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EFFECT OF RAINFALL VARIABILITY ON THE YIELD OF RICE AND FARMERS' RESILIENCE TOWARDS FOOD SECURITY IN SELECTED LOCAL GOVERNMENT AREA OF BENUE STATE OF NIGERIA

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ABSTRACT

This study examined the impact of rainfall variability on rice yield and farmers' resilience towards food security in selected Local Government Areas of Benue State, Nigeria. Historical monthly rainfall data were sourced from the Nigerian Meteorological Station's archives in Oshodi, Lagos. Rice yield data were collected from the Benue State Agricultural and Rural Development Agency's (BNARDA) archives. The study utilized 42 years (1980-2022) of rainfall and rice yield data to characterize the rice yield response to rainfall patterns. Multistage sampling technique was used to select six local government areas. Seven hundred and eighty-three farmers were purposively sampled. Questionnaire, interview and focused group discussion were used to get information from the farmers. Trend line equations were used to show the trend of rainfall, while Pearson's Correlation Coefficient (r) was used to determine the degree of relationship between rainfall and rice yield. The trend line equation revealed an increase in total annual rainfall (y =7.3207x + 1084.5). Similarly, the yield pattern of rice showed an increase in rice yield (y= 0.036x+2.2331). However, the correlation analysis indicated a weak negative correlation coefficient of -0.180, which was not statistically significant (p-value = 0.340). Although the correlation analysis did not show a significant relationship between rainfall and rice production, these findings corroborate previous research, which confirmed that rainfall does not entirely influence rice yield in Benue State. The increase in yields was attributed to the increased knowledge and adoption of viable adaptation strategies/improved production practices by farmers. Based on these findings, the study recommends the adoption of viable adaptation strategies for continuous rice production towards food security in the area. Specifically, farmers should be encouraged to adapt measures such as: improved seed varieties, use of organic or inorganic fertilizers, use of early maturing varieties and other improved production practices.

Keywords: *rainfall; relationship; rice production; variability and yield*

INTRODUCTION

Rainfall distribution, patterns, and seasonality have become a growing concern globally, particularly in rain-fed agricultural areas. The erratic nature of rainfall, characterized by irregular amounts and uneven distribution, poses a significant threat to agricultural production, leading to declining crop yields and high variability in annual production (Agidi, 2017). Rainfall variability is the fluctuations of rainfall occurrence annually or seasonally above or below a long-term normal value. Every year, the rainfall of a location can be different in a specific period, either above or below normal (Intergovernmental Panel on Climate Change [IPCC], 2022). Rainfall values in last decade reduced drastically and affected crop yields across Nigeria (Iornongo, 2021).

According to Ibebuchi and Abu (2023) and Vinaya et al. (2017), climate change and natural climate variability are the major causes of weather extremes such as heavy rainfall and drought conditions. In Nigeria, rainfall variability has substantially impacted crop yields, with amounts fluctuating above or below normal levels from year to year. The unpredictable onset and cessation of rainfall, as well as the length of the growing season, can adversely affect farmers in areas reliant on rainfall for their agricultural activities (IPCC, 2022). Nigeria is among the countries most vulnerable to climate change, with the agricultural sector bearing the brunt of its impacts. The variability in rainfall has placed farmers in Nigeria's savanna regions in a precarious situation, as agricultural practices in this zone are largely rain-fed (Tiamiyu et al. 2015). Rice, in particular, is a significant crop in Nigeria's semi-arid regions, accounting for 60-70% of cereal production, along with other grain crops like maize, sorghum and soyabeans. However, these crops rely heavily on rainfall, which is often irregular and unpredictable.

Consequently, the production of major crops like rice has declined over the past few decades, despite a growing population. This scenario exacerbates the risk of hunger and food insecurity, leading to increased reliance on food aid at national and household levels. To address this challenge, a significant increase in the productivity of staple crops, particularly rice, is crucial. As a vital staple food crop in northern Nigeria and Benue State, rice constitutes a substantial portion of grain production and consumption. However, rice yields in Benue State have remained persistently low, despite the state's considerable potential for grain production (Iornongo, 2021).

Rainfall characteristics significantly impact rain-fed agriculture, leading to crop viability loss and income loss for farmers. Inter-annual variation in rainfall is a primary cause of crop yield decline. In northern Nigeria, annual rainfall variation is substantial, often resulting in climate hazards like floods and droughts, which devastate food production and cause associated calamities. Despite Nigeria's potential for crop production, frequent agricultural droughts due to erratic rainfall distribution and/or rain cessation during the growing season hinder production increases, particularly in the northern region where most grains are produced (Ariko et al., 2024).

