	450	100

Central Nigeria is mainly on medium scale of operation and this is in line with the findings of Abubakar *et al.* (2016). The source of capital as shown in Table 2b shows that equity is the main capital source for many of the respondents in Benue State (120; 80%), Nasarawa State (115; 76.6%) and Niger State (125; 83.3%),

Table 3: Rice Farmers' awareness of and resilience to climate variability trend in north-central.

Items/States	Benue		Nasarawa		Niger		North-Central	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Aware of climate variability								
No	31	20.7	32	21.4	9	6	72	16
Yes	119	79.3	118	78.7	141	94	378	84
Total	150	100.0	150	100.0	150	100	450	100
Source of awareness								
Radio	60	40.3	34	22.7	51	34	145	32.2
Television	20	13.4	18	12.1	16	10.7	54	12
Extension contact	40	26.7	65	43.4	22	14.7	127	28.2
Print media	3	2.0	0	0	0	0	3	0.7
Social media	2	1.3	0	0	0	0	2	0.4
Social gathering	13	8.7	2	1.3	23	15.3	38	8.4
Other farmers	7	4.6	22	14.7	3	2	32	7.1
Observed changes	5	3.3	9	5.9	25	16.7	39	8.7
Total	150	100.0	150	100.0	150	100	450	100
Knowledge of Climate change								
Natural occurrences	91	60.7	79	52.7	146	97.3	316	70.2
Man-made actions	33	22.0	44	29.3	4	2.7	81	18
I do not know	26	17.3	26	17.3	0	0	52	11.6
Total	150	100.0	150	100.0	150	100	450	100

respectively. So, many of the respondents in North-Central Nigeria used equity capital to finance rice farming (360%).

Rice Farmers' awareness of and resilience to climate variability trend in North-Central

Table 3 shows that the respondents are aware of climate variability in Benue State 119 (79.3%), Nasarawa State 118 (78.7%) and Niger State 141 (94%), respectively. So, the awareness of climate variability by the respondents in North-Central Nigeria is remarkable 378 (84%). The results depict that rice farming in North-Central Nigeria knows about climate variability. The (Table 3) revealed that the source of awareness of climate variability is mainly radio 60 (43.3%) in Benue state; extension contacts 65 (43.4%) in Nasarawa State and radio 51 (34%) in Niger State. So, the main source of awareness of climate variability by the respondents in North-Central Nigeria is radio 145 (32.2%). These results are in agreement with study of Onyegbula (2017) who studied rice farmers' perception of effects of climate change on rice.

The Table 3 further revealed that the respondents mainly understand climate variability to be natural occurrences in Benue State (91; 60.7%), Nasarawa State (79; 52.7%) and Niger State (146; 97.3%). Therefore, climate variability is believed to be natural occurrences 316 (70.2%) by the respondents in the North-Central Nigeria. The results depict that the rice farmers' knowledge of climate variability need to be broadened in North-Central Nigeria. These results are in line with the study of Asekun-Olarinmoye *et al.* (2014) who examined Public perception of climate change.

The results of the estimated regression of the effects of climate variables on rice output variability in North-Central, Nigeria from 1980-2020 is presented in (Table 4). In Benue, the regression result in (Table 4) shows that the four variables: average rainfall variability, average temperature variability, average humidity variability and production capacity variability were significant at 1% level of probability, coefficient of determination (R^2) is 0.9335, the Adj. R^2 is 0.9261, Generalized Autoregressive Conditional Heteroscadascity (GARCH) is 0.9061, and Generalized Error Distribution (GED) is 0.5332.The coefficient of determination (R^2) is 0.9335 which implies that 93.35% variation in rice output was explained by average rainfall variability, average temperature variability, average humidity variability and production capacity variability while about 6.65% is explained by the error term (µ). The R^2 value is statistically significant, since the computed Log likelihood value of about-249.5472is significant at 1% level of probability. Most variables have the expected signs except average temperature variability.

