

## **Assessment of Temperature Variability Effect on Rice Production in Nasarawa State, Nigeria**

**Oladeinde Stephen Olufemi<sup>1\*</sup>, Magaji I. Joshua<sup>2</sup> and Ekpo Abraham Salamatu<sup>3</sup>**

<sup>1</sup>*National Space Research and Development Agency (NASRDA -COPINE), Obafemi Awolowo University (OAU), Ile Ife, Osun State, Nigeria.*

<sup>2</sup>*Department of Geography, Faculty of Environmental Science, Nasarawa State University, Nasarawa State, Keffi, Nigeria.*

<sup>3</sup>*Department of Environmental Management, Faculty of Environmental Science, Nasarawa State University, Nasarawa State, Keffi, Nigeria.*

### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author OSO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MIJ managed the analyses of the study. Author EAS managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

The output of cereal farmlands is imperative for sustainable global food security. Quantity of production from cereal croplands are partly a function of climatic elements and are connected to the pulses of climatic variation. Hence, this paper assessed temperature variability effect on rice production in Nasarawa State, Nigeria. Daily maximum and minimum temperature data were obtained from the Nigerian Meteorological Agency and converted into monthly averages while annual rice production data was obtained from the office of Nasarawa State's Agricultural Development Programme. Acquired data were analysed using Linear Multiple Regression Model, coefficient of variation and spatial data analysis techniques. Although rice production in the State is being affected by the fluctuations in both minimum and maximum monthly temperature, the later poses grave concern for sustainability of rice production with a negative effect size of -3.145 and a coefficient value of -191,324.30 metric tons. This negative impact of maximum temperature

\*Corresponding author: E-mail: [femioladeinde@gmail.com](mailto:femioladeinde@gmail.com);

fluctuations on rice production indicates that rice production in Nasarawa State is vulnerable to climate variability with increasing maximum temperature. LGAs in the south senatorial district has more favourable locations for rice production in comparison to those in the North and West districts given that less temperature fluctuation was observed in the former. Government and non-governmental institutions as well as individuals planning to establish rice farm project(s) in the study area should consider doing so in the South Senatorial District in order to avoid the adverse effect of temperature variability.

*Keywords: Climate; variability; temperature; rice production; spatial vulnerability.*

## 1. INTRODUCTION

The output of cereal farmlands is imperative for sustainable global food security. In 2011 the cereal crops of maize, rice and wheat were ranked second, third and fourth respectively in terms of universal production of agricultural commodities and rice had the highest worldwide net production value [1]. Globally, croplands cover 12% of the terrestrial land surface and combined cropland and pasture now cover similar extend of land than forests and have already exhausted the best farmland [2,3]. The food security of large proportions of the world population depend on 'focal' regions of exhaustive cropping.

Rice in particular, is one of the major cereal crops to feed the world's growing population [4]. About 3 billion people consume rice daily. As one of the most common staple foods for humans, it feeds more people than any other crop [5]. In Nigeria, rice production is very important because it is the commonest staple diet of the Nigerian people. Rice production needs to increase to meet future population growth. Any decline in rice production through climate change and variability would thus critically impair food security in the country. Therefore, quantifying the effects of climate change on rice farming and assessing the potential of rice farmers to adapt to climate change are urgent research topics. The Food and Agriculture Organization (FAO) asserts that the level of Nigeria's self-sufficiency in cereals has been falling resulting in rapid growth in the amounts of cereals imports, especially rice imports, which increased 130 percent in 2001 over the previous five-year average [6].

Quantity of production from cereal croplands are partly a function of climatic elements and are connected to the pulses of climatic variation [7,8]. Variations in climate determinants or rise in climatic variation may possibly reduce levels of cereal crop production [8]. Universally, billions of people have been susceptible to productivity losses in some 'focal' cereal production systems.

This is revealed by the 2008 food price where the highest impacts on the poorest segment of society came from deficits in production and food price instabilities [9].

