

ASSESSING THE IMPACT OF TEMPERATURE VARIABILITY ON RICE FARMING IN IKWO, EBONYI STATE, NIGERIA: IMPLICATIONS FOR CLIMATE RESILIENCE.

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Abstract: This study examined the impact of temperature changes on rice yield in Ikwo, Ebonyi State, Nigeria. The research aimed to assess long-term temperature trends and their implications for rice farming, addressing critical gaps in localized knowledge. A quantitative research design was adopted, integrating the analysis of climatic data with a structured questionnaire survey administered to rice farmers. Monthly average temperature data from 1993 to 2023, sourced from the Nigerian Meteorological Agency (NiMet), provided the basis for trend analysis. The study population comprised 15,000 registered rice farmers, from which a sample size of 390 was determined using Yamane's formula. A multi-stage sampling technique ensured proportional representation across 13 communities. Findings revealed a gradual increase in both minimum and maximum annual average temperatures, with recent maximum temperatures frequently exceeding 35°C. This trend correlated with farmers' perceptions of reduced yields, particularly during critical growth stages, as evidenced by an overall mean score of 4.34 from survey responses. High temperatures were reported to exacerbate heat stress, disrupt planting schedules, and increase water demands, contributing to economic losses. These findings underscore the need for adaptive strategies, including the adoption of heat-tolerant rice varieties and improved water management, to mitigate the adverse impacts of temperature fluctuations on rice farming in Ikwo.

Keywords: Changes, Rice, Temperature, Yield

I. Introduction

Rice is a critical staple food in Nigeria in that it serves as a major source of sustenance for a significant portion of the population. Ikwo Local Government Area in Ebonyi State is a notable rice-producing region. However, the area is heavily reliant on climatic factors such as temperature and rainfall for optimal yields. Over the years, fluctuations in temperature patterns, attributed to climate change, have adversely impacted agricultural productivity, particularly rice cultivation in this area. These climatic changes pose serious risks to food security, rural livelihoods, and economic stability in Nigeria (Onyeneke, 2020). This study examines the implications of temperature changes on rice yield in Ikwo, aiming to fill critical gaps in understanding the localized effects of climate variability.

Globally, agriculture is increasingly vulnerable to climate change, with rising temperatures and erratic rainfall patterns leading to crop failures and reduced yields. In Nigeria, the agricultural sector is primarily rain-fed, making it highly susceptible to climate-induced changes. According to a World Bank Report (2019), Nigeria is one of the top ten exposed countries to the effects of climate change, with about 6% of its area estimated to be exposed to extreme weather events like flooding and drought. Although, the report focused on the whole country, the local economic dynamics suggest that the vulnerability varies across the countries, with rural areas being mostly vulnerable. As rightly asserted by Audu et al. (2017), rice farming, reliant on environmental elements, places paramount importance on some factors, which significantly influence agricultural output. The successful production of rice necessitates an optimal blend of production inputs to achieve high yields. These inputs extend beyond the conventional resources and include various environmental factors inherent in nature. Rainfall attributes such as intensity and duration, in addition to relative humidity and temperature, significantly impact both the yield and variability of rice production. While some factors are anticipated to enhance yield variance, others are expected to produce contrary effects (Eakin and Wehbe, 2020).

Recent studies emphasize the correlation between temperature variations and reduced productivity of key crops like rice. For example, rising temperatures have been shown to significantly impact rice yields due to heat stress during critical growth phases such as flowering and grain filling (Onyeneke et al., 2021). Furthermore, unpredictability in rainfall patterns exacerbates the challenges of temperature changes, leading to soil degradation and reduced water availability, which are critical for rice farming (Mba et al., 2022).

While the root causes of the challenges facing rice production in Ikwo are complex, global warming is one of its major drivers. Human-induced climate change, driven by greenhouse gas emissions, is a major factor contributing to the observed changes in weather patterns globally and regionally. According to Onyeneke et al. (2021), there is a trend of changing temperature and precipitation pattern in Ebonyi state. The scope of the problem extends beyond immediate agricultural losses to encompass broader socio-economic and environmental implications. Rice is a staple food and an economic lifeline for many rural households in Ikwo. A decline in rice productivity directly impacts food security, increases poverty, and exacerbates rural-urban migration as farmers seek alternative livelihoods. Moreover, environmental degradation associated with improper farming techniques and climate-induced changes threatens the long-term sustainability of agriculture in the region (Chagwiza, 2020).