Rice (*Oryza sativa L.)* is one of the major cereal crops worldwide and is the staple food for millions of people in Nigeria. It is consumed across all geopolitical zones and by people of different socio-economic classes. Rice (*Oryza sativa*) is consumed by more than half of the world's population. Rice is the world`s second most popular crop after maize. It is an increasingly important crop in Nigeria. The position acquired by rice is attended by great demand on the Nigerian market. The agriculture sector is the third- best valuable business in the world. Therefore, rice production in Nigeria, one of the most popular products in the country, promises to be successful. Statistically, Nigeria is the highest importer of rice globally and the largest producer in West Africa (International Rice Research Institute [IRRI] 2011).

Rice is grown under a range of agroclimatic conditions. Rice production has increased significantly in Nigeria in recent years, with the country now one of the largest producers and consumers of rice in Africa (Bin et al, 2023). However, there are still challenges in the production of rice in Nigeria, including limited access to high-yielding and disease-resistant varieties, poor agronomic practices, climate variability, and environmental stresses (Jonah et al, 2023). Consequently, the demand for rice in Nigeria has quadrupled, thereby, far exceeding production levels. As a result, rice imports keep growing at a fast rate, as local rice production has been mainly under upland conditions and primitive agronomic practices, with farmers clearing new forest lands every year (Somado et al, 2008).

The main rice- producing states in Nigeria are: Benue, Ebonyi, Kaduna, Kano, Niger, Taraba and Borno. Other states include Enugu and Cross River (FAO, 2012). It is a cereal grain that grows in swampy areas, in regions with high rainfall but can still be grown in areas with little rainfall using water controlling terrace systems; it's sensitive and requires a lot of care and attention to grow well. It takes about 120-200days after planting, depending on the areas and other factors for the grains to get ready for harvest.

Rice needs an optimal temperature for effective growth between 22°C and 31°C and requires 5 to 6 hours of sunshine per day. Rice needs a significant amount of water, estimated to be around 500 to 600 mm (Odeniyi et al. 2020). Upland rice grows well where 5 days total rainfall is more than 20 mm from sowing to 15 days before harvesting (about 90 days).

Previous studies (Ibebuchi and Abu, 2023; Tesfage et al., 2020; Iornongo 2021; Bin et al., 2023) studied the impact of rainfall variability on rice production at various location. These studies did not work on adaptation strategies. This study focuses on the relationship between rainfall variability and the yield of rice and farmers' resilience strategies towards food security in selected Local Government Areas (LGAs) in Benue State, Nigeria.

OBJECTIVES

(1) To determine the annual rainfall trends in the area from 1980 to 2022 (42 years)

(2) To identify the trends in rice yield patterns from 1980 to 2022

(3) To analyze the significant relationship between annual rainfall data and annual rice yield in the area from 1980 to 2022

(4) To identify the resilience strategies adopted by rice farmers in the area.

METHODOLOGY

Benue State, created on February 3, 1976, is situated in the lower River Benue trough within Nigeria's middle belt region and is renowned as the "Food Basket of Nigeria." The state lies between Latitudes 6°25'59''N and 8°8'06''N and Longitudes 7°30'14''E and 10°00'53''E, covering 34,059 square kilometers (Terdoo et al., 2016; National Bureau of Statistics, 2018). Benue State shares boundaries with five states and the Republic of Cameroon, with a vegetation characteristic of the southern Guinea Savanna biome (Nigerian Investment Promotion Commission [NIPC], 2020).