Climatic variability refers to the oscillation which occurs from year to year and the statistic of extreme situations such as severe rainstorms or abnormally hot seasons [10]. According to Christensen, et al. [11], climatic variability refers to spatio-temporal disparity in climatic situations beyond individual climatic events. Likewise, Houghton, et al. [12] also define climatic variability as changes in the mean condition and other statistical descriptions of extreme climatic conditions at all time and space scales further than individual climatic activities. Climate variability and the occurrence of extreme climatic events are of great importance in the African region. Agriculture has been exposed to various extreme meteorological events, for example, droughts, floods and temperatures increase every year with significant economic losses, as with Indian farmers [13].

Temperature is a vital parameter that limits the growth of plants and crops. Therefore, there seems to be some affiliation between temperature and yields from cultivation. High temperatures influence some crops and lead to reduced yields [14], which eventually affect food security. The study by Deressa and Hassan [15] shows that a slight upsurge in temperature in summer and winter has caused a decrease in crop yield and yield per hectare. Reducing farmers 'income and incomes has a significant impact on farmers' livelihoods and on some of the socio-economic roles they play in the family.

Also, Basak [16] used simulation model to investigate the influence of climate fluctuations and change in rice production in Bangladesh. A drastic reduction from 13.5 to 2.6% and from 28.7 to 0.11% was found harvest yield, if the maximum temperature increases by 2°C and 4°C respectively. Although the maximum and minimum temperatures give rise to reduced harvest yields, the model showed that higher

temperature effect on yield is higher than the effect of low temperature on yield.

According to Lobell, et al. [8], high climate variability represents a delicate balance between agricultural production and food security. Lobell also thinks that changes in agronomical relevant climatic variables (for example, rising temperatures and decreasing levels and rainfall distribution) are likely to reduce yields of rice, maize, and other cereals, in the semi-arid regions of the world. Particularly in developing countries, global climate variability is resulting to yield decline for most important crops [14].

A forward looking assessment by Parry et al., [17] of the effect of climate variability on four cereal crops (wheat, maize, soyabean and rice) using two different climate models revealed that India and Nigeria are the worst affected regions and will experience yield reductions of 2.5% and 5%, respectively, between 1990 and 2020. Impacts are expected to be generally more pessimistic by 2020, except for India, where the potential yield changes should be lower (between 0 and -2.5%). Losses are forecast to be slightly more widespread across sub-Saharan Africa.

Reports opined that increasing global temperature is likely to boost agricultural production in the temperate regions; it is expected to reduce yields in the tropical regions of the world [18]. It is projected that many African regions will suffer from drought and floods with greater frequency and intensity in the nearest future [19]. The report further suggested that the rise in average temperature between 1980/1999 and 2080/2099 would be in the range of 3-4°C across the entire African continent which is 1.5 times more than the global level. The report continued that Africa's Mediterranean region will experience a decrease in precipitations during the century. These dry conditions would affect the northern boundary of Sahara and West African coast where Nigeria lies.

Rain-fed agriculture remains the mainstay of the majority of households in Nigeria and Nasarawa State in particular, and is a significant sector in Nigeria's economy. The significance of the agricultural sector to Nigeria's economy cannot be overemphasized as it is a catalyst for food provision, contribution to the gross domestic product (GDP), provision of employment, provision of raw materials for agro-allied industries, and generation of foreign earnings. A sectoral analysis in 2006 of the real GDP indicated that the agricultural sector contributed to about 42 percent of the GDP compared with

41.2 percent in 2005 [20]. Over 60% of the Nigerian populace depends so much on agriculturally related activities for sustenance and crop production takes significant aspect of agricultural related activities in Nigeria. For instance, crop production contributes more than 80% of Agricultural GDP and more than 48% of total non-oil GDP in Nigeria [20]. Today, climate change and food insecurity are twin devils that have been identified as urgent world problems. This is because food security which is mainly from agriculture is threatened by the emergence of climate variability as agriculture serves as one of the sensitive sectors to this threat. Ayinde, et al. [21] opined that climatic fluctuation is putting Nigeria's agriculture system under serious threat and stress. This implies that rural sustenance and food security of the country is under serious threat as crop production takes significant aspect of agricultural activities in Nigeria.