Evidently, the impact of temperature changes on rice yields in Ikwo represents a critical research area with far-reaching implications for food security and rural development in Nigeria. This study seeks to deepen understanding by examining this issue through localized analysis, and offer solutions to mitigate the adverse effects of climate variability on rice farming in the region.

II. REVIEW OF RELATED LITERATURE

Okonta and Nwagbo (2022) contributes to the ongoing discussion on climate change through a study aimed to provide insights into the practical steps farmers took to mitigate the effects of climate change on their agricultural practices and livelihoods. The study revealed that smallholder farmers in Enugu State were indeed adopting various adaptation strategies, including altering crop varieties, tree planting, and employing irrigation techniques. However, a significant finding was that, despite their efforts, these strategies were not always sufficient to fully counteract the negative consequences of climate change. This aligns with the broader narrative of climate change posing significant hurdles to agricultural production and livelihoods. One intriguing aspect of the study was its identification of factors influencing the likelihood of farmers adopting climate-smart agricultural practices. The research emphasized that farmers with access to resources and information, including training and credit facilities,

were more inclined to adopt such practices. Additionally, the study highlighted the role of community-based organizations in facilitating adoption, suggesting that collaborative efforts could enhance the efficacy of adaptation strategies.

The study by Okonta and Nwagbo presented an alternate perspective compared to the broader research body by showcasing instances where farmers successfully adapted to climate change, even enhancing their agricultural productivity. This underscores the intricacies of climate change impacts on Nigerian agriculture, indicating that outcomes are influenced by various contextual factors. However, it's important to note that, like other studies of its kind, the Okonta and Nwagbo (2022) study was a case study, limiting the extent to which its findings could be applied to the larger population of smallholder farmers in other states such as Ebonyi state.

Apata (2020) conducted an empirical analysis aimed to present the impacts of global warming on Nigerian agriculture and estimate the determinants of climate change adaptation. Data for the study were sourced from both secondary and primary sources. The research analyzed the 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 results indicated that if grain production does not keep pace with population growth in an unfavorable climatic environment, hunger-related deaths could increase.

Nwaka (2022) provided valuable insights into the effects of climate change on agricultural production and the livelihoods of rural households in Nigeria. The study utilized cross-sectional data to analyze the influence of climate change, revealing detrimental effects on both agricultural production and the well-being of rural households.

The research identified several manifestations of climate change impacts, including diminished crop yields, increased incidents of pests and diseases, and more frequent and severe occurrences of droughts and floods. These consequences, in turn, had a notable impact on food security and poverty levels in Nigeria. The study emphasized the vulnerability of smallholder farmers, who faced challenges due to restricted access to essential resources such as land, water, and credit. Additionally, their limited ability to adopt climate-resilient agricultural practices made them more prone to crop losses and food insecurity.

More so, Okoli and Okwuma (2022) in a study, which systematically reviewed existing data to investigate the impact of climate change on agricultural production and rural livelihoods in Nigeria, made a valuable contribution to the understanding of the challenges faced by rural households. The empirical review consistently highlighted the negative consequences of climate change on both agricultural production and the livelihoods of rural households in Nigeria. The study identified recurring effects, including decreased crop yields, increased occurrences of pests and diseases, and a higher frequency and intensity of droughts and floods. These combined impacts posed a significant threat to food security and exacerbated poverty issues in Nigeria's rural communities. The review also emphasized the heightened vulnerability of smallholder farmers, who faced challenges such as limited access to critical resources like land, water, and credit.

