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Research Article

Assessment of Climate Variability and The Determinants of Rice Productivity in Southeastern Nigeria

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Abstract: The study assessed the variabilities in climate and key factors of rice production in southeastern Nigeria. Trend analysis and spatial interpolation expressed the spatiotemporal variabilities in the climate and rice yield. Copies of the questionnaire were used to assess four hundred and eighty farm households from 12 local government areas. Other analyses included descriptive statistics, logistic regression, and Productivity Index. The farmers' socioeconomic characteristics show that the majority (62% of them are young males aged between 30-39 years. Over 80% of them were married while about 72% has household sizes between 5-9 persons. A greater proportion (54%) of them generate between N240,000.00 (578 USD) to N480,000.00 (1156 USD) annually. About 96 % have a farming experience above 10 years, while 50% have basic education (primary education). Logistic regression shows that sex (0.02), category of the farmer (0.00), age (0.03) (0.00), educational qualification (0.02) (0.00), membership of cooperative society (0.00), extension workers' visit (0.03) were the statistically significant determinants of rice productivity in the area. The area experiences significant rising temperatures and declining rainfall. This trend is more obvious in Ebonyi state. Study results acknowledge the necessity of an enabling environment for rice farming through adequate rural infrastructure, improved rice varieties, access to information, and improved government policies, programs, and interventions to accommodate non-ADP rural rice farmers in order to enhance rice production against the unwanted climate changes

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1. Introduction

Rice (*Oryza sativa)* is a major staple food across West Africa (Nosiru et al., 2014; Niang et al., 2017 and 2018). Its importance notwithstanding, local production often lags behind the demand (GATSBY, 2014; Niang et al., 2017 and 2018). Rice demand is increasing sharply in Nigeria due to rising population, urbanization, relative ease of preparation, affordability, and ease of storage (Uga et al., 2013). Additionally, rice is widely consumed across all cultures, ethnic groups, or diverse geographical regions. It is highly priced and widely accepted as food during festivities (Basorun, 2013). Thus, sustainable production of rice is key to ensuring an adequate supply of rice to the teeming Nigerian population.

However, in recent years, rice production is declining. Accordingly, the price increased beyond what the average Nigerian can afford (Ajala and Gana, 2015). Due to the shortfall in supply, the country has depended heavily on rice importation (Okeowo, 2016; Obisesan, 2019). The import gulps up to $800 million of scarce foreign exchange (Ojogho and Alufohai, 2013). To boost local rice production and shore up the foreign reserve, a 75% hike in tariff was slammed on rice importation by the Nigerian Government. The policy reinvigorated interest in domestic rice production and research with the attendant rise in demand for local rice (Onyekwena, 2016; Ugalahi et al., 2016). However, rice supply still lags behind its demand (Talpur et al., 2011; GATSBY, 2014; FAOSTAT, 2015; Okeowo, 2016; Obisesan, 2019).

Additionally, to boost rice production and other food crops, the current administration launched the Agricultural Promotion Policy (APP) with an emphasis on boosting food production to ensure a food-secure Nigeria (FMARD, 2016; Ojong and Anam, 2018). This initiative also called the Green Alternative (Hendriks, 2018), is to leverage the successes of the Agricultural Transformation Agenda (ATA) that preceded the National Economic Empowerment and Development Strategy (NEEDS) (Smith, 2018). It aims to reposition agriculture as a business, food as a human right, and agriculture as critical to long-term economic growth and security (FMARD, 2016; Ojong and Anam, 2018). This is in line with the ECOWAS Agricultural Policy and the Comprehensive Africa Agricultural Development Program (ECOWAP/CAADP) that aims to increase yield including making the agricultural sector more attractive and competitive (Nwozor and Olanrewaju, 2020). The initiatives aim to create jobs and stem the tide of alarming food insecurity in Africa according to FAO (FAO et al., 2019). It will fast-track the attainment of SDGs target of eradicating hunger by 2030. Thus, to complement the government's action, research is key to finding solutions (Bennett, 2014; Mogga et al., 2019).

Thus, the above issues amongst others peculiar to rice farmers reinforce the need to assess the determinants of rice production from a geosocial perspective. It has been reported that labour hours, urea fertilizers, and irrigation significantly bolster rice yield in Pakistan (Ali et al., 2022) Some authors have cited factors that militate against rice productivity to include poor infrastructure, insufficient or unavailability of irrigation facilities, unavailability of high yielding varieties, unreliable rainfall, importation as well as difficulty in sourcing machinery and funding (Ita et al., 2013; Kadiri et al., 2014; Koirala et al., 2014; Onyekwena, 2016; Tanko et al., 2016; Adenuga et al., 2016; Ugalahi et al., 2016; Niang et al., 2017; Mogga et al., 2019; Hayat et al., 2020).

Further, curtailing farmer-herdsmen conflict and technological capacity building for rice farmers will boost productivity (Obi-Egbedi et al., 2012). There has been an appreciable increase in rice production from 2010 to 2019 but it is disproportionate to local demand (Okeowo, 2016; Onyekwena, 2016; Olasehinde et al., 2022). This is because most of rice farmers operate below their optimal potential (Obianefo et al., 2020 and 2021). The demand for rice has been rising at a fast rate of 10.3% annually (Maji et al., 2015) which is more than its supply. This increase in rice production has been at the expense of extensive land use rather than intensification of production. Yet agricultural intensification is advocated in recent years to curtail the impact of climate change (Foley et al., 2011; Talpur et al., 2011). Also, Nigeria has failed to attain self-sufficiency in rice production despite increased land size put into use (Kim et al., 2017).

Therefore, it has been suggested that an upgrade to/of irrigation will significantly boost rice production (Ugalahi et al., 2016). Diagne et al. (2013) highlighted the significance of improving extension services, weed, and pest control in addition to intensification. While water availability/irrigation, labour, capital, rice prices, fertilizer, and acreage are positively correlated with rice yield (Shaikh et al., 2016; Kamal Jan and Khan, 2019), the temperature was reported to have a negative correlation (Mech, 2017). Labour, irrigation, and hybrid seeds/quantity of seeds have a constructive impact on the technical efficiency of rice farmers (Balogun et al. 2021) but experience and tenure status have a negative impact on technical efficiency in a study carried out in the Indo-Gangetic plains(Chandel et al., 2022). Interannual variations in rainfall and spatial variations in soil moisture content affect rice yield (Niang et al., 2018). Rice farmers' technical efficiency is affected by irrigation, production techniques, and the amount of agricultural supporting staff in Cambodia (Kea et al., 2016). However, Ara et al. (2016) find that irrigation has a stronger influence on rice yield than climatic conditions such that rainfall and temperature have negative impacts on yield. Nosiru et al. (2014) found farmers' age to have a negative influence on total productivity. Furthermore, climate change influences rice yield (Sarker et al., 2013; Akanbi et al., 2022; Heriansyah et al. 2022). The extent of per capita land area of rice harvested rather than yield per hectare is the key determinant of rice production in Southeast Asia (Dawe, 2013).