In order to achieve related Sustainable Development Goals (goal 1-End poverty in all its forms everywhere; goal 2-End hunger, achieve food security and improved nutrition and promote sustainable agriculture; goal 8-Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; goal 12-Ensure sustainable consumption and production patterns and most of all, goal 13-Take urgent action to combat climate change and its impacts) at local and specific levels like in Nasarawa State, it has become imperative to assess the effect of climatic variability on such important cereal as rice for informed planning towards sustainable production.

## 2. MATERIALS AND METHODS

Nasarawa State is located in the basement complex of Nigeria's central between longitudes 6°45' 03" and 9°45'03" of the Greenwich, and latitude 7°45' 00' 'and 9°35' 00' ' of the Equator. The state has an area of approximately 26,385.04 square kilometers, and stands at an altitude of 400 meters above sea level. It shares geographic boundaries with Kaduna state in the north, Federal Capital Territory (FCT) in western part, Kogi and Benue, in the south, and Taraba and plateau to the east. The climate of Nasarawa State is typical of a tropical sub-humid climate having two distinctive seasons. The rainy season sets in from about the beginning of May and last until October. The dry season is experienced between November and April. The annual rainfall amount ranges between 1100 mm to roughly 2000 mm. About 90% of the rain in the State falls from May to September, with the highest

amounts being recorded in the months of July and August. High temperatures are generally recorded in the State during the day time, particularly between the months of March and April. The mean monthly temperatures in the State ranges between 20°C and 34°C [22].

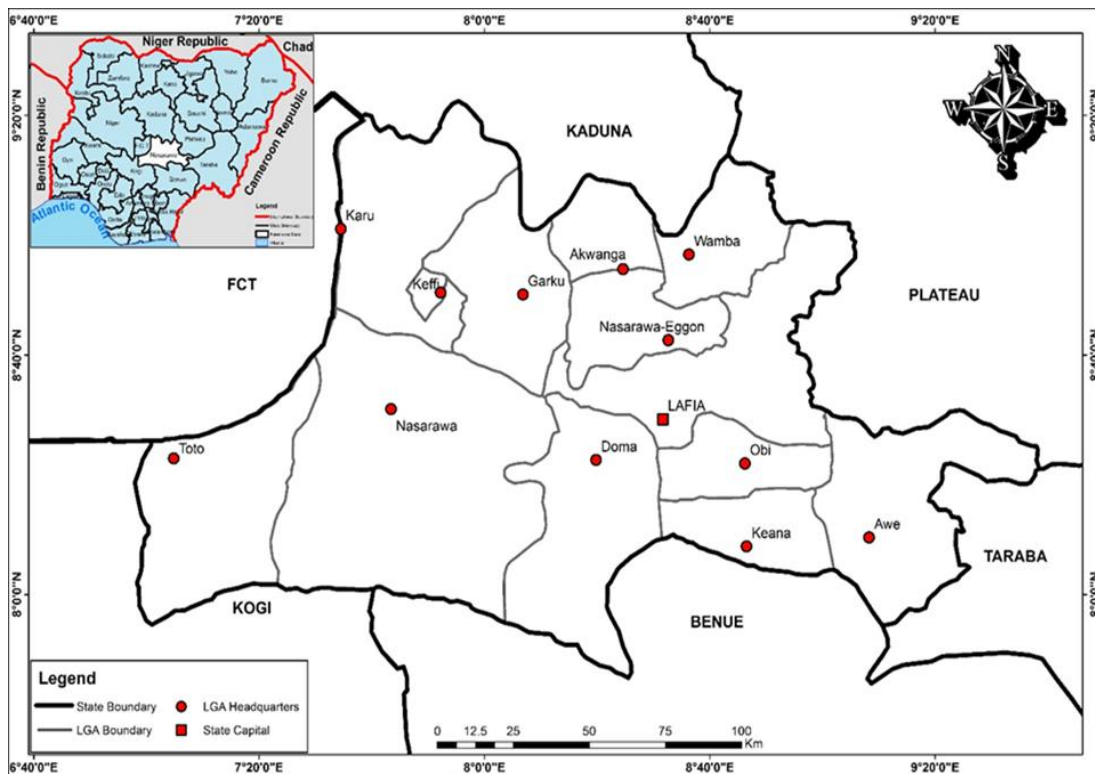
Daily records of maximum and minimum temperature for a period of 21 years (1997 – 2017) were obtained for Nasarawa State and specific locations (Local Government Area Headquarters) from the Nigerian Meteorological Agency (NiMET) and analysed for information. The 21 years' period was used because the State had only been that old and to also match with the available rice production data which was obtained from the Nasarawa Agricultural Development Programme (NADP), Lafia, Nasarawa State.