Okoli and Okwuma's study underscored the difficulties smallholder farmers encountered in adopting climate-smart agricultural practices, further worsening their vulnerability and increasing the likelihood of crop losses and food insecurity. The systematic review approach employed by the researchers enhances the credibility of their findings by ensuring a comprehensive evaluation of the available empirical evidence. The study contributes to the ongoing discussion by providing an empirical understanding of how climate change affects agricultural

production and rural livelihoods in Nigeria, shedding light on the challenges faced by rural households in the context of changing climate patterns.

Onyeneke, Umeh and Onyeneke (2023) assessed crop farmers' access and utilization of climate information services (CIS) and the impact of CIS on crop yields in Ebonyi State, Nigeria. The study selected 405 farmers from the state using a multi-stage sampling procedure, and data were collected through a questionnaire-based survey. The researchers utilized descriptive statistics, endogenous treatment effect, and Heckman probit selection model to analyze the collected data. The findings of the study revealed that a significant majority (89%) of the farmers had access to climate information, with agricultural extension officers, fellow farmers, and radio being the common sources of climate information. Moreover, 88% of the farmers were found to actively use climate information services in making their farming decisions.

While national-level studies on climate change and agriculture abound, localized studies focusing on Ikwo and its unique climatic, geographical, and socio-economic context are scarce. This gap in localized research limits the development of targeted interventions that could enhance resilience and productivity in this rice-dependent region. Although previous research has explored the broader relationship between climate change and rice production in Nigeria, significant gaps remain. Studies have predominantly focused on aggregated national data, overlooking localized dynamics critical for regions like Ikwo. For instance, Onyeneke et al. (2021) analyzed climate-smart agricultural practices across Ebonyi State but did not isolate the specific impacts of temperature changes in Ikwo.

III. METHODOLOGY

3.1 Research Design

This study adopted a quantitative research design to investigate the effects of temperature fluctuations on rice yield in Ikwo, Ebonyi State, Nigeria. The approach combined the analysis of long-term temperature data with insights gathered through a structured questionnaire survey, ensuring a comprehensive understanding of the issue. Monthly average temperature data for Ebonyi State from 1993 to 2023, sourced from the Nigerian Meteorological Agency (NiMet), provided a robust foundation for identifying trends and correlations in temperature changes over time. Additionally, a structured questionnaire was administered to a representative sample of rice farmers in the region, capturing their perceptions and experiences regarding the impact of temperature variations on rice cultivation. This dual approach facilitated the integration of objective climatic data with farmer-reported observations, enabling a nuanced analysis of both measurable trends and localized impacts on agricultural productivity.

3.2 Area of Study

Ikwo is one of the thirteen local government areas in Ebonyi State, Nigeria. It is situated in the Ebonyi Central Senatorial Zone and shares boundaries with Cross River State to the east, Ezza South Local Government Area to the west, Izzi Local Government Area to the north, and Onicha Local Government Area to the south. Geographically, Ikwo lies approximately between latitudes 5°40' and 6°45' north of the Equator and longitudes 7°30' and 8°30' east of the Greenwich Meridian (Okorie et al., 2020). Covering an area of about 500 square kilometers (Ani, Maxwell, and Ecoma, 2017), the region's hydrology and water resources are vital for its socio-economic growth and environmental sustainability. The area is primarily drained by the Cross River and its tributaries, which exhibit a dendritic drainage pattern in the lower courses and a parallel pattern in the upper courses (Onwe-Moses, Ozumba, and Chijiuka, 2020). These river systems play a crucial role in groundwater

recharge and ensuring surface water availability, supporting agricultural activities, domestic needs, and industrial processes in Ikwo.

3.3 Sample Size and Sampling Technique

The study focused on a population of 15,000 registered rice farmers in Ikwo Local Government Area, Ebonyi State. The sampling frame comprised a list of the registered farmers in each of the thirteen communities within the local government area. To determine the sample size, the Yamane Taro formula was utilized, as shown below:

$$n = \frac{N}{1 + N \times (e)^2} \quad (1)$$

In this equation, n represents the required sample size, N is the total population, and e denotes the margin of error, which was set at 5 percent for this study. Applying the formula, the calculated sample size was determined to be 390 rice farmers.