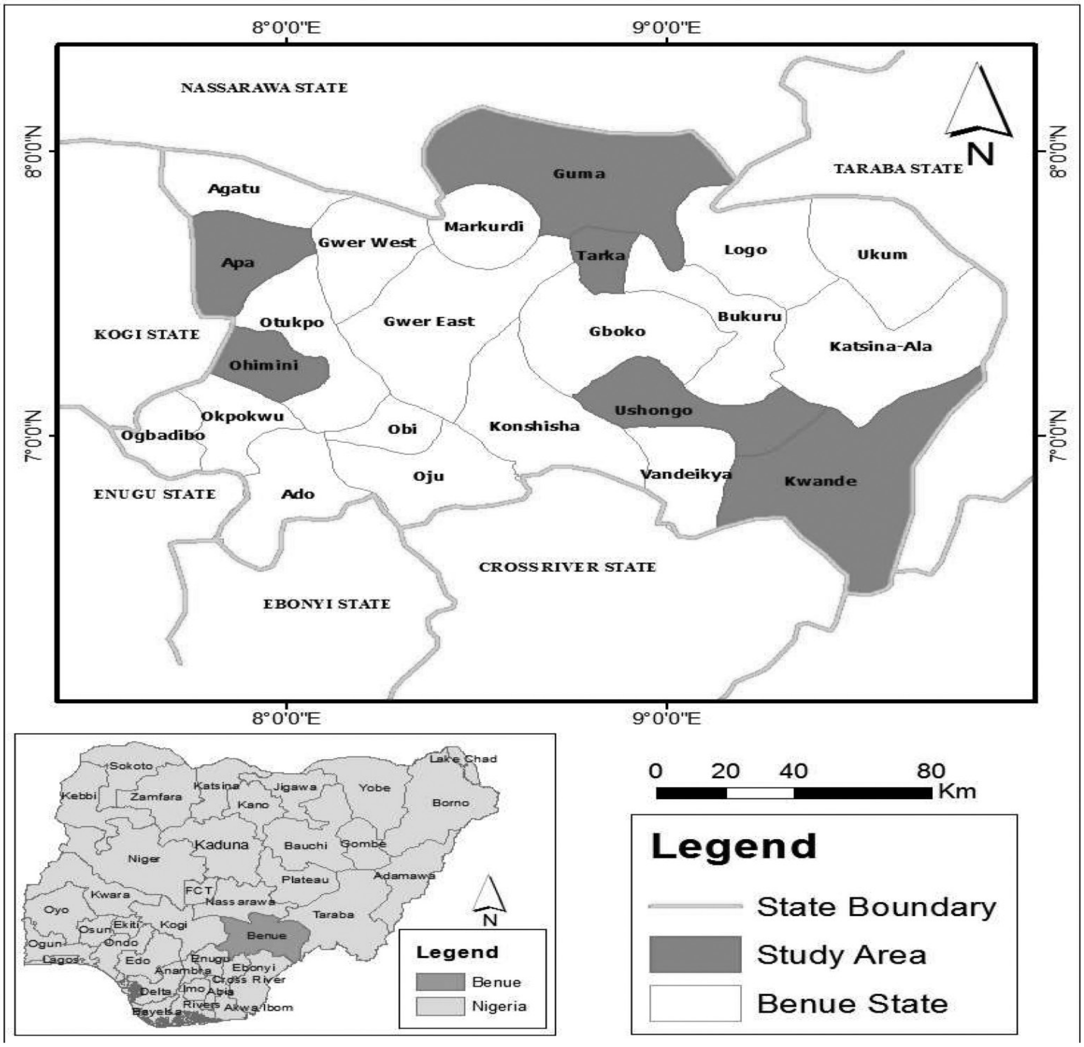

Fig. 1 : Benue State (Study Area)

According to the Köppen climatic classification, Benue State falls within the AW climate, characterized by two distinct seasons: the wet season and the dry season. The state typically experiences 7-10 months of rainfall (Hula, 2010), with the rainy season spanning from April to October and annual rainfall ranging from 1000-2000 mm. The dry season begins in November and ends in March. Temperatures fluctuate between 21°C and 37°C throughout the year. However, the south-eastern part of the state, adjacent to the Obudu-Cameroun Mountain range, has a cooler climate, similar to that of Plateau State (Ologunorisa and Tersoo, 2006). Notably, temperatures within Makurdi, the state headquarters, are consistently high, averaging between 28°C and 32°C, and sometimes reaching up to 37°C (Hula, 2010).

Modified by GIS Lab Department of Geography, A.B.U. Zaria.

The state's dominant geographical feature is the River Benue, with numerous tributaries, including the Katsina-Ala River. Benue State has a population of approximately 4,437,148 (2006 Population Census) with the Tiv, Idoma, and Igede people being the predominant ethnic groups. Agriculture is the backbone of the state's economy, engaging over 70% of the population, with major cash crops including soybeans, rice, peanuts, and food crops like yam, cassava, and maize (Terdoo et al. 2016).