The regression result shows that the coefficient of average rainfall variability is positive and significant (1.1057) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average rainfall variability led to an increase in rice output variability by about 1.1057 units during the period under review.

Table 4: Effects of climate variables on rice output in North-Central, Nigeria from 1980-2020.

	Benue		**Nasarawa**		**Niger**	
Variable	**Coeff.**	**z-Stat**	**Coeff.**	**z-Stat**	**Coeff.**	**z-Stat**
RNF	1.1057	3.4337***	0.5050	4.8978***	-0.4668	-1.0658
ATE	-12.5938	-4.5634***	10.6178	3.4908***	-48.1182	-42.9105***
REH	0.5748	5.2452***	-14.673	-6.1814***	-1.1625	-0.9449
PDC	0.0032	81.411***	0.0032	85.7109***	0.0035	22.6641***
C	179.0695	1.7934	501022	2.2800***	1477.594	50.1980***
Variance Equation						
C	731.0861	0.312831	-1.3418	-0.0057	-939.8763	-1.4710
RESID(-1)^2	0.3432	0.4041	1.6202	0.6941	0.1066	0.2410
GARCH(-1)	0.9061	3.4825***	0.6231	1.7873**	1.3002	4.5986***
GED PARAMETER	0.5332	2.3363**	0.6563	2.9243**	1.0065	1.9044**
R-squared	0.9335	420.1646	0.925176	420.6524	0.6199	398.2952
Adjusted R-squared	0.9261	662.3639	0.916863	866.4237	0.5777	402242
S.E. of regression	180.0475	12.6121	249.8209	11.12464	263.1471	12.0821
Sum squared resid	1167016.	12.9882	2246777.	11.50079	2492871.	12.4582
Log likelihood	-249.5472	12.7490	-219.0550	11.26161	-238.6820	12.2190
Durbin-Watson stat	0.7688		0.376711		0.8149	

Computed by the author and it was aided by the use of e-view software. Where RNF = rainfall; ATE = average temperature; REH = relative humidity; OPT = output; PDC = production capacity.

This agrees with the result of Ajetomobi *et al.* (2005) and varies with the result of Lalego *et al.* (2019) who reported the potential impact of climate change on Nigerian agriculture. The regression result shows that the coefficient of average temperature variability is negative and significant (-12.5938) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average temperature variability led to a decrease in rice output variability by about 12.5938 units during the period under review. This varies with the result of Lalego *et al.* (2019) who reported the potential impact of climate change on Nigerian agriculture. The regression result shows that the coefficient of average relative humidity variability is positive and significant (0.5748) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average relative humidity variability led to an increase in rice output variability by about 0.5748 units during the period under review. The regression result shows that the coefficient of production capacity variability is positive and significant (0.0032) at 1% level of probability in explaining rice output variability. This shows that a unit increase in production capacity variability led to an increase in rice output variability by about 0.0032 units during the period under review.

Test of hypothesis: the test of overall significance was carried out using (Table 4). Critical *z* value (n= 40) 1.96 for 5% two tailed.

Since z_{cal}(3.4337; $p = 0.006$) with 99.7% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{01}), which stated that the average rainfall did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average rainfall significantly affected rice output in North-Central, Nigeria. Since z_{cal} (-4.5634; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{02}), which stated that the average temperature did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average temperature significantly affected rice output in North-Central, Nigeria.

Since z_{cal} (5.2452; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{03}), which stated that the average relative humidity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average relative humidity significantly affected rice output in North-Central, Nigeria.

Since z_{cal}(81.411; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{04}), which stated that the production capacity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the production capacity significantly affected rice output in North-Central, Nigeria.

The implication is that the variation in rice output in the North-Central, Nigeria was explained by climate variability and production capacity (which explain resilient actions against climate variability such as government intervention, farms' adaptive capability). The negative relationship between rice output variability and average temperature variability supported the evidence of intolerant of some rice variety to high temperature requirement.