Furthermore, in Nigeria, Kadiri et al (2014) examined the determinants of sustainable rice growth and yield in the Niger Delta region of the country. Omofonmwan and Kadiri (2007) examined the problems and prospects of rice production in the Central District of Edo State, Nigeria, focusing mainly on farming systems and practices. Onyeneke (2017) assessed the determining factors for adopting improved technologies by rice farmers in Imo State which are contact with extension workers, age, income, cooperative membership, size of household, and education level. Cooperative marketing via membership of a cooperative society is boost to farmers' income. A similar study was done in southwestern Nigeria where farm size cultivated, frequency of extension contacts, and yield ratings of improved varieties are the key factors for adoption (Saka and Lawal, 2009). Climate change affects rice farmers and thus, it is advocated that capacity building at the farm level which is key to improving crop, soil, and water management be provided with an expansion of irrigation and effective extension service delivery (Akanbi et al., 2022). Pest infestation and difficulties of finance are the major constraints for rice farmers in Ekiti State, Nigeria (Osanyinlusi and Adenegan, 2016). However, only very little research exists that provides information on the determinants of rice production and the variabilities of climate in the southeastern region of Nigeria.

Yet, the region has notable floodplains for rice production. It has one of the fastest rates of urbanization and population growth in Nigeria which requires increased food availability. Hence, the research assessed the determinants of rice production on a regional scale via the following objectives: (i) to investigate the climate variabilities of the region (ii) to assess the socio-economic characteristics of rice farmers, and (iii) spatio-temporal appraisal of the key factors of rice production across the region. This permitted the advance of recommendations to boost production that will help in achieving food security in Nigeria and attainment of the SDG's goal of total eradication of hunger by 2030.

2. Materials and Methods

2.1. Study location

Southeastern Nigeria comprises five States; Abia, Anambra, Ebonyi, Enugu, and Imo. Nigeria has six geo-political zones which southeast is one of them. The geographical location of the region is shown in Figure 1. It shares a border to the north with Benue and Kogi States, to the south with Rivers State, to the east with Akwa-Ibom and Cross River States, and to the west, it is bounded by Delta State (Figure 1).

The relief of the study area can be broadly classified into lowlands regions and escarpments (Ofomata, 1975 and 2002). The lowlands comprise areas with heights less than 350 meters above mean sea level comprising the River Niger-Anambra plains and the undulating lowlands of the Bende-Ameke-Umuahia axis. The escarpments rise to heights above 350 meters above mean sea level and comprise the Nsukka-Okigwe and Awka-Orlu uplands (Ofomata, 2002).

The climate of the area is the tropical rainforest of the Koppen's classification (Koppen, 1936) with a long wet season and a short dry season. The rainy season lasts for about 8 to 9 months with a mean rainfall of 1800 to 2300mm per annum. The study area has a more humid climate in the south than in the northern part, which is almost a transition zone between the Rainforest and the Savanna climates. The northern part of the area has a derived savannah but the southern lowland area has rainforest in the south. The northern part has the derived Savanna due to human influence that has drastically altered its rainforest vegetation and now composed of a secondary forest/regrowth that resembles the Guinea Savanna region. The study area had a population of 16.4 million persons in 2006 (FGN, 2006), which was projected to be 30.61 million persons in 2022.

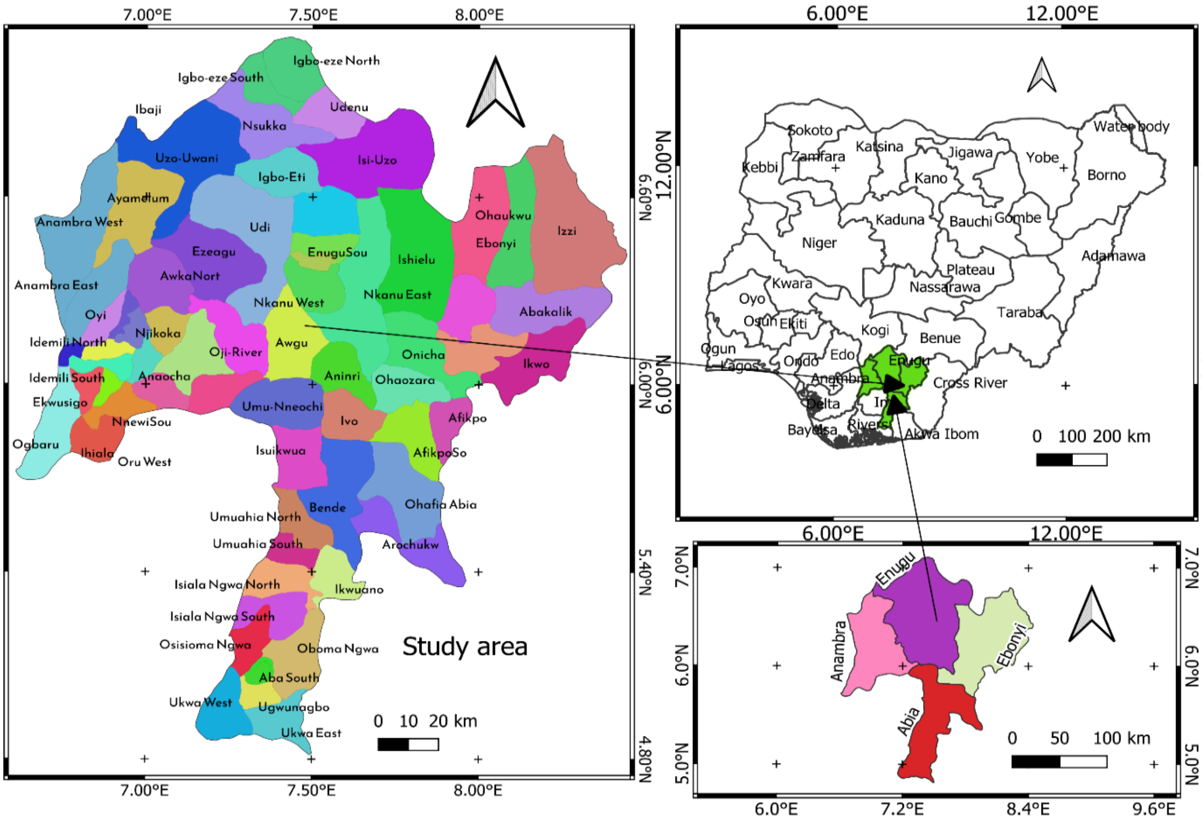

Figure 1. The study area.

2.2. The study and sample sizes

The rice farmers in the study area constitute the sampling frame. The study employed a multi-stage sampling to select the States, Local councils, and communities. The farmers' households were selected in the following ways: Four States comprising Abia, Anambra, Enugu, and Ebonyi. Purposive sampling was used to select those dominant rice-producing States in the region (Figure 4). Three Local council areas were purposively selected from each of the States because the pilot field study reveal they are the major rice growing areas in the zone. Twenty farmers' households from two communities were sampled from the selected 12 Local Government Areas, who are involved in rice production (i.e. 40 farmers' households per local council) totaling 480 households. The same number of respondents were selected from each of the sampled locations to achieve equity and fair representation from each local council.

2.3. Data collection

Two data sources were utilized in the study. The secondary data comprise historical rainfall and temperature data from 1991 to 2021 accessed from the National Aeronautics and Space Administration (NASA) (NASA, 2020) at https://power.larc.nasa.gov/data-access-viewer/. The data are freely acquired from the website that comprises high-resolution daily climatologic data on 0.5^{O} by 0.625^{O} horizontal resolution. The attributes of the data points were displayed in Table 1 and were used to assess climate variability in the region as a key determinant of rice production.

2.3.1. Household data collection

The data for the reliability test were collected by the authors and the internal consistency of the instrument was determined using Cronbach alpha (α) reliability co-efficient. The Cronbach alpha reliability coefficient was chosen because the questionnaire items were major of the multiple response types which gives a more suitable measure of homogeneity (Ezeh, 2005). The result showed that the instrument had an internal consistency of 0.79 which was considered high and reliable based on Emeka's (2009) decision, and could be useful in collecting data for the study.