A multi-stage sampling technique was employed to select the participants. In the first stage, Bourley's sample size proportion allocation formula expressed in equation (2) was applied to allocate samples proportionally to each of the communities listed in the sampling frame.

$$n_b = \frac{n(h)}{N} \quad (2)$$

In this formula, n_b represents the sample proportion allocated to a specific community, n is the total sample size, h denotes the population of a specific community, and N is the overall population of the study.

Using this method, the required sample size for each of the thirteen communities was calculated proportionally based on their respective populations. Once the sample proportions were determined, the next stage involved employing a simple random sampling technique to select the specified number of rice farmers from each community, ensuring equal representation across all groups.

IV. RESULTS AND DISCUSSIONS

This section presents the key findings of the study, encompassing trends in average monthly temperatures and their implications for rice farming in the region. By analyzing both temperature data and farmer-reported insights, the results offer a comprehensive understanding of how temperature variability impacts critical aspects of rice cultivation, including growth cycles, productivity, and resilience to climatic stressors. These findings shed light on the interplay between climatic patterns and agricultural performance, highlighting the challenges posed by temperature fluctuations in rice farming.

4.1 Annual Average Minimum and Maximum Temperatures

Minimum and maximum monthly temperature data for Ebonyi State from 1993 to 2023 were analyzed to derive annual average minimum and maximum temperatures. These averages were further examined to identify trends and patterns over the study period. Figure 1 visualizes these findings, highlighting fluctuations in both minimum and maximum temperatures and revealing broader patterns of variation over time.

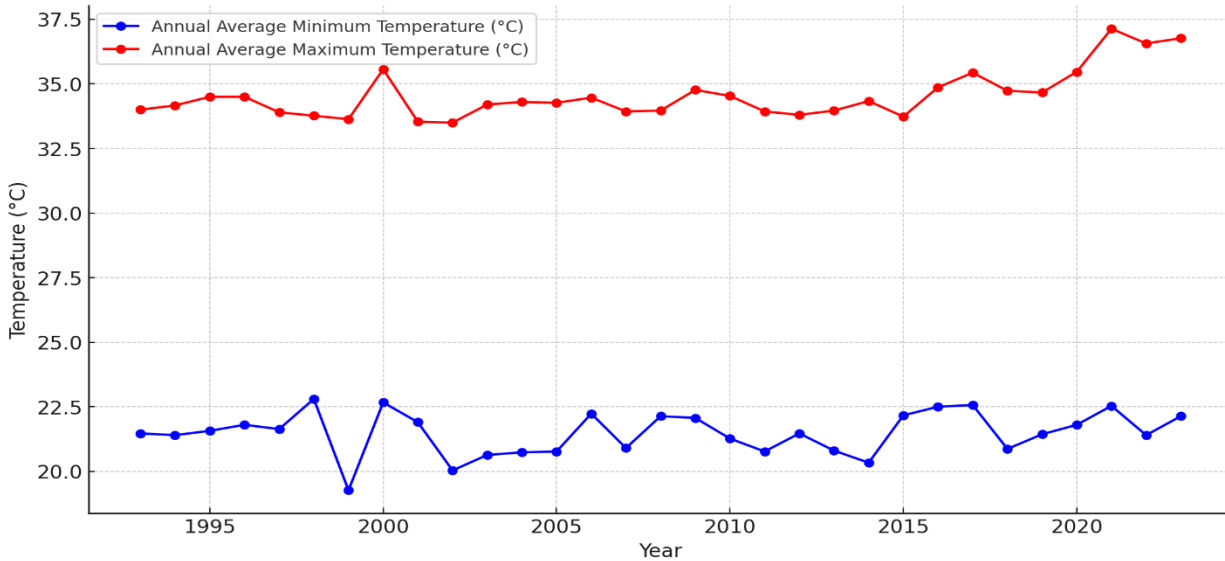


Figure 1: Annual average minimum and maximum temperature in Ebonyi state (1993-2023)

The analysis of temperature data from Ebonyi State between 1993 and 2023 indicates a gradual increase in both minimum and maximum temperatures. It shows that there is particularly a sharp rises in maximum temperatures in recent years, reaching levels above 36°C in 2021, 2022, and 2023. This trend suggests that climate change is leading to higher temperatures over time, which could be a disruptive factor for rice production in Ikwo LGA, Ebonyi State.