This study employed a quantitative research approach. A multistage sampling technique was utilized to select 6 LGAs from the 23 LGAs (Kwande, Ushongo, Guma, Tarka, Apa and Ohimini). (Table 1). The sample size was determined using Krejcie and Morgan's (1970) sample size determination formula, recommending a sample size of 783 for a population ranging from 500,000 to 10,000,000, at a 95% confidence level and a 3.5% margin of error. This margin of error was chosen to minimize errors, as smaller sample sizes typically yield larger margins of error.

Primary and secondary data were used, including structured questionnaires, interviews, FGDs, rainfall, temperature, and yield data. The instruments used for data collection were the self-structured Crop Farmers' Perception Questionnaire (CFPQ) and the interview guide titled Crop Farmers' Perception Interview Guide (CFPIG). Purposive sampling technique was used to select farmers who are above 30 years of age. It is believed that farmers above the age of 30 should have the prerequisite knowledge on the climate system of the area. Six multiple FGDs were designed for the six selected LGAs, each comprising eight experienced crop farmers and two extension workers. These participants were selected by the Heads of farmers from each LGA to explore pertinent issues affecting crop production in the area.

The 2006 census figures were projected to 2023 using Newman's (2001) population projection method. The projection of sampled localities' population was based on the Benue State population growth rate of 3%. The formula used was:

$$Pn = Po + ((1+R)/100 \times Po) \times n \quad (1)$$

Where:

Pn = Population in the recent year;

Po = Population in the base year;

R = annual growth rate;

n = number of intermediary years.

The Relative Importance Index Technique (RII) was used to determine the relative importance of various resilience strategies to rainfall variability and change in the study area. The RII formula used was:

$$RII = \Sigma W / (A \times N) \quad (2)$$

Where:

W = Weight given to each factor by the respondents;

A = Highest weight (i.e., 3 in this case);

N = Total number of respondents.

The three-point scale ranged from 1 (Not at all) to 3 (Always). The higher the value of RII, the more important or effective was the resilience strategy to rainfall variability in the study area.

RESULTS AND DISCUSSION

The socio-demographic characteristics of the farmers in the selected LGAs were identified, analyzed and presented in Table 1. The demographic characteristics of the respondents provide valuable insights into their backgrounds and potential influences on their responses. The majority of respondents are male (586, 75%), while females constitute a smaller proportion (194, 25%). This imbalance may impact the generalizability of the findings, particularly if there are significant gender differences in the variables being studied.

Table 1: Socio-demographic characteristics of the farmers (n=780)

Parameters	Options	Respondents	Percent
Sex	Male	586	75
	Female	194	25
Age	30 – 40 years	389	50
	41 – 50 years	213	27
	51 – 60 years	114	15
	61 – 70 years	56	07
	>71	08	01
Religious Belief	Christianity	724	93
	Islam	30	04
	Traditional	26	03
Marital Status	Single	315	40
	Married	401	51
	Widowed	64	08
Level of Education	Primary	289	37
	Secondary	301	39
	Tertiary	180	23
	Others	10	01
Respondents' years of residency in the study area	20 – 30 years	564	72
	31 – 40 years	189	24
	>41 years	27	03

Source: Field Survey, 2024

The age distribution of respondents is skewed towards the middle-aged group, with 50% (389) falling within the 30-40 years range (Table 1). The 41-50 years age group constitutes 27% (213) of respondents, followed by 15% (114) in the 51-60 years range. The oldest age groups (>61 years) make up a smaller proportion of respondents, with 7% (56) in the 61-70 years range and 1% (8) above 71 years. This age distribution may influence respondents' perspectives, experiences, and attitudes, particularly if age-related factors are relevant to the research topic.

Christianity is the dominant religion among respondents, with 93% (724) identifying as Christians (Table 1). Islam and traditional beliefs make up smaller proportions, with 4% (30) and 3% (26) of respondents, respectively. This religious distribution may impact respondents' values, beliefs, and practices, particularly if the research topic is sensitive to religious influences.

The majority of respondents are married (401, 51%), followed by singles (315, 40%). Widowed individuals constitute a smaller proportion of respondents (64, 8%) (Table 1). Marital status may influence respondents' experiences, attitudes and perspectives, particularly if family-related factors are relevant to the research topic.