The household data were principally from primary sources using copies of the questionnaire. The Agricultural Development Programme (ADP) is a program to assist farmers by the authority. Those who do not register with them are non-ADP farmers. They were specifically included in the research as a disadvantaged group and are also larger in number than the ADP farmers. It is an attempt to let their voices heard so that the concerned authority may make policy interventions and programs to accommodate them. Unlike the non-ADP farmers, the ADP farmers are registered rural farmers whose government has their database. They attend government programs for farmers and access all government interventions in agriculture. It also enabled us to find a distinction between the two groups in their output. ADP farmers are supported by the government in terms of soft loans and access to some farm inputs.

The data generated from the questionnaire were used in the analysis to determine the key factors of rice production in southeastern Nigeria. The studied variables were presented in Table 1.

Table 1. Variables studied

Determinants of rice production.	• Household size • Annual income • Sex • Category of farmer • Age • Educational attainment • Membership of cooperative society • Extension workers' visit

The data were standardized with the use of standard error estimate of the regression such as the standard deviation. The characteristics of the sample locations were presented in Table 2.

Table 2. The characteristic of the sample locations

Location	State	Latitude	Longitude	Height (m) asl
Abakaliki	Ebonyi	6.335	8.133	88.4
Awka	Anambra	6.220	7.061	103.94
Enugu	Enugu	6.444	7.490	151.33
Umuahia	Abia	5.542	7.506	92.75

2.4. Data analysis

2.4.1. Trend analysis

The study applied the Mann-Kendall test statistic to investigate the nature of the trend that exists in the data. It is a non-parametric test that is commonly applied for detecting monotonic trends in environmental and hydroclimatic data series (Hamed, 2011, 2009; Hamed and Rao, 1998; Önöz and Bayazit, 2012; Pohlert, 2020; Endale et al., 2021). The test requires the position of a null hypothesis which often is stated thus: "That the data are from a population that have independent realizations and are identically distributed which imply no trend exists within them". However, the alternate hypothesis posits the existence of a monotonic trend in the data. The test statistic is expressed as shown in equation 1 (Mann, 1945; Kendall, 1975; Pohlert, 2020)

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(X_j - X_k\right) \quad (1)$$

where $$\mathrm{sgn} = \begin{cases} 1 & if \quad x > 0 \\ 0 & if \quad x = 0 \\ -1 & if \quad x < 0 \end{cases} \tag{2}$$

Hence, the mean of S is $E[S] = 0$ with the variance σ^2 as shown in eq. 3

$$\sigma^2 = \left\{ n(n-1)(2n+5) - \sum_{j=1}^{p} t_j (t_j - 1)(2t_j + 5) \right\} \Big/ 18 \tag{3}$$

where p represents the number of tied groups in the series, t_j stands for the number of data points in the j^th tied group (Pohlert, 2020). For a long data distribution, the S statistic is nearly normally distributed following the Z-transformation (eq. 4).

$$Z = \begin{cases} \dfrac{s-1}{\sigma} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \dfrac{s+1}{\sigma} & if \quad S < 0 \end{cases} \tag{4}$$

The S statistic has a close relationship with the Kendall's tau given as

$$\tau = \frac{S}{D} \tag{5}$$

where

$$D = \left[\frac{1}{2} n(n-1) - \frac{1}{2} \sum_{j=1}^{p} t_j (t_j - 1) \right]^{1/2} \left[\frac{1}{2} n(n-1) \right]^{1/2} \tag{6}$$

To obtain the trend following the above method, the study applied the trend package (Pohlert 2020) and due to the autocorrelation that exists in the data sets, the modified Mann-Kendall test was invoked utilizing the modified Mann-Kendall (modified mk) package (Hamed, 2011; Storch, 1999; Yue and Wang, 2004; Önöz and Bayazit, 2012; Patakamuri et al., 2021). Therefore, the pre-whitened Mann Kendall (pw mk) and (bbs mk) functions were used (Hirsch et al., 1982; Khaliq et al., 2009; Önöz and Bayazit, 2012; Patakamuri et al., 2021).

2.4.2. Descriptive statistics

The distribution of the rainfall and temperature in those selected stations was described with charts and graphs. The simple statistics also helped to reveal the spatiotemporal variations in their distribution. However, interpolation was employed to show the spatial variations in rainfall and temperature over the area in Quantum Geographic Information System (QGIS).

Furthermore, descriptive statistics were utilized to assess the socio-economic attributes of rice farmers in all the States in the region, and the obtained results were shown in bar charts. The productivity Index was used to determine rice yield in the previous growing seasons. They were analyzed using the STATA software version 12. All analyses were done at 0.05 level of significance.

2.4.3. Productivity index

The productivity index was employed to estimate rice productivity in the 2019 farming season. It was limited to 2019 due paucity of data on rice productivity and the inability of the farmers to recall distant past records. The productivity of the farmers was assessed using a productivity index (P1) (eq. 7). The index is vital for comparing and assessing outputs among farmers across different locations. This is because it considers not the total output but rather takes into consideration the output per hectare.

$$P_i = {}^{Y}\!/_{A} \quad (7)$$

where P1 is the productivity index, Y of the yield or output of the ith farmer in kilograms and A is the Area of farmland cultivated in hectares.

2.4.4. Logistic regression analysis

The binary logistic Regression Analysis model was used to find the key determinants of rice production in the study area. We recorded the productivity variable into high productivity (1) and low productivity (0) to become the dependent variable. Following Ekesiobi et al. (2018), we specify the binary logistic regression model to reflect the dichotomous of a rice farmer having high productivity or not as follows (eq 8):

$$\text{Logit}p_x = \log[\frac{P(Y=1)}{1-P(Y=1)}] = \sum_{k=1}^{k} \alpha_k X_k \quad \ldots\ldots\ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots (8)$$

Equation eight shows that there is a linear relationship between the logitp_x and the vectors of explanatory variables X. Therefore, the study can state the probability of a rice farmer having high output as thus;

$$\Pr(Y=1) = \frac{\sum_{e^{k=1}}^{k} \alpha_k X_k}{\sum_{e^{k=1}}^{k} \alpha_k x_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Whereas the probability of not having high output (which is 1 minus the probability of having high output) is specified thus:

$$\Pr(Y = 0) = \frac{1}{\sum_{e^{k=1}}^{k} \alpha_k X_k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Equations 8 to 10 show the binary nature of the dependent variable which is the rice farmer recording high output categorized as 1 and not recording high output categorized as 0. The final model for the determinants of a rice farmer recording high yield or not is specified below as equation (11);

$$\text{Logit}(P) = \ln[\frac{P}{1-p}] = \propto_0 + x\beta_1 + x\beta_2 + x\beta_3 + \ldots\ldots\ldots\ldots + x\beta_n + \varepsilon \quad \ldots\ldots\ldots \ldots\ldots (11)$$

The choice of the method was based on the nature of the dependent and independent variables. Firstly, the dependent variable was binary in nature so can be best analyzed using a binary probability model. Secondly, the independent variables were majorly nominal which doesn't produce coherent and reliable results if regressed using OLS regression. The descriptive statistics of the variables in the model were represented in Table 3.