For rice farmers in the region, the increase in maximum temperatures presents significant challenges. High temperatures, especially during the critical flowering and grain-filling stages, can reduce rice yields by affecting grain formation and lowering grain quality. Rice plants are particularly sensitive to temperatures exceeding 35°C during flowering, which can lead to heat stress, sterility in the rice panicles, and reduced yield. Given that temperatures now frequently approach or exceed this threshold, rice farmers in Ikwo LGA are likely to face more frequent yield losses associated with heat stress. Moreover, the slight increase in minimum temperatures may also impact rice production. While warmer nights may lengthen the growing season, they also raise the respiration rates of rice plants, potentially reducing the net carbohydrate accumulation needed for optimal grain development. This effect, combined with the high daytime temperatures, could lead to an overall decrease in productivity and quality.

4.2 Extreme Temperature Days in Ebonyi State

Studies has shown that temperatures above 35°C is deteremental for rice growth as well as temperature below 20°C. Given this, the temperature of the study area over the years from 1993 to 2023 was analyzed to determine periods with temperatures in the extreme. The result is presented in Figure 2.

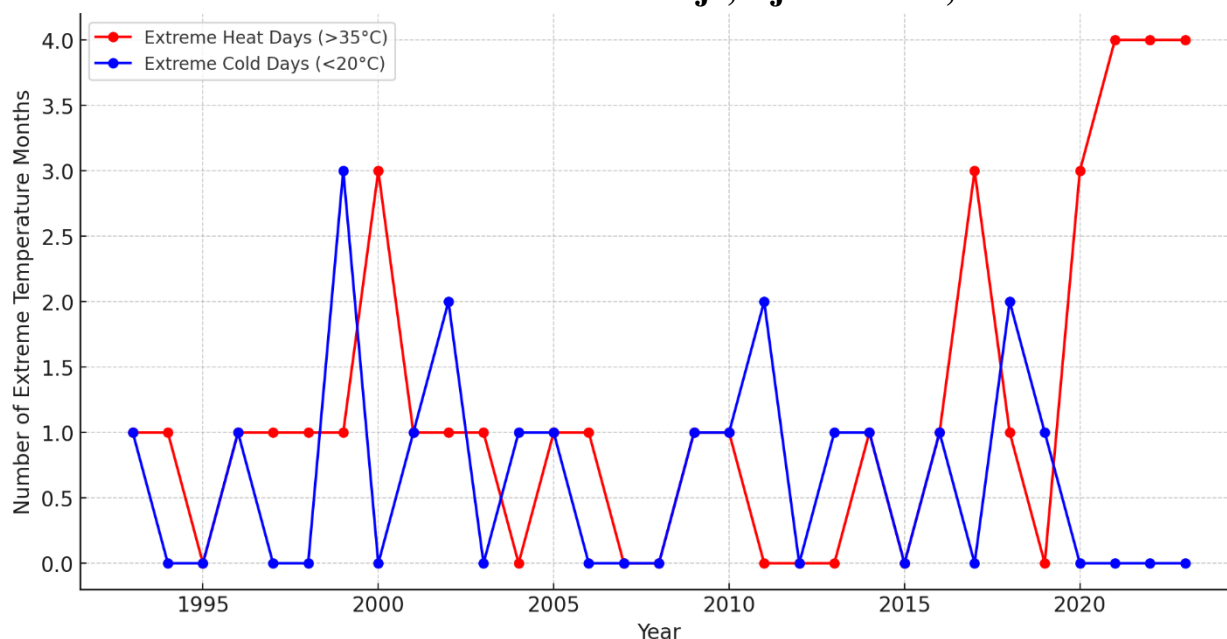


Figure 2: Frequency of Extreme Temperature days in Ebonyi state (1993-2023)

The extreme temperature events as visualised in the Figure 2 revealed critical insights that directly relate to rice crop performance in the region. The analysis identifies an upward trend in the frequency of months where maximum temperatures exceed 35°C, especially prominent in the last decade. For rice crops, temperatures above this threshold are associated with physiological stress that affects several key growth stages, including flowering and grain filling. Heat stress at flowering, which occurs when daytime temperatures exceed 35°C, can cause spikelet sterility. The occurrence of this problem ultimately reduces the number of viable grains and the overall yield. Additionally, sustained high temperatures during grain filling lead to accelerated maturation, which can result in smaller, less dense grains, further diminishing yield and quality.