The level of education among respondents is relatively balanced, with 37% (289) having primary education, 39% (301) having secondary education, and 23% (180) having tertiary education (Table 2). A small proportion of respondents (10, 1%) have no formal education. Education level may impact respondents' knowledge, attitudes, and practices, particularly if the research topic requires specific educational background or knowledge.

The majority of respondents (72%, 564) have lived in the study area for 20-30 years, indicating a relatively stable and long-term resident population. Smaller proportions of respondents have lived in the area for 31-40 years (24%, 189) or more than 41 years (3%, 27). Length of residency may influence respondents' familiarity with the area, their social networks, and their experiences with local services or issues.

Climatic characteristics of the study area

The rainfall data analysis revealed a characterized rainfall pattern in the study area, presented in Figure 2, with a linear regression equation (y=7.3207x + 1084.5) indicating a positive correlation, where every one-unit increase in x corresponds to a 7.3207-unit increase in rainfall data (y), suggesting an increasing trend over time or with respect to the independent variable (x), likely due to environmental or climate-related factors. This finding aligns with previous studies by Adamgbe and Ujoh (2013) and Akinola et al. (2019) Pandey et al. (2023), which reported increasing rainfall trends in Benue State, supporting the perception of farmers and observed rainfall variability.

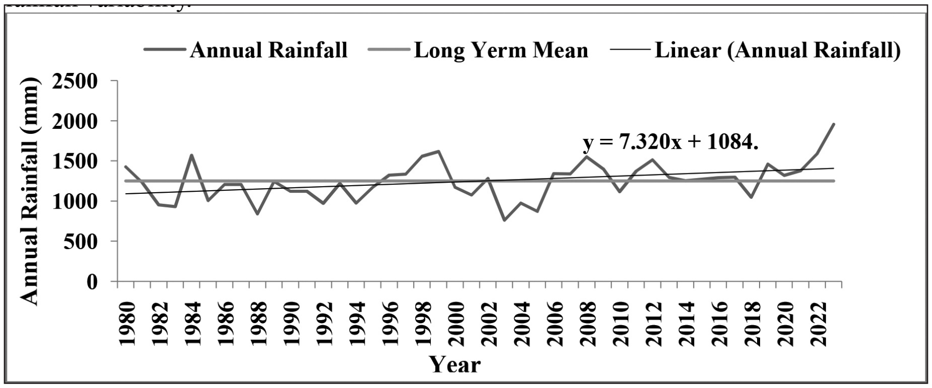

Fig. 2: Rainfall data of the study area (1980 – 2022)

The linear regression equation for rice yield from 1980 to 2022 is: y = 0.036x + 2.2331. The slope (0.036) represents the change in rice yield (y) for a one-unit change in the independent variable (x), which in this case is likely time (years). A positive slope indicates that rice yield has been increasing over time. Specifically, for every additional year, rice yield increases by approximately 0.036 units (metric tons per hectare). The positive slope indicates an increasing trend in rice yield over the 42-year period (1980-2022). This suggests that rice production has been improving over time, possibly due to factors such as: improved agricultural practices and technologies, increased use of fertilizers, pesticides and irrigation, enhanced crop varieties and breeding programmes and better farm management and extension services

Implications and future prospects

The increasing trend in rice yield is a positive sign for food security and agricultural development. However, it is essential to consider the sustainability and environmental implications of this trend. Future research and policy efforts should focus on:

(i) Identifying the key drivers of the increasing trend in rice yield

(ii) Assessing the environmental and social impacts of intensified rice production

(iii) Developing sustainable and climate-resilient agricultural practices to ensure long-term food security

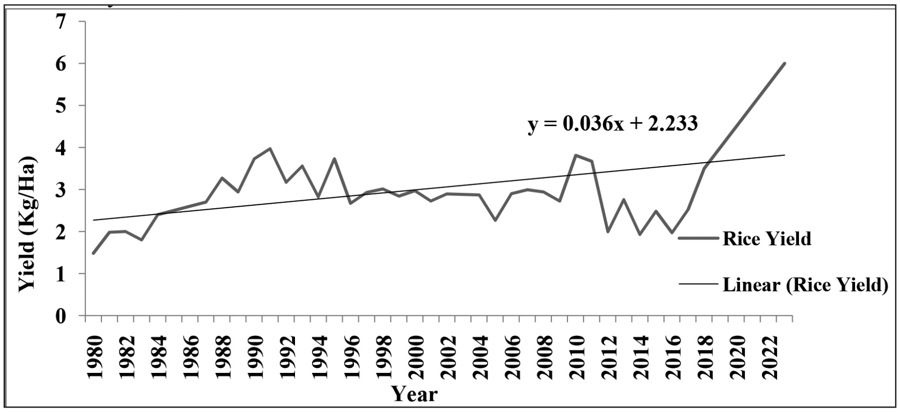

Fig. 3: rice yield in the study area (1980–2022)