Table 3. Descriptive Statistics for the Variables in the model

Response Options	Frequencies	Percentages
Rice productivity by farmers		
Low	242	50.42
High	238	49.58
Household size of farmer		
0 to 4 household members	60	12.50
5 to 9 household members	320	66.67
Above 9 household members	100	20.83
Monthly income of farmer		
Below N20,000	48	10.00
N20,000 to N40,000	257	53.54
Above N40,000	175	36.46
Sex of farmer		
Male	297	61.88
Female	183	38.12
Category of farmer		
ADP farmer	98	20.42
Non ADP farmer	382	79.58
Age of farmer		
20 to 29 years	86	17.92
30 to 39 years	271	56.46
Above 39 years	123	25.62
Highest completed education of the farmer		
FSLC	241	50.21
SSCE	167	34.79
First Degree and above	28	5.83
Others	44	9.17
Membership of cooperative society		
No	182	37.92
Yes	298	62.08
Number of extension visits		
Once	69	14.38
Twice	182	37.92
More than twice	46	9.58
None	183	38.12

From the descriptive statistics in Table 3, rice farmers had approximately 50% low rice productivity and 50% high rice productivity. A majority (67%) of the respondents have a household size of 5-9 persons, and 54% make #20,000 to #40,000 Naira monthly income. A greater proportion (62%) of the farmers were males, 80% were non-ADP farmers, 56% were aged 30-39 years, 50% had FSLC and 62% were members of cooperative society, 38% had no extension visits and another 38% had extension visits twice.

3. Results and Discussion

3.1. Rainfall and temperature distribution

The rainfall and temperature distribution vary slightly across the study area. There is higher rainfall in the southern part of the study area comprising Abia, the southern part of Anambra, and some parts of Ebonyi State (Figure 2). The temperature distribution is nearly similar to that of the rainfall with higher temperatures in the southern and eastern parts of the study area. This concurs with the fact that rainfall decreases as one moves hinterland away from the southern coast of the country holds here (Odekunle and Adejuwon, 2007; Ezeh et al., 2016). Similarly, the lower temperatures in the north-central part of the study area could be attributed to the moderating effect of the higher plateau over there exemplified by the Udi-Okigwe-Awka-Orlu escarpment.

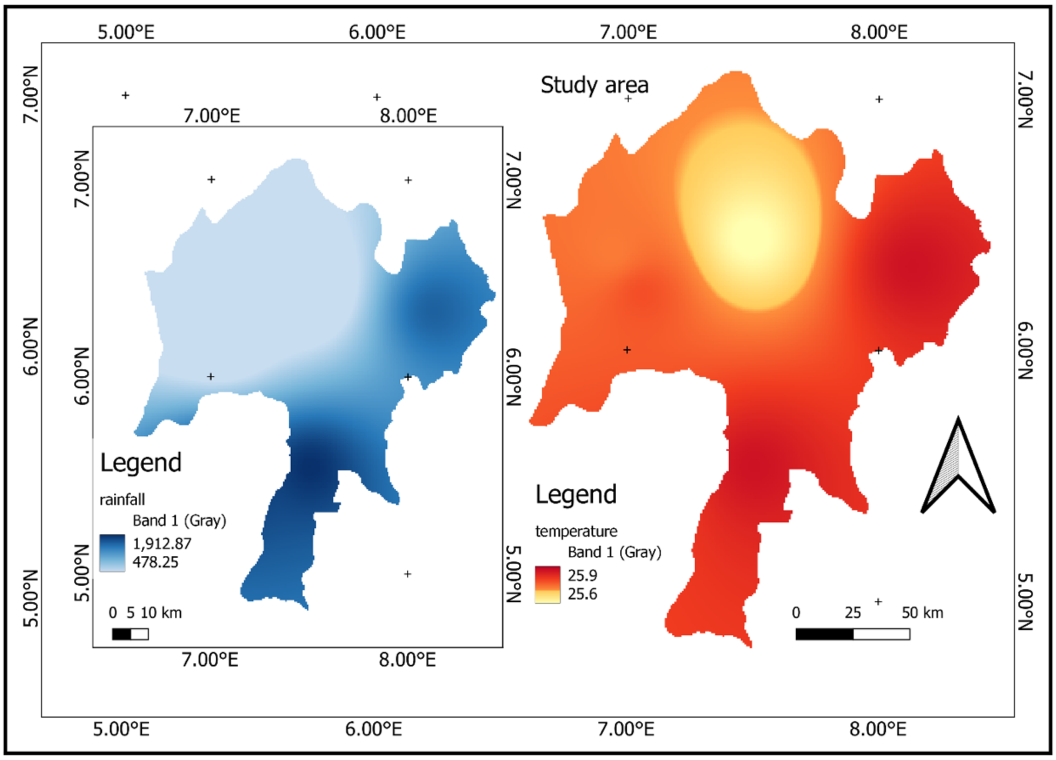

Figure 2. Spatial variations in rainfall and temperature over the region.

The mean monthly rainfall and temperature over the area show that rainfall maxima occur around July-September (Figures 3 and 4). The effect of the little dry season (Anyadike, 2002; Adejuwon and Odekunle, 2006; Ayadiuno et al., 2021) is very much more pronounced in Umuahia, Awka, and Enugu than it is in Abakaliki (Figure 3). The temperature distribution nearly follows the same pattern, increasing in November but dropping in December-January and again rising in February, peaking in March/April, and dropping gradually as the rainy seasons prevail from May to October (Figure 4). Thus, the lowest temperatures are obtained from July to September, the peak of the rainy season when the cloud cover is thicker than ever and thereby hinders the penetration of the insolation. Also, the temperature is low in December/January due to the effect of the harmattan wind that comes with much dust and haze that inhibit insolation.

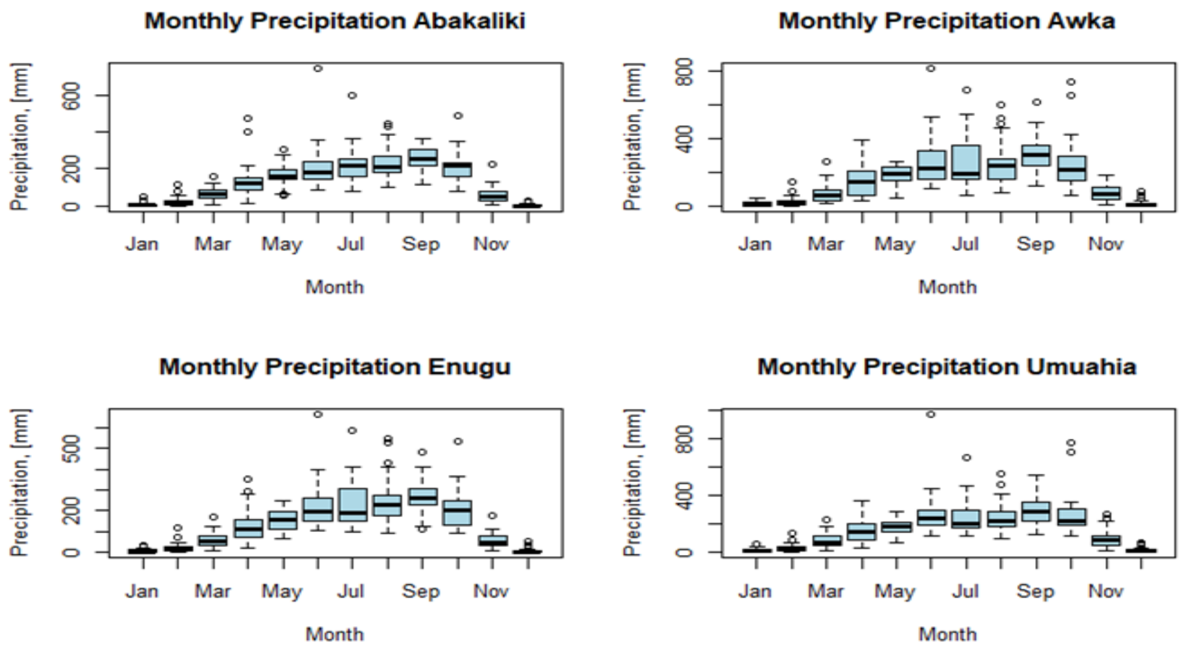

Figure 3. The rainfall distribution in the study area.