Given the increase in extreme heat events, rice farmers in Ikwo LGA are experiencing more frequent and severe reductions in crop yield. This pattern reflects broader climate change impacts. Evidently, it signals that if current trends persist, these temperature extremes could disrupt the local agricultural calendar and challenge the viability of traditional rice varieties that may not be adapted to such conditions.

The trend also show a decline in the frequency of months with minimum temperatures below 20°C, indicating a reduction in extreme cold events over the years. While low nighttime temperatures can sometimes support rice plants by slowing down respiration and promoting carbohydrate storage in grains, extreme cold (below 20°C) may hinder early vegetative growth, affecting seedling establishment and vigor. However, with fewer cold events recorded in recent years, this aspect of climate change may have a limited but beneficial effect by reducing the likelihood of early-stage cold stress. Yet, any gains from reduced cold events are likely offset by the greater impact of heat stress on yield.

For rice farmers in Ikwo LGA, the increasing occurrence of extreme heat presents a major risk to rice yields. Farmers are likely experiencing yield losses more frequently as these heat events align with critical growth periods, especially during the reproductive phase. As such, adaptation strategies become imperative to mitigate these impacts. Farmers might need to consider adopting heat-tolerant rice varieties, which can withstand higher temperatures, or adjust planting times to avoid peak heat periods during sensitive growth phases. Furthermore,

introducing improved water management practices, such as keeping paddy fields adequately flooded, can help reduce the impact of heat stress on crops by maintaining cooler soil temperatures.

Summarily, the trend on extreme temperature events underscores the role of climate change as a disruptive factor in rice production in Ikwo LGA, Ebonyi State. The rise in extreme heat days represents a direct threat to crop yields, potentially destabilizing rice farming in the region unless adaptive measures are taken.

4.3 Field Survey Results

The survey component of this study sought to capture farmers' perspectives on the impact of temperature changes on rice cultivation in Ikwo, Ebonyi State. Out of the 390 questionnaires distributed, 358 were returned in a completed and usable form, representing a response rate of 91.8%. Consequently, the analysis and interpretation of the survey findings were based on these 358 valid responses. The response provided a reliable foundation for understanding the localized experiences of rice farmers and their perceptions of climatic variability's effects on agricultural productivity.

Table 1: Mean scores and standard deviations of participants on the impact of temperature changes on rice yield in Ikwo LGA, Ebonyi state, Nigeria

Item No	Item	SA (%)	A (%)	N (%)	D (%)	SD (%)	Total	Mean	Std. Dev.
1	Higher temperatures during the growing season negatively affect rice yields.	283 (79.1)	57 (15.9)	12 (3.4)	4 (1.1)	2 (0.6)	358	4.72	0.64
2	Prolonged high temperatures lead to increased water evaporation, reducing rice growth.	277 (77.4)	54 (15.1)	17 (4.7)	6 (1.7)	4 (1.1)	358	4.66	0.75
3	Increased temperatures cause heat stress in rice plants, leading to lower yields.	310 (86.6)	32 (8.9)	10 (2.8)	4 (1.1)	2 (0.6)	358	4.80	0.59

Item No	Item	SA (%)	A (%)	N (%)	D (%)	SD (%)	Total	Mean	Std. Dev.
4	Rice flowering and grain filling are adversely affected by high temperatures.	186 (52.0)	104 (29.1)	31 (8.7)	24 (6.7)	13 (3.6)	358	4.19	1.08
5	Variability in temperature during the growing season impacts rice crop development.	172 (48.0)	118 (33.0)	39 (10.9)	18 (5.0)	9 (2.5)	358	4.20	0.99
6	High nighttime temperatures reduce rice grain quality and yield.	134 (37.4)	116 (32.4)	57 (15.9)	33 (9.2)	18 (5.0)	358	3.88	1.16
7	Rice crops in Ikwo LGA are more susceptible to diseases due to rising temperatures.	153 (42.7)	119 (33.2)	39 (10.9)	31 (8.7)	16 (4.5)	358	4.01	1.14