The acquired data was analysed using Microsoft Excel, Statistical Package for Social Sciences (SPSS, version 23) and ArcGIS 2.2. Descriptive (coefficient of variation), inferential (Linear multiple regression) and spatial

(interpolation) data analysis techniques were used to analyse the time series data of temperature and rice production so as to determine the effect of temperature variability on rice production as well as identify areas of high and low rice crop vulnerability to fluctuations in temperature. The daily maximum and minimum temperature data were converted to monthly averages using the AVERAGE-function in Microsoft Excel.

Coefficient of variation (CV) was used to determine both the inter annual variability of the maximum and minimum temperature. Although, there are many measures of variability, the two most widely used are the relative variability (that is the CV) and the standard deviation. Measurement of CV is the most efficient for this type of study [23] and has been widely used by other studies. Therefore, it was adopted and used in this study. It is a measure of dispersion given by:

$$\text{Co-efficient of variation} = (\text{Standard deviation} / \text{mean}) * 100.$$



**Fig. 1. Administrative map of Nasarawa State**  
 Source: Geography Department, Nasarawa State University, Keffi

The mean and the standard deviations of the climatic variables were first calculated, and then the co-efficient of variation determined as a percentage of the mean. The coefficient of variation (CV) is mathematically expressed as:

$$CV = \delta / \bar{x} \cdot 100 \quad (1)$$

Where  $\delta$  is the standard deviation, defined by:

$$\delta = \{\sum (x - \bar{x})^2\} / N \quad (2)$$

Where  $x$  is the value of a given variable for a given period,  $\bar{x}$  is the mean of the variable and  $N$  is number of the sample taken of the variable.

Multiple Linear Regression function of SPSS (version 23) was used to establish the relationship between temperature variability and rice production in the study area. The variance analysis (ANOVA) section was used to evaluate the significance of the regression model and standardized beta values and P-values used to evaluate the contribution of each independent variable. Variables with probabilities of 0.05 or less ( $P \leq 0.05$ ) were considered important, while those with higher probabilities ( $P \geq 0.05$ ) were regarded as insignificant. Confidence in multiple regression data for the study was determined by the adjusted co-efficient of determinant ( $AR^2$ ).

This analysis method operates on assumption that the relationship between one variable, dependent variable  $y$  and a host of all other variables  $x$ , (1, 2, 3, 4...n) called the independent variables, may be expressed by an equation of the form:

$$Y = b_0 + bx_1 + bx_2 \dots bx_n = \sum \quad (3)$$

Where

$y$  = dependent variable (Crop production)

$b_0$  = constant term

$b_1, 2$  = regression coefficient (each  $b$  represents the amount of change in  $Y$  (crop production) for one unit of change in the corresponding  $x$ -value when the other  $x$  values are held constant).

$x_1, 2..x_n$  = the independent variables (the climatic variables).

$\sum$  = error term that can enter the model

Prior to conducting the linear multiple regression, preliminary analyses were conducted to ensure there has been no violation of the assumptions underpinning regression analyses. The residual and scatter plots indicated that apart from the assumptions of normality, all other assumptions (linearity, homoscedasticity and multicollinearity)

were all satisfied. The collinearity statistics (Tolerance and Variance Inflation Factor-VIF) were all within the accepted limits. The Inverse Distribution Function (IDF) method of Data transformation given by Templeton [24] was used to normalize the rice production data.