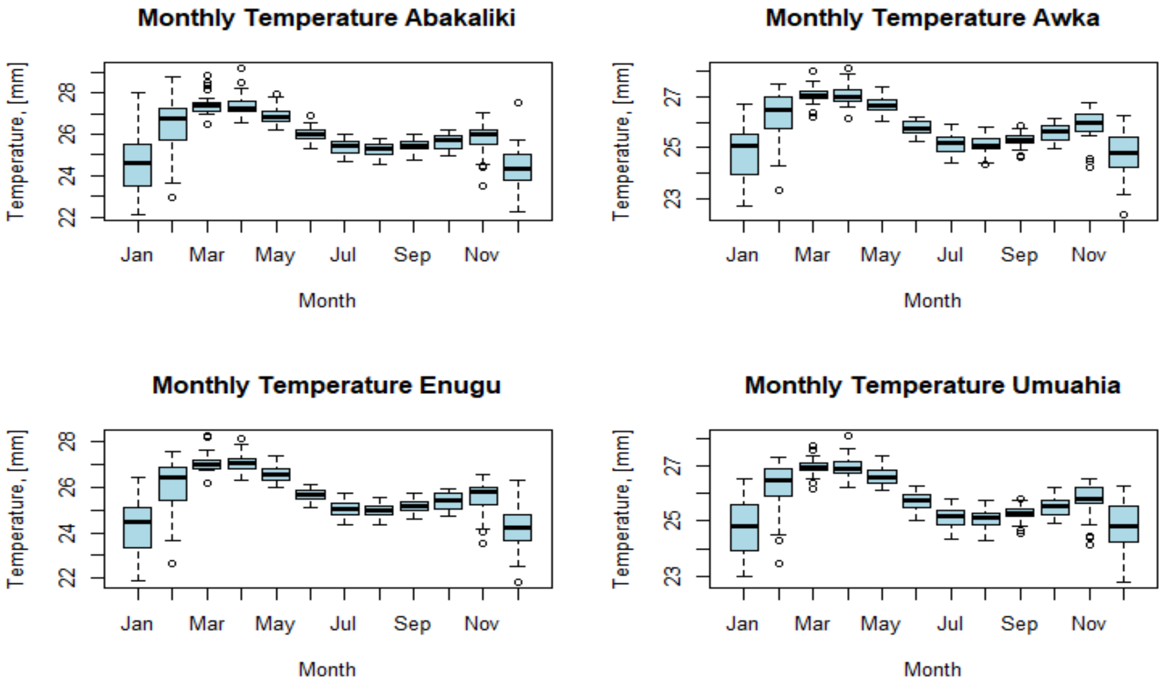

Figure 4. The temperature distribution in the area.

The coefficients of variation of the monthly rainfall and temperature are shown in Table 4.

Table 4. The Monthly CV for Rainfall

Rain	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	**1.58**	1.21	0.54	0.67	0.37	0.56	0.46	0.37	0.29	0.38	0.75	1.51
2	**1.12**	1.12	0.76	0.62	0.33	0.55	0.58	0.53	0.37	0.59	0.59	1.55
3	**1.29**	1.16	0.59	0.58	0.31	0.51	0.48	0.46	0.32	0.44	0.62	1.70
4	**1.06**	0.96	0.61	0.55	0.26	0.58	0.48	0.44	0.32	0.54	0.66	1.31

*1 is Abakaliki, 2 is Awka, 3 is Enugu and 4 is Umuahia.

Table 5. The Monthly CV for temperature

Temp.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	**0.056**	0.050	0.019	0.02	0.015	0.013	0.014	0.013	0.012	0.014	0.032	0.045
2	**0.044**	0.037	0.012	0.015	0.012	0.011	0.015	0.014	0.011	0.014	0.025	0.038
3	**0.051**	0.044	0.016	0.016	0.013	0.011	0.014	0.013	0.011	0.015	0.030	0.040
4	**0.051**	0.044	0.016	0.016	0.013	0.011	0.014	0.013	0.011	0.015	0.030	0.040

Tables 4 and 5 shows that December to February has the highest coefficient of variations for the rainfall and temperature distribution while September has the least coefficient of variations in the rainfall and temperature. That shows that these climate variables are more variable during the dry season months than during the rainy season. Related findings were obtained by Ayanlade et al. (2018) except that their result has August with high variability which might be due to the severe little dry season in their area of study. The rainfall distribution in terms of the number of days with rainfall above 20 mm and above 90 mm was investigated (Table 6). It shows that Umuahia has a higher number of days with rainfall above 20 mm and 90 mm followed by Awka (Table 6). This shows that there is a sufficient supply of rainwater for rice production in the region, however such intensity of its occurrence can be detrimental for crops at the incipient stage.

Table 6. Number of days with rainfall above certain thresholds

20 mm	days	Rainfall amount	Mean amount
1	330	9940.8	30.1
2	547	17908.4	32.7
3	346	10931.3	31.6
4	479	15685.1	32.7
90 mm			
1	0	0	0
2	8	1060	132.5
3	3	345.5	115.2
4	8	966	120.8

3.2. Trend analysis

The initial diagnostics were done with the autocorrelation function (acf) in r. It was done with a lag of one and it revealed that there is significant autocorrelation in the monthly data (Figure 5). The rainfall data had significant seasonality and to visualize it, the number of lags was increased to fifteen (Figure 6). The results of the trend analysis indicate that temperature is increasing at all stations at a significant rate (Table 7). The monthly rainfall trend has a decreasing trend though none of the stations exhibits a significant trend. The rate of increase in temperature is higher at Abakaliki than at any of the other locations.

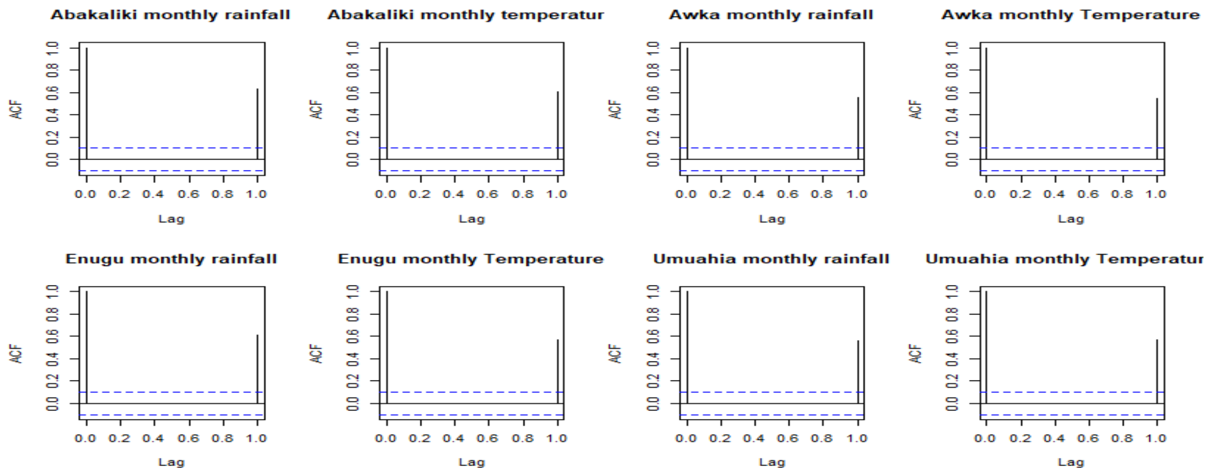

Figure 5. The autocorrelation results for the monthly data.