In Nasarawa, the regression result in (Table 4) shows that the four variables: average rainfall variability, average temperature variability, average moisture variability and production capacity variability were significant at 1% probability level, the coefficient of determination (R2) is 0.9252, the Adj. R2 is 0.9169, the generalized autoregressive conditional heteroskadasticity (GARCH) is 0.6231 and the generalized error distribution (GED) is 0.6563. The coefficient of determination (R2) is 0.9252, which means that 92.52% of the rice production variability was explained by the average rainfall, average temperature, average humidity and production capacity variability, while about 8.48% is explained by the error term (µ). The R2 value is statistically significant as the calculated log-likelihood value of about 219.0550 is significant at the 1% probability level. Most variables have the expected signs, except for the average variability of relative humidity.

The regression result shows that the coefficient of average rainfall variability is positive and significant (0.5050) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average rainfall variability led to an increase in rice output variability by about 0.5050 units during the period under review. This agrees with the result of Sufiyan *et al.* (2020) assessed Rainfall and Crop Yield Simulation in Nasarawa Town Nasarawa State Nigeria. The regression result shows that the coefficient of average temperature variability is positive and significant (10.6178) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average temperature variability led to an increase in rice output variability by about 10.6178 units during the period under review. This is in line with the result of Lalego *et al.* (2019) who reported the potential impact of climate change on Nigerian agriculture.

The regression result shows that the coefficient of average relative humidity variability is negative and significant (-14.673) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average relative humidity variability led to a decrease in rice output variability by about 14.673 units during the period under review. The regression result shows that the coefficient of production capacity variability is positive and significant (0.00317) at 1% level of probability in explaining rice output variability. This shows that a unit increase in production capacity variability led to an increase in rice output variability by about 0.00317 units during the period under review.

Test of hypothesis: the test of overall significance is carried out using (Table 4). Critical *z* value (n= 40) 1.96 for 5% two tailed. Since z_{cal} (4.8978; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{01}), which stated that the average rainfall did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average rainfall significantly affected rice output in North-Central, Nigeria.

Since z_{cal}(3.4908; $p = 0.006$) with 99.7% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{02}), which stated that the average temperature did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average temperature significantly affected rice output in North-Central, Nigeria. Since z_{cal}(-6.1814; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{03}), which stated that the average relative humidity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average relative humidity significantly affected rice output in North-Central, Nigeria.

Since z_{cal}(85.7109; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{04}), which stated that the production capacity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the production capacity significantly affected rice output in North-Central, Nigeria. The implication is that the variation in rice output in the North-Central, Nigeria was explained by climate variability and production capacity (which explain resilient actions against climate variability such as government intervention, farms' adaptive capability). The negative relationship between rice output variability and average relative humidity variability supported the evidence of intolerant of some rice variety to high humidity requirement.

In Niger, the regression result in (Table 4) shows that the two variables: average temperature variability, and production capacity variability were significant at 1% level of probability, coefficient of determination (R^2) is 0.6199, the Adj. R^2 is 0.5777,Generalized Autoregressive Conditional Heteroscadasticity (GARCH) is 1.3002, and Generalized Error Distribution (GED) is 1.0065.The coefficient of determination (R^2) is 0.6199 which implies that 61.99% variation in rice output was explained by average rainfall variability, average temperature variability, average humidity variability and production capacity variability while about 38.01% is explained by the error term (µ). The R^2 value is statistically significant, since the computed Log likelihood value of about-238.6820is significant at 1% level of probability. Most variables do not have the expected signs except average production capacity variability.