Coefficient of variation (CV) in maximum temperature was also calculated for each point location of the 13 LGA headquarters in the study area. The calculated CV was imported into ArcGIS 2.2 desktop environment as XY data and linked with the study area's political boundary (polygon shapefile). Inverse Distance Weighted (IDW) interpolation technique was then performed to show spatial variability of maximum temperature. The degrees of rice vulnerability to the fluctuations of maximum temperature were categorized as: Highly vulnerable areas, vulnerable areas and marginally vulnerable areas. This categorization was based the spatial distribution of CV, the first three range of values were categorized as areas of relatively low vulnerability, the next three were for marginal vulnerability and the last three for high vulnerability.

Furthermore, LGAs that boosts the greatest opportunity for rice production and those that poses greatest threat with respect to variability of maximum temperature in the 21 years' period were identified. This was accomplished by subjecting the final vulnerability map to zonal analysis using the 'Tabulate Area' tool located in the ArcGIS Spatial Analyst toolbox. This operation was not performed for minimum temperature because; it was found to have positive significant relationship with rice production over the investigated period. Hence, its activities in the study area pose no threat to sustainable rice production.

### 3. RESULTS AND DISCUSSION

#### 3.1 Effect of Maximum and Minimum Temperature on Rice Production (1997-2017)

Table 1 shows that a combination of the variations in average monthly maximum and minimum temperatures accounted for 68.7% ( $R^2 = 0.687$ ) of the changes in Nasarawa State's rice production during the study period. Furthermore, average maximum temperature made the strongest contribution to explaining the variations in the State's rice production with a significant ( $p$ -value = 0.02) negative effect size of -3.145 and a coefficient value of -191324.30 which

**Table 1. Result of regression analysis for rice production and average monthly maximum and minimum temperature**

Model	Unstandardized coefficients		Standardized coefficient	T	Sig.
	B	Std. Error	Beta		
(Constant)	4171905.851	2540390.354	-	1.642	0.124
Average maximum temperature	-191324.298	72515.349	-3.145	-2.638	0.02*
Average minimum temperature	156736.523	40691.414	1.683	3.852	0.002**
R <sup>2</sup> = 0.687					

\*\*Coefficient is significant at 1% confidence level; \* Coefficient is significant at 5% confidence level

Source: Data analysis 2018

implies that every single unit increase that occurred in average maximum temperature during the period, resulted in annual rice production decline of 191,324.30 metric tons and vice-versa. Average monthly minimum temperature also had a significant (p-value = 0.002) effect on rice production in the study area but with a positive effect size of 1.683 and a coefficient value of 156,736.52. Hence every unit increase in this variable had contributed to an annual rice production increase of 156,736.52 metric tons.