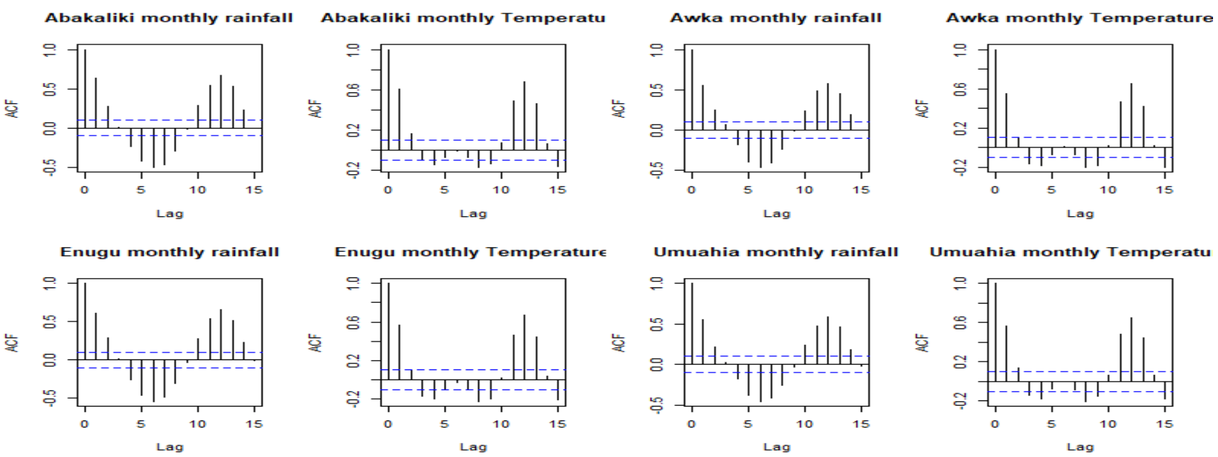

Figure 6. The seasonality plot for the annual rainfall and temperature data

Table 7. The trends of monthly rainfall and temperature

Location	Z	tau	Ss	Pw_Ss	p-va	L-T	U-T	Z-L	Z-U
			Rainfall						
Abakaliki	-1.393	-0.05	-0.04		0.16	-0.093	0.095	-2.763	2.866
Awka	-0.118	-0.004	-0.003		0.91	-0.102	0.100	-2.870	3.037
Enugu	-0.927	-0.032	-0.03		0.35	-0.098	0.103	-2.858	2.918
Umuahia	-0.267	-0.009	-0.01		0.79	-0.098	0.102	-2.787	2.93
		Temperature							
Abakaliki	2.97	0.103	0.0011	0.003	0.003				
Awka	2.24	0.078	0.0008	0.002	0.025				
Enugu	2.34	0.082	0.0009	0.002	0.019				
Umuahia	2.59	0.09	0.0009	0.002	0.009				

*L-T is Kendall's Tau Bootstrapped confidence interval lower bound, U-T is the upper bound, Z-L is the Z-value Bootstrapped confidence interval lower bound, Z-U is the upper bound. *Ss is Sen's slope, pw Ss is pre-whitened Sen's slope, tau is Kendall correlation, Z is the test statistic.

Additionally, the initial diagnostics performed on the annual data indicate that the temperature data have serial correlation while the rainfall data do not have (Figure 7). The annual trend analysis shows that there is a significant rising trend in temperature but not in rainfall (Table 7). Also, it shows that the rate of change is higher in the Abakaliki data than in any of the other locations (Table 7). The increasing warming in the area portends an increase in the rate of evapotranspiration in the area and could harm rice productivity due to reduced moisture during periods of low rainfall like August. This is in line with the studies that unreliable rainfall and temperature negatively affect rice yield (Ita et al. 2013; Tanko et al. 2016; Mech 2017). This could be a contributory factor to favorable productivity in Abakaliki as it is the only state with the least effect of the little dry season in August amongst the states (Figure 3)

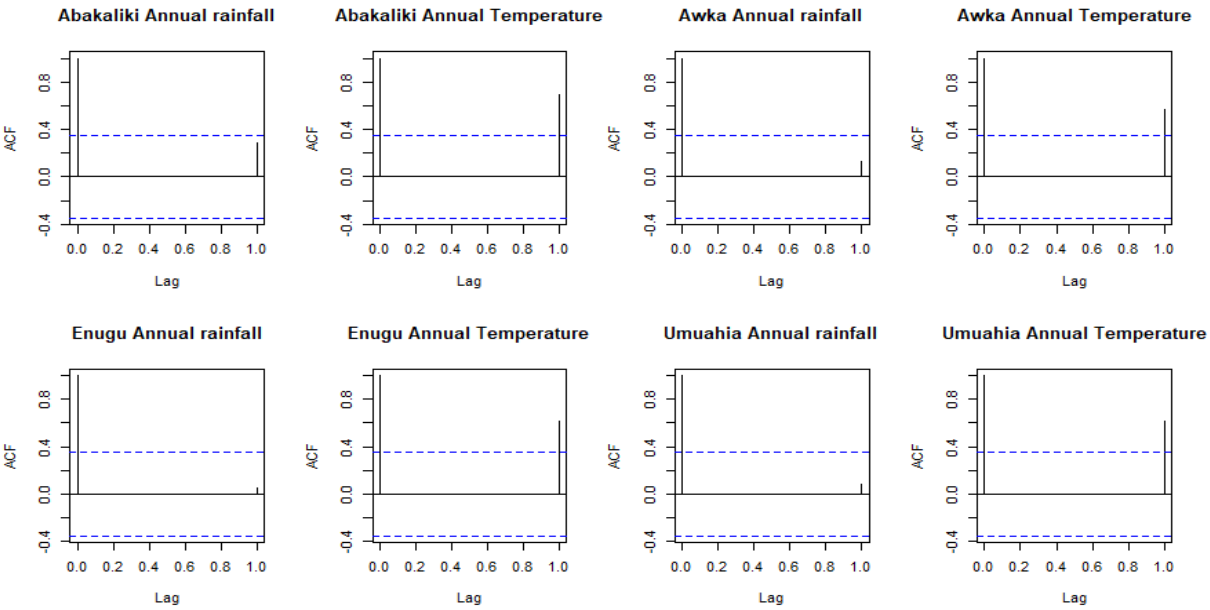

Figure 7. The autocorrelation results for the annual data.

Table 8. The trends of annual rainfall and temperature

Location	Z	tau	Ss	Pw_Ss	p-value
	Rainfall				
Abakaliki	**-2.355**	**-0.306**	**-15.06**	**-14.04**	0.019
Awka	**-0.428**	**-0.057**	**-1.01**	**-2.907**	0.670
Enugu	**-1.890**	**-0.246**	**-8.70**	**-10.46**	0.059
Umuahia	**-0.640**	**-0.085**	**-1.75**	**-4.97**	0.790
	Temperature				
Abakaliki	2.966	0.103	0.003	0.001	0.003
Awka	2.237	0.078	0.002	0.001	0.025
Enugu	2.344	0.082	0.002	0.001	0.019
Umuahia	2.594	0.090	0.002	0.001	0.009

*Ss is Sen's slope, pw Ss is pre-whitened Sen's slope, tau is Kendall correlation, Z is the test statistic.