8	Temperature fluctuations during critical growth stages reduce rice productivity.	253 (70.7)	77 (21.5)	18 (5.0)	8 (2.2)	2 (0.6)	358	4.59	0.74
9	Increased temperatures lead to higher pest infestations in rice fields.	147 (41.1)	129 (36.0)	38 (10.6)	26 (7.3)	18 (5.0)	358	4.01	1.12
10	Extreme temperature changes disrupt the planting schedule of rice in Ikwo LGA.	183 (51.1)	104 (29.1)	36 (10.1)	24 (6.7)	11 (3.1)	358	4.18	1.06
11	Higher temperatures require more irrigation for rice farming, affecting water resources.	236 (65.9)	81 (22.6)	21 (5.9)	12 (3.4)	8 (2.2)	358	4.47	0.92
12	The economic impact of temperature changes on rice farming in Ikwo LGA is significant.	226 (63.1)	78 (21.8)	21 (5.9)	14 (3.9)	19 (5.3)	358	4.34	1.10
Overall mean/ standard deviation								4.34	0.95

Evident from Table 1, the majority of participants agreed that higher temperatures during the growing season negatively affect rice yields. This item recorded a mean score of 4.72 and a standard deviation of 0.64, with 79.1 percent of respondents strongly agreeing and 15.9 percent agreeing. Similarly, prolonged high temperatures leading to increased water evaporation and reduced rice growth was strongly affirmed, with a mean score of 4.66 and a standard deviation of 0.75. The data showed that 77.4 percent of participants strongly agreed with this statement, while 15.1 percent agreed. The perception that increased temperatures cause heat stress in rice plants, thereby lowering yields, received the highest level of agreement as shown in Figure 3, with a mean score of 4.80 and a standard deviation of 0.59. A significant 86.6 percent of respondents strongly agreed with this view, while 8.9 percent agreed. Adverse effects of high temperatures on rice flowering and grain filling were also highlighted, with a mean score of 4.19 and a standard deviation of 1.08. Here, 52.0 percent of participants strongly agreed, and 29.1 percent agreed, reflecting notable concern.

Temperature variability during the growing season was identified as a key factor impacting rice crop development. This item had a mean score of 4.20 and a standard deviation of 0.99, with 48.0 percent strongly agreeing and 33.0 percent agreeing. High nighttime temperatures were perceived to reduce grain quality and yield, with a mean score of 3.88 and a standard deviation of 1.16. Although lower in agreement levels, 37.4 percent of participants strongly agreed, and 32.4 percent agreed.