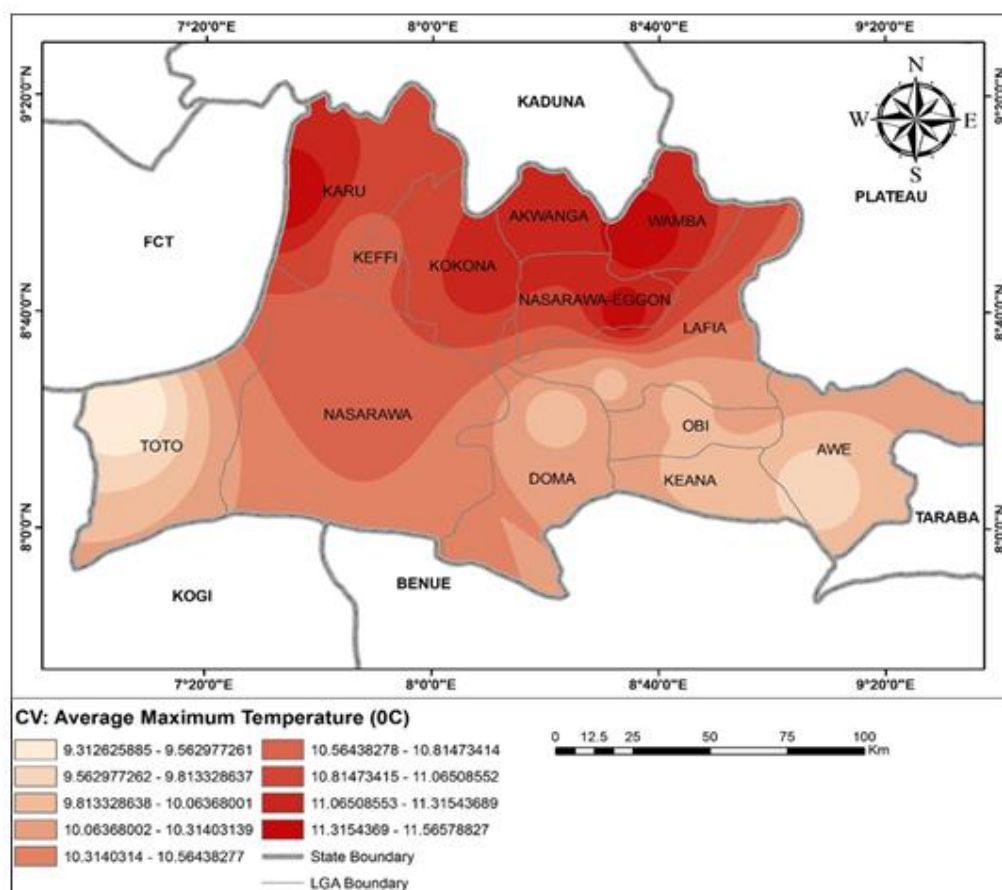
According to Prakash [25], increases in maximum temperature during the ripening phase of rice growth contribute to an increase in rice production up to a critical threshold of 29.9°C. When maximum temperature goes beyond this threshold, rice yield declines. In this study, the average maximum temperature for the period of 1997 to 2017 is was 31.94°C. Thus, this explains the observed decline in rice productions in the study area given that the production process must have been negatively affected by the fluctuations in the daily maximum temperature with a generally increasing pattern.

Additionally, Basak [16] studied the impact of climate variability and change on rice production in Bangladesh using the simulation model. The study showed a drastic reduction in crop yield from 13.5 to 2.6 percent and from 28.7 to 0.11 percent when the maximum temperature was increased by 2°C and 4°C. On effect size, the finding of this study agrees with Sarker et al., [26] who found that the effects of maximum temperature and minimum temperature are more pronounced as compared to rainfall. Also, Mahmood, et al. [27]; Peng, et al. [28] and Saseendran, et al. [29] all stated that an increase in maximum temperature and affects rice production.

### 3.2 Spatial Vulnerability of Rice Production to Maximum Temperature Variability (1997 – 2017)

Fig. 2 and 3 show the spatial variations in average maximum temperature and the locations where rice production in the study area is most and least vulnerable to maximum temperature variability. It was revealed that variability in average maximum temperature which ranged from 9.31% to 11.57% was mostly severe in the northern parts of Nasarawa State compared to the southern parts indicating areas of high vulnerability for rice production. Moving down south, the variability in maximum temperature was found to be less severe indicating merely vulnerable areas. Also, the fluctuations of maximum temperature created marginally vulnerable condition for rice production only in small areas of the north-western and southwestern parts of Toto and Awe LGAs respectively. This finding is in agreement with Souleymane, et al. [30] who spatially analyzed annual and monthly temperature variability in Senegal and found that the highest annual variability occurs in the north with greater negative effect on crops production, and the values decrease from northwest to southeast.

Table 2 shows the statistical summary of the rice production vulnerability map. It reveals that a total area of 167108.92 hectares in Nasarawa State was characterized by relatively minimal degree of variability in maximum temperature during the study period and was designated areas of marginal vulnerability for rice production in Nasarawa State. Most (64.67%) of the marginally vulnerable areas are situated in Toto LGA and Awe LGA (39.59%) followed by a 3.41% in Keana LGA.