3.3. Socioeconomic characteristics of rice farmers

Results on socioeconomic characteristics of rice farmers in the study area reveal that across Southeastern Nigeria, a majority (62%) of the rice farmers are males, while 38% are females (Figures 8 and 9). This implies that the sex distribution among rice farmers is skewed in favour of males.

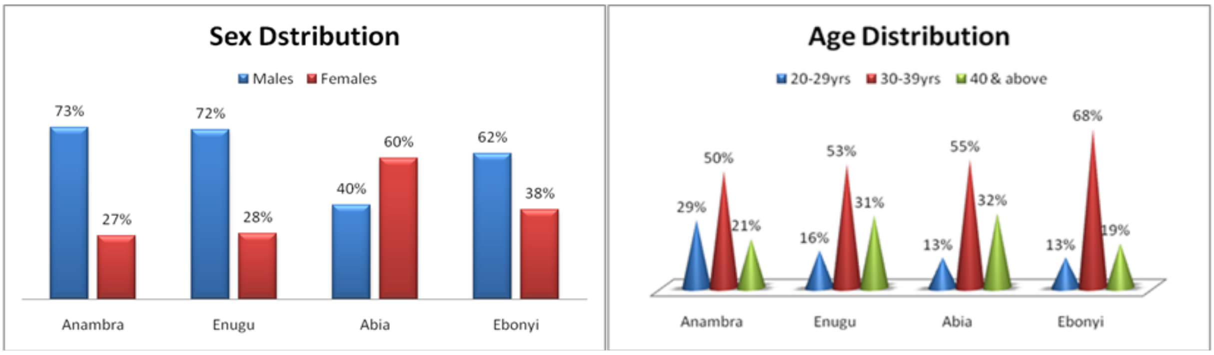

Figure 8. Sex and Age Distribution of Rice Farmers across the States.

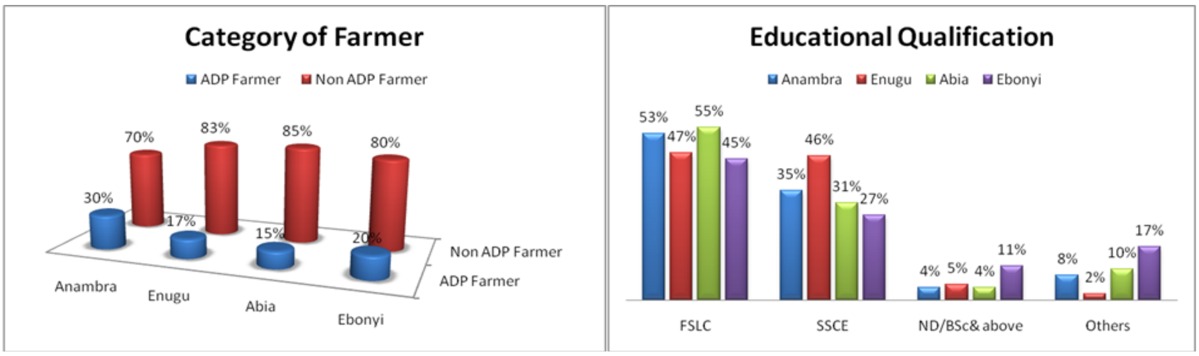

Figure 9. Categories of Rice Farmers and their Educational Qualification across the States.

The ages of the rice farmers in Southeastern Nigeria show that a greater percentage of the farmers' ages is between 30-39 years with variations among the States. More than (80%) of the rice farmers were married with a majority (72%) of the rice farmers' household size being between 5-9 persons. A greater proportion (80%) of the rice farmers were non-ADP farmers (Figure 9). A greater proportion (54%) of them generate between N240 000.00 (578 USD) to N480 000.00 (1156 USD) annually. Ninety-six percent (96%) had farming experiences above 10 years while 50% had First School Leaving Certificate (FSLC) as their highest educational qualification (Figure 9).

The mean productivity curve in Figure 8 displays the level of rice productivity across the states. The result indicates that the States in the region had an estimated mean rice productivity value of 28.117

kg ha^{-1} in the 2018/2019 growing season (Mba et al. 2021). The rice productivity per hectare shows that Enugu, Anambra, and the Abia States have low mean productivity values (6 839 kg ha^{-1}, 6 776 kg ha^{-1}, and 6 697 kg ha^{-1}) of rice productivity respectively, while Ebonyi State has the highest with an estimated mean productivity value of 7805kgha^{-1} (Figure 10). The States of Anambra and Ebonyi are endowed with notable floodplains and better drainages (Anambra River and Ebonyi Rivers). Yet productivity per hectare in Enugu surpasses that of Anambra state. This shows that factors other than suitable land size affect productivity like labour availability. However, a contrary result was reported by Dawe (2013) in southeast Asia that rice yield per capita is not the key determinant of rice production but the amount of per capita rice area harvested which is dependent on the proportion of well-suited land for rice-growing. Additionally, Anambra and Abia states are highly commercialized and the major employer of labour is commerce and trade. The result also indicates the existence of a negative effect on rice farmers in the study area of non-ADP farmers. The average yield is still low in Nigeria (Kamai et al., 2020).

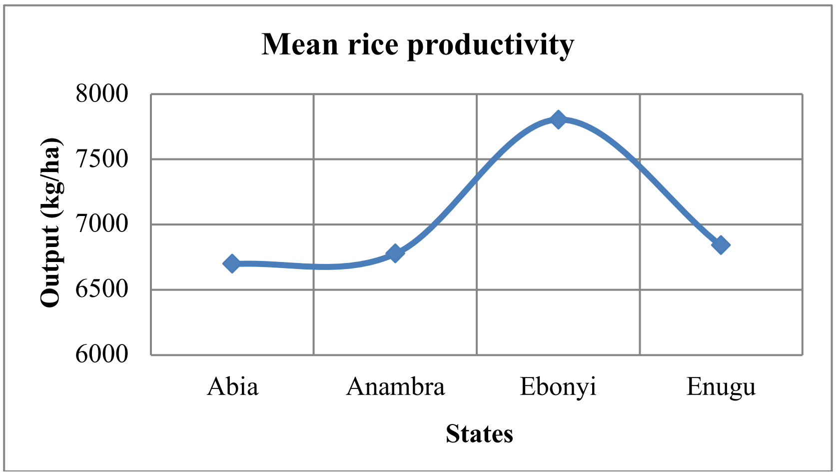

Figure 10. Rice Productivity of the States. Source: Mba et al. (2021).

The region was classified based on its level of productivity and a map of the mean productivity was produced to depict the spatial variations in productivity across the region (figure 11). It shows that Abakaliki is a very high productivity area, Enugu (high), Anambra (moderate), and Abia (low) productivity area (Figure 11).