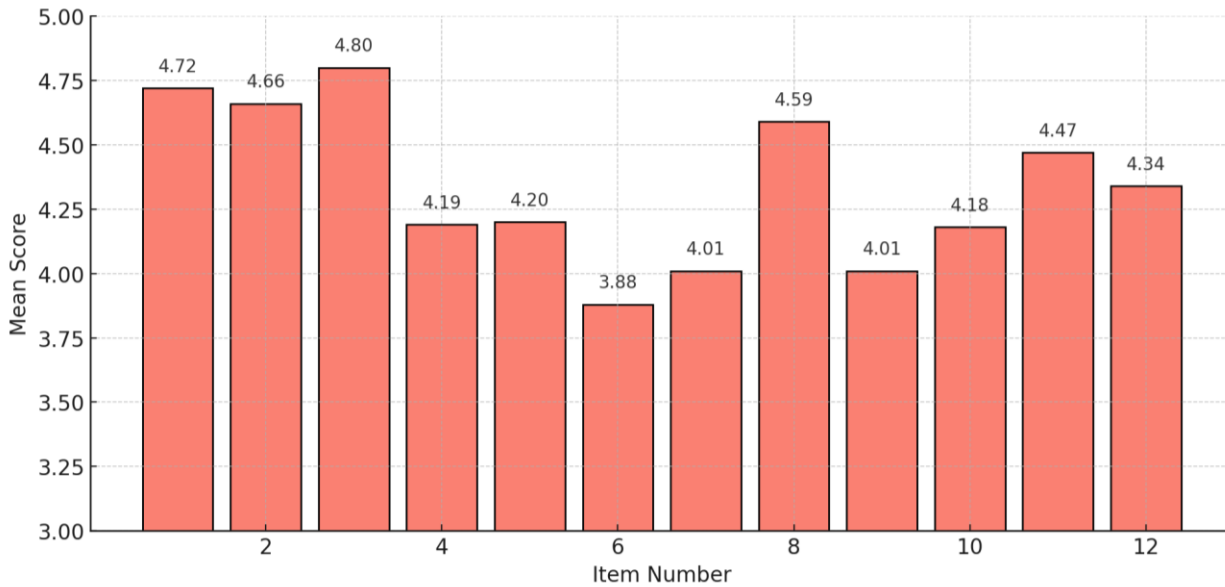


Figure 3: A bar chart showing the mean scores for each item on the impact of temperature changes on rice yield in Ikwo LGA, Ebonyi State

Participants expressed concerns that rising temperatures increase the susceptibility of rice crops to diseases. This item recorded a mean score of 4.01 and a standard deviation of 1.14, with 42.7 percent strongly agreeing and 33.2 percent agreeing. Temperature fluctuations during critical growth stages were identified as a significant cause of reduced rice productivity, achieving a mean score of 4.59 and a standard deviation of 0.74. A strong 70.7 percent of participants strongly agreed with this assertion, and 21.5 percent agreed. Increased temperatures were also seen as leading to higher pest infestations in rice fields. This item had a mean score of 4.01 and a standard deviation of 1.12, with 41.1 percent strongly agreeing and 36.0 percent agreeing. The disruption of planting schedules due to extreme temperature changes was emphasized, with a mean score of 4.18 and a standard deviation of 1.06. Fifty-one percent of respondents strongly agreed with this view, while 29.1 percent agreed. Lastly, participants highlighted that higher temperatures require increased irrigation, thereby straining water resources, with a mean score of 4.47 and a standard deviation of 0.92. A majority, amounting to 65.9 percent, strongly agreed with this sentiment, while 22.6 percent agreed. Furthermore, the economic impact of temperature changes on rice farming was perceived as significant, with a mean score of 4.34 and a standard deviation of 1.10. Sixty-three percent of participants strongly agreed, and 21.8 percent agreed with this view.

Conclusively, the results reflect a grand mean of 4.34 and a standard deviation of 0.95, indicating a widespread consensus among participants that temperature changes have profound and multifaceted impacts on rice farming in Ikwo LGA. This underscores the need for targeted adaptive measures to address these challenges effectively.

V. Conclusion

This study investigated the impact of temperature changes on rice yield in Ikwo, Ebonyi State, Nigeria, combining quantitative climatic data with insights from rice farmers. Key findings highlighted the significant role of temperature variability in influencing rice farming outcomes. The analysis of temperature trends revealed a consistent increase in both minimum and maximum temperatures over the study period, with extreme heat events becoming more frequent in recent years. These changes were linked to critical disruptions in rice growth cycles, particularly during flowering and grain-filling stages. Farmer-reported insights corroborated these findings, emphasizing that high temperatures lead to heat stress, increased water demand, and shifts in planting schedules,

all of which contribute to declining yields. Furthermore, temperature variability heightened the susceptibility of rice crops to pests, diseases, and environmental stress, compounding the challenges faced by farmers.

The implications of these findings are far-reaching, underscoring the vulnerability of rice farming in Ikwo to climate change. Adaptive measures such as the adoption of heat-resistant rice varieties, improved irrigation practices, and strategic shifts in farming schedules are imperative to safeguard agricultural productivity. These strategies are essential not only for sustaining rice yields but also for ensuring food security and the economic stability of the region's farming communities in the face of ongoing climatic changes.

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