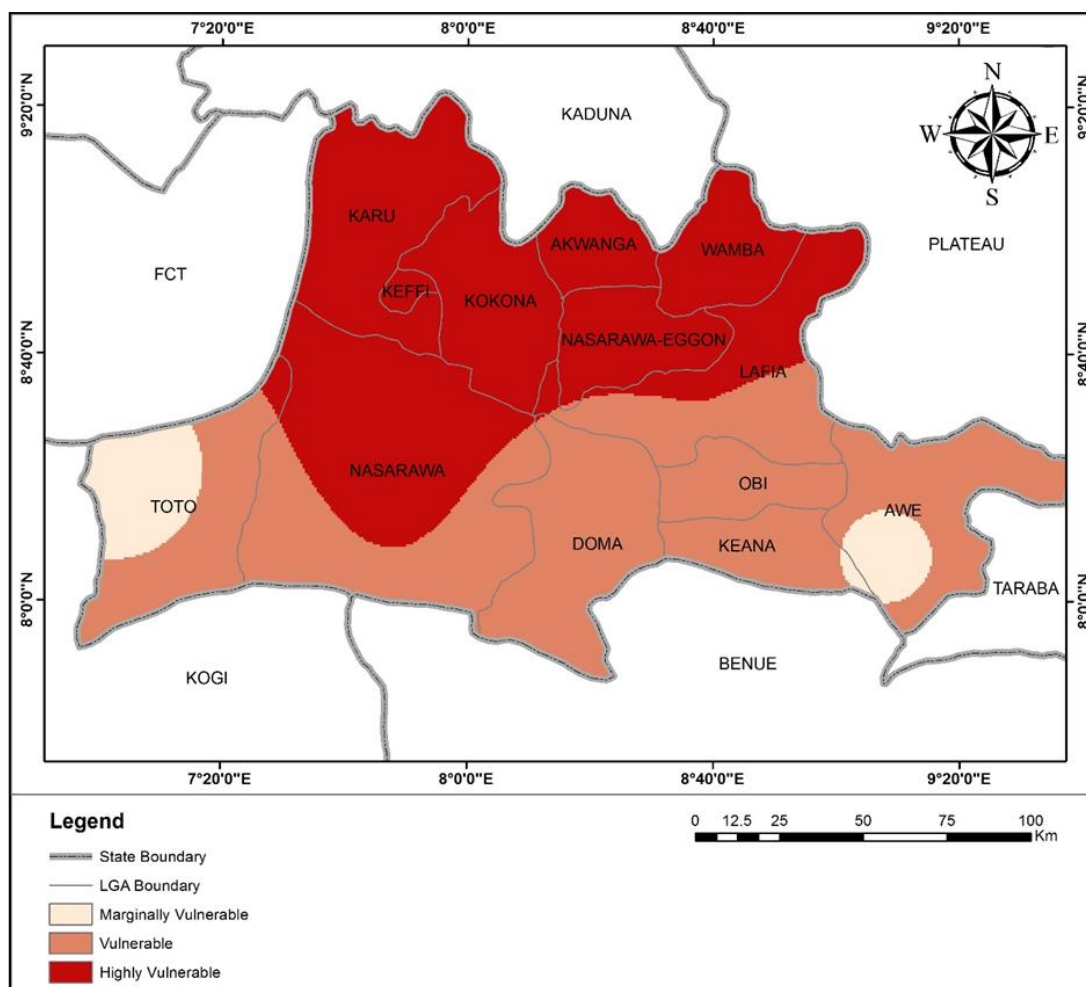


**Fig. 2. Spatial variation of average maximum temperature in Nasarawa State (1997 – 2017)**  
 Source: Spatial analysis of coefficient of variation derived from monthly temperature data