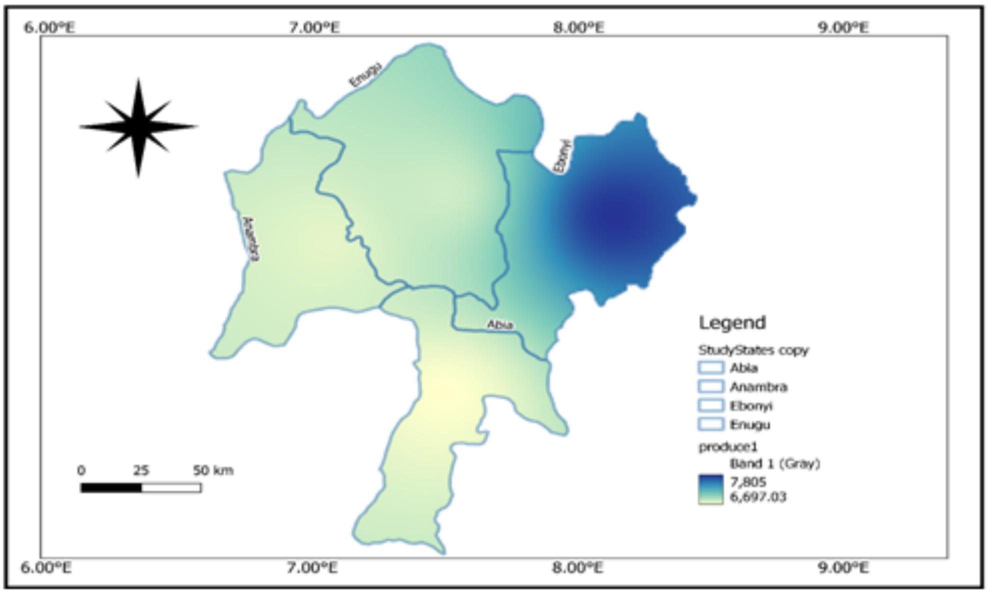

Figure 11. Spatial distribution of rice productivity in the area.

Figure 9 depicts the spatial differentiation in rice productivity in southeastern Nigeria. It shows that Ebonyi State followed by Enugu State recorded the highest levels of productivity based on the mean annual produce. However, modest to low yield was recorded in Anambra and Abia States. This spatial variation in rice productivity across the States is due to factors such as the category of the farmer, age, labour availability, level of education, infrastructural facilities, topography, capital, and climate. It shows that productivity increases from the southern to the northern part of the region.

3.4. Determinants of Rice yields in Southeastern Nigeria

Logistic regression was applied to determine the key factors of rice production across southeastern Nigeria as presented in Table 9.

Table 9 Logistic regression on determinants of rice production across Southeastern Nigeria

Determinants		Odds Ratio	Z	P>|z|
Household size	5 to 9 household members	2.18	1.73	0.08
	Above 9 household members	1.98	1.33	0.18
Monthly income	N20,000 to N40,000	0.66	-0.93	0.35
	Above N40,000	0.94	-0.14	0.89
Sex	Female	1.84	2.30	0.02*
Category of farmer	Non ADP Farmer	5.69	4.46	0.00*
Age	30 to 39 years	0.51	-2.23	0.03*
	Above 39 years	4.66	3.78	0.00*
Highest completed education	SSCE	0.80	-0.85	0.40
	First Degree and above	2.38	1.08	0.28
	Others	2.40	2.38	0.02*
Membership of cooperative society	Yes	0.40	-3.31	0.00*
Number of Extension visits	Twice	0.19	-4.24	0.00*
	More than twice	3.18	2.18	0.03*
	No Extension visit	0.56	-1.59	0.11
Constant		0.39	-0.88	0.38
Pseudo R^2			0.39	
Prob> chi square			0.00*	

Probability values with * denote significance at 95% confidence interval.

From Table 9, the Pseudo R-squared value of 0.39 explains 39% of the variation in rice productivity as accounted for by the combined effects of the 8 variables. This implies that the independent variables explained almost 40 % of the behaviour of the dependent variable. The calculated Chi-square probability value of 0.00 implies that there is a significant impact between the predicted variable and the predictor variables. For the probability effects of the independent variables on rice productivity; sex, category of the farmer, age of the farmer, educational qualification, membership of the cooperative society, and extension visits were the significant determinants of rice productivity in the study area (Table 9). This corroborates the findings of earlier studies (Ita et al., 2013; Osanyinlusi and Adenegan, 2016; Niang et al., 2017; Balogun et al., 2021; Chandel et al., 2022).

Specifically, male farmers are significantly (p = 0.02) more likely to produce a high quantity of rice (1.84) when compared to female rice farmers. This shows that male farmers who cultivate rice produce 84% more rice output than female rice farmers. In the same vein, the ADP farmers are significantly (p = 0.00) more likely to produce a high quantity of rice (5.69) when compared to non-ADP farmers. This implies that ADP farmers have 469% more output than the non-ADP farmers.

Again, rice farmers who are between 30 to 39 years compared to those who are above 39 years are significantly (p = 0.03) less likely to produce more rice by 0.51. This indicates that rice farmers who are 39 years and below produce 51% lower output than those that are aged 30 to 39 years. This is in line with Echebiri and Mbanasor's (2003) finding that rice production requires able-bodied farmers with a lot of experiences. That is, manpower and experience are key to increased rice production. Just as Balogun et al. (2021) showed that labour in addition to irrigation impacts rice production.

On the highest educational qualification of the sampled rice farmers, the study discovered that rice farmers with First School Leaving Certificate (FSLC) as the highest education qualification significantly (p = 0.02) increase rice output by 2.40. This indicates that rice farmers with FSLC are more likely to increase their rice output by 140% more than those with others as their highest completed education. More so, rice farmers who do not belong to any cooperative society compared to those who belong significantly (p = 0.00) reduce rice output by 0.40. This indicates that rice farmers who do not belong to any cooperative society produce 40% lower output than those who belong to a cooperative society. Therefore, membership in a cooperative society is a bolstering factor in rice production as there are several benefits from such membership which help to increase production.

Similarly, rice farmers who had only one extension visit compared to those with two visits significantly (p = 0.00) reduces rice output by 0.19. The implication of this is that rice farmers with only one extension worker visit produce 19% lower output than those with two extension visits. In the same way, rice farmers who had only one extension visit compared to those with more than two visits significantly (p = 0.03) reduce rice output by 0.56. This indicates that rice farmers with only one extension worker visit produce 56% lower output than those with more than two extension visits. This concurs with related findings that extension workers' visit influences rice production (Diagne et al. 2013).

Conclusion

The study assessed the climate variability and the determinants of rice production in the southeast of Nigeria. It reveals the existence of increasing warming in the area due to significant rising temperatures. It shows that rainfall is decreasing though not statistically significant. Significant warming with declining rainfall might lead to the depletion of soil moisture due to accelerated evapotranspiration. The study recommends that since an ADP farmer has a lot of perquisites such as getting enough government attention in terms of provision of improved farm inputs, improved technology, and attending state cooperative federation workshops, awareness should be created on the importance of being an ADP farmer to attract a greater number of farmers to belonging to ADP farmers. In other words, there should be increased access to information for the farmers while access to belonging should be open to all who want to belong at any point in time.

The results have emphasized the necessity of rainfall to increase rice productivity. However, with increasing warmth and declining rain, there should be a need of providing adequate irrigation facilities to assist farmers, especially during the dry season to ensure food production in all seasons rather than being rain-dependent. Therefore, there should be partnerships among the farmers, the state authorities, aid agencies, and other stakeholders in actualizing this in order to meet the 2030 SDGs of hunger reduction and achieving food security in Nigeria. Also, Anambra/Imo River Basin Development Authority projects should be revitalized to enhance and ensure adequate water supply all year round to rice farms in the area.

Finally, the findings of the study will aid policymakers and other stakeholders in devising policies and future scenarios to improve rice production in the southeast of Nigeria and the country at large. Therefore, more awareness should be created to enable more farmers to benefit from being ADP farmers in the region.

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