Relationship between rainfall variability and the yield of rice

The average rainfall value is approximately 1224mm (Tabler 2). This suggests that the study area receives a significant amount of rainfall, which could be beneficial for rice production. The Standard Deviation measures the amount of variation or dispersion in the rainfall data. A standard deviation of 209.92 units indicates that the rainfall values are spread out moderately around the mean. This could be due to various factors such as differences in elevation, soil type, or weather patterns.

Table 2: relationship between rainfall and rice yield

Descriptive Statistics	Mean	Std. Deviation	N
Rainfall	1224.2976	209.91624	42
Rice metric tonnes	2.9303	.52862	42

Source: Author's Computation

The average rice production value is approximately 2.93 metric tonnes. This suggests that the study area has a moderate level of rice production. The standard deviation for rice production is relatively small (0.53 metric tonnes), indicating that the rice production values are clustered closely around the mean. This could be due to factors such as consistent farming practices, similar soil types or favourable weather conditions.

Comparison and insights

(i) The mean rainfall value is significantly higher than the mean rice production value, which suggests that rainfall is not the only factor influencing rice production.

(ii) The standard deviation for rainfall is much higher than for rice production, indicating that rainfall values are more variable and unpredictable.

Implications and future research directions

(i) Further research is needed to explore the relationship between rainfall and rice production, including the impact of other factors such as soil type, temperature and farming practices.

(ii) The moderate level of rice production and relatively small standard deviation suggest that the study area has a stable rice production system. However, efforts to improve rice production and reduce variability should focus on optimizing farming practices, soil management and irrigation systems.

(iii) The data can be used to inform agricultural policies, extension services and research initiatives aimed at improving rice production and reducing the impact of climate variability on agriculture.

Correlation coefficient between total annual rainfall and rice yield

The correlation coefficient measures the strength and direction of the linear relationship between two variables (rainfall and rice yield). The Pearson correlation coefficient is -0.180, indicating a weak negative linear relationship between the two variables.

Table 3: Pearson Correlation Coefficient between Rainfall and Rice

Correlations		Rainfall	Rice Metric Tonnes
Rainfall	Pearson Correlation	1	**-.180**
	Sig. (2-tailed)		.340
	N	42	42
Rice metric tonnes	Pearson Correlation	**-.180**	1
	Sig. (2-tailed)	.340	
	N	42	42

Source: Author's Computation

Interpretation of correlation coefficient

A correlation coefficient of -0.180 suggests that as rainfall increases, rice production tends to decrease slightly, and vice versa. However, the relationship is weak, indicating that other factors may be influencing rice production. The negative correlation may seem counterintuitive, as one might expect rainfall to have a positive impact on rice production. However, excessive rainfall can lead to flooding, nutrient leaching, and reduced rice yields.

Significance Levels

The significance level, also known as the p-value, indicates the probability of observing the correlation coefficient (or a more extreme value) assuming that there is no real relationship between the variables. The p-value is Sig. (2-tailed) 0.340, which is greater than the typical significance level of 0.05. This suggests that the observed correlation coefficient is not statistically significant and the relationship between rainfall and rice production may be due to chance.

Implications and future research directions

(i) The weak negative correlation between rainfall and rice production suggests that other factors, such as temperature, soil type, and farming practices, may be more influential in determining rice yields.

(ii) Further research is needed to explore the relationships between rainfall, rice production, and other environmental and management factors.

(iii) The non-significant correlation coefficient suggests that the relationship between rainfall and rice production may not be reliable or generalizable.

Overall, the correlation analysis suggests that the relationship between rainfall and rice production is complex and influenced by multiple factors.