The regression result shows that the coefficient of average rainfall variability is negative but not significant (-0.4668) even at 10% level of probability in explaining rice output variability. This shows that a unit increase in average rainfall variability led to a decrease in rice output variability by about 0.4668 units during the period under review. This agrees with the result of Sufiyan et al. (2020) examined rainfall trend and it impact in Keffi Nasarawa State. The regression result shows that the coefficient of average temperature variability is negative and significant (-48.1182) at 1% level of probability in explaining rice output variability. This shows that a unit increase in average temperature variability led to a decrease in rice output variability by about 48.1182 units during the period under review. This varies with the result of Lalego *et al.* (2019) who reported the potential impact of climate change on Nigerian agriculture.

The regression result shows that the coefficient of average relative humidity variability is negative but not significant (-1.1625) even at 10% level of probability in explaining rice output variability. This shows that a unit increase in average relative humidity variability led to a decrease in rice output variability by about 1.1625 units during the period under review. This is in agreement with Ayinde *et al.* (2013). The regression result shows that the coefficient of production capacity variability is positive and significant (0.0035) at 1% level of probability in explaining rice output variability. This shows that a unit increase in production capacity variability led to an increase in rice output variability by about 0.0035 units during the period under review.

Test of hypothesis: the test of overall significance is carried out using (Table 4). Critical *z* value (n= 40) 1.96 for 5% two tailed. Since z_{cal}(-1.0658; $p = 0.4532$) with 54.68% confidence at 5% level of probability, the study fail to reject the null hypothesis (H_{01}), which stated that the average rainfall did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average rainfall did not significantly affected rice output in North-Central, Nigeria.

Since z_{cal}(-42.9105; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{02}), which stated that the average temperature did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average temperature significantly affected rice output in North-Central, Nigeria.

Since z_{cal}(-0.9449; $p = 0.3422$) with 65.78% confidence at 5% level of probability, the study fail to reject the null hypothesis (H_{03}), which stated that the average relative humidity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the average relative humidity did not significantly affected rice output in North-Central, Nigeria. Since z_{cal}(22.6641; $p = 0.002$) with 99.98% confidence at 5% level of probability, the study fail to accept the null hypothesis (H_{04}), which stated that the production capacity did not significantly affect rice output in North-Central, Nigeria. It therefore concluded that the production capacity significantly affected rice output in North-Central, Nigeria. The implication is that the variation in rice output in the North-Central, Nigeria was explained by climate variability and production capacity (which explain resilient actions against climate variability such as government intervention, farms' adaptive capability). The negative relationship between rice output variability and climate variability supported the evidence of intolerant of some rice variety to high climate variable requirements.

Conclusion

The study examined the impact of climate variability on rice production in north-central Nigeria (1980 - 2020). Climate variability indices and production capacity are found to have a significant impact on rice production over time, but rice farmers' awareness and resilience to the impacts of climate variability is affected by inadequate extension contacts. In summary, the study has empirically shown that rice farmers have adaptive capacities that can be explained by socio-economic quality, but their resilience to the impacts of climate variability is highly inadequate, as indicated by the resilience indices proposed in the study.

Recommendations

The recommendation were made base on the study findings as follow:

i. Since the time variables shows both positive and negative trends of the climate variables and rice output in the selected states. It is therefore recommended that government should not only focus on the fixed short term policy interventions without flexible long term components.

ii. Since the result shows that the rice farmers have adaptive capacity because it is dominated by married males who attained mainly secondary school and belong to cooperative society with reasonable years of farming experience. It is therefore recommended that government should through policy interventions promote improved rice technology transfer, adoption and diffusion among the rice farmers

iii. Since the results show that the respondents are aware of climate variability trend and effects as natural occurrences in the selected States. It is therefore recommended that government-farmers information sharing platform should be encourage through government agencies.

iv. Since the results depict that many of the vulnerable rice farmers accepted that the pre-requisite to prompt response to trend of climate variability are not readily available. It is therefore recommended that government should encourage investments in rice farming resilience activities by providing funding in-kind.

(v) Since the results show that the climate variables significantly affect rice output. It is therefore recommended that government should create buffers through price policy.

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