**Table 2. Statistical summary of spatial vulnerability of rice production in Nasarawa State**

LGA	Spatial vulnerability class: Area (percent %)					
	Marginally vulnerable		Vulnerable		Highly vulnerable	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
TOTO	108071.03	64.67	160373.05	13.34	10400.97	0.82
NASARAWA	0.00	0.00	256507.72	21.34	323222.51	25.59
DOMA	0.00	0.00	245116.19	20.39	643.87	0.05
KEANA	5695.77	3.41	100889.41	8.39	0.00	0.00
OBI	0.00	0.00	96134.68	8.00	0.00	0.00
AWE	53342.12	31.92	201630.23	16.78	0.00	0.00
KARU	0.00	0.00	0.00	0.00	267503.03	21.18
KEFFI	0.00	0.00	0.00	0.00	14759.47	1.17
KOKONA	0.00	0.00	0.00	0.00	183899.05	14.56
LAFIA	0.00	0.00	140660.73	11.70	135212.61	10.71
WAMBA	0.00	0.00	0.00	0.00	119908.32	9.49
AKWANGA	0.00	0.00	0.00	0.00	84445.97	6.69
NASARAWA-EGGON	0.00	0.00	544.81	0.05	122880.03	9.73
Total	167108.92	100	1201856.81	100	1262875.83	100

Source: Spatial (Zonal) analysis of the vulnerability map (2018)



**Fig. 3. Spatial vulnerability of rice production to variability in the average maximum temperature of Nasarawa State (1997 – 2017)**

Source: Spatial analysis of coefficient of variation derived from monthly temperature data

Furthermore, 1201856.81 hectares of the study area accounted for the places where rice production is considered vulnerable to climate variability due to significant degree of variations in monthly average temperature. Out of this, 21.34% was found to be situated in Nasarawa LGA, followed by 20.39% in Doma, 16.78% in Awe, 13.34% in Toto and 11.70% in Lafia LGA. Approximately 8% of Keana and Obi LGAs were characterized by vulnerable maximum temperature condition for rice farming during the investigated period of 21 years.

Highly vulnerable conditions for rice farming due to fluctuations of monthly average maximum temperature characterized as high as 1262875.83 hectares of Nasarawa State between 1997 and 2017. Areas characterized by this condition were most found in Nasarawa LGA

with a 25.59% share, followed by Karu (21.18%) and Kokona (14.46%) LGAs. Other locations where rice farming is expected to be highly vulnerable to fluctuation of maximum temperature include: Lafia (10.71%), Nasarawa-Eggon (9.73%), Wamba (9.49%), Akwanga (6.69%), Keffi (1.17%), Toto (0.82%) and Doma (0.05%).

#### 4. CONCLUSION

Crop-climate effect and vulnerability analysis provides an insight on how climate variability affects crops output and also helps to identify which climate parameter(s) creates vulnerable condition for crops production per time and the spatial locations that where the conditions are most and least felt. Variation in monthly temperature has continued to affect rice



production in Nasarawa State, although rice production in the State is being affected by the fluctuations of both minimum and maximum monthly temperature, the later poses grave concern for sustainability of rice production. This is because rice production was found to be negatively and significantly related to variations in monthly maximum temperature. Every single unit increase that occurred in maximum temperature, caused a decline in the State's annual rice production.

This negative impact of maximum temperature fluctuations on rice production indicates that rice production in Nasarawa State is vulnerable to climate variability with increasing maximum temperature. Places where rice production is mostly vulnerable to maximum temperature fluctuations in the study area include: Nasarawa, Karu, Kokona, Lafia, Nasarawa-Eggon, Wamba, Akwanga and Keffi LGAs, whereas places of least vulnerability are mostly found in Toto, Awe and Keana. Hence, the south senatorial district has more favourable locations for rice production in comparison to the North and West districts.

Agricultural Extension Officers (AEOs) should be deployed, particularly to the North Senatorial District and the North-Central parts of the West Senatorial District to guide farmers through routine visits and sensitization programmes on variability in maximum temperature; use of farm inputs and monitoring of crop-climate (temperature) relationship in order to achieve improved rice production. Also, government and non-governmental institutions as well as individuals planning to establish rice farm project(s) in the study area should consider doing so in the South Senatorial District in order to escape the adverse effect of temperature variability.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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