The Pearson correlation coefficient between rainfall and rice metric tonnes is -0.180, indicating a weak negative relationship. The p-value (0.340) is greater than 0.05, meaning the correlation is not statistically significant. Thus, there is no strong evidence to suggest that rainfall significantly affects rice production in this dataset

Resilience strategies

Climate change resilience refers to the proactive process of preparing for and adjusting to the impacts of climate change, including both negative consequences and potential opportunities (World Bank, 2011). Enhancing the adaptive capacities of local farmers in the study area can strengthen their resilience to climate-related shocks. While planned adaptation offers a strategic approach to addressing climate change, identifying and integrating local resilience strategies is crucial for effective adaptation. As Adeshina and Odekunle (2011) noted, proposed resilience strategies may either introduce entirely new approaches to an area or build upon existing community knowledge and practices. In Benue State, farmers have adopted various resilience strategies as a means of coping with the effects of climate change and rainfall variability.

Table 4 : Resilience strategies adopted by rice farmers in the study area (n=780)

Sr. No.	Resilience Strategies	Always Used	Rarely Used	Not at all	RII	Rank
1	**Early Planting**	635	125	20	0.9	2
2	**Use of organic manure**	672	78	30	0.9	2
3	**Use of inorganic manure**	575	145	60	0.9	2
4	**Planting of pest and disease resistant crop**	555	172	53	0.9	2
5	**Increase in number of weeding**	362	262	156	0.7	6
6	**Mixed farming practices**	299	289	192	0.7	6
7	**Loans, grants and subsidies**	257	307	216	0.6	7
8	**Mixed cropping**	744	16	2	1.0	1

Source: Field Work 2024

The result revealed that out of the eight adaptive strategies, five were "highly adopted" by the farmers as reflected in their RII scores of 0.9 and 1.0.

Most frequently used strategies

(i) Mixed Cropping: This strategy is used by almost all respondents (744), indicating its widespread adoption and potential effectiveness.

(ii) Use of Organic Manure: A large majority of respondents (672) always use organic manure, highlighting its importance in maintaining soil health and fertility.

Highly adopted strategies

The following strategies have a high adoption rate (RII = 0.9) and are used by a significant proportion of respondents:

(i) Early Planting (635 respondents)

(ii) Use of Inorganic Manure (575 respondents)

(iii) Planting of Pest and Disease Resistant Crop (555 respondents)

Moderately adopted strategies

The following strategies have a moderate adoption rate (RII = 0.6-0.7) and are used by a smaller proportion of respondents:

(i) Increase in Number of Weeding (362 respondents)

(ii) Mixed Farming Practices (299 respondents)

(iii) Loans, Grants, and Subsidies (257 respondents)

The ranking of mixed cropping as the top resilience strategy aligns with existing research, including a study by Ikpe et al. (2018) that found most farmers in Goronyo LGA of Sokoto State, Nigeria, adopted mixed cropping to cope with climate change, and another by Nhemachena and Hassan (2007) that identified mixed cropping, crop diversification and varied planting dates as key resilience strategies in Southern Africa. This finding is further supported by the outcomes of the Focus Group Discussion (FGD), which revealed that farmers in the study area value mixed cropping for its multiple benefits, including multiple harvests, crop security and additional income sources, ultimately reinforcing its position as a highly adopted resilience strategy.

CONCLUSION

This study examined the impact of rainfall variability on rice yield and farmers' resilience strategies in selected LGAs of Benue State, Nigeria, revealing a significant increase in rainfall and over the past four decades, which supports rice cultivation, as evidenced by rising yields. Rainfall is not the only factor responsible for the high yield of rice. Other factors such as adoption of viable adaptation strategies were factors. Mixed cropping emerged as the most widely adopted adaptation strategy among farmers, offering benefits such as enhanced crop diversity, multiple harvests, crop security, and additional income sources. To enhance food security and promote climate resilience, the study recommends scaling up successful strategies like mixed cropping and organic manure use, and promoting integrated farming practices, including mixed farming and crop rotation, to improve soil health, reduce pests and diseases, and boost agricultural productivity.

RECOMMENDATIONS

(1) Scale up successful strategies: build on the success of mixed cropping and organic manure use by scaling up these strategies and promoting them to more farmers.

(2) Improve access to credit: enhance access to loans, grants and subsidies to help farmers adopt more adaptation strategies and improve their resilience.

(3) Promote integrated farming practices: encourage farmers to adopt integrated farming practices, such as mixed farming and crop rotation, to improve soil health and reduce pests and diseases.

By adopting these recommendations, farmers in the study area can improve their resilience to climate change, enhance rice yields, and contribute to food security in Benue State, Nigeria.

CONFLICT OF INTEREST

This is to declare that there is "No conflict of interest" among researcher.

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