American Journal of Biological and Environmental Statistics
2026, Vol. 12, No. 3, pp. 57–69
https://doi.org/10.11648/j.ajbes.20261203.13

SciencePG
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Research Article

Patterns in Rainfall Cessations and Public Policy Implications on Sustainable Food Security Under Distinct Imo Agro-Climatic Zones

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Abstract

The collective efforts in tackling climate change impacts have gained popularity at the global level, but regional and local agro-land users tend to suffer failures due to limited capacity to adapt to the uncertainties in annual rainfall indices of onset, growing season, and cessation. This study evaluates the space-time dimension of uncertainties in rainfall cessations and its implication on crop yield and food security in Imo State. The state was stratified into three agro-land zones. Rainfall data were extracted from secondary sources using gridded method from 19981 to 2023 (43) climatic years and analyzed using diverse descriptive and inferential statistical tools. The results reveal that Imo East recorded the highest mean value of 321.232 mm, while Imo West recorded the highest standard deviation of 13.898 mm. The earliest rainfall cessation is recorded in Imo on 21st October. 1998, while late cessation occurs homogenously in Imo West and Imo East on 26th December, 1990climatic year. The time series evaluation offers a uniform positive trend pattern but at distinct rates across the sampled agro-climatic zones. The regression models of the trend dimensions reveal that Imo North exhibits a positive highest predictive equation of 0.288x+311.8 and a corresponding highest co-efficient of 0.077. ANOVA test of the proportion variance in uncertainties in rainfall cessation among the agro-climatic zones led to a conclusion that the uncertainties in rainfall cessations in Imo State are independent of geographic location. This study recommends for the urgent increased capacity building through farmers' education and sustainable financing of multiple land use practices for improved crop yield per farmland and food security in Imo State.

Keywords

Space-time, Rainfall Cessation, Agro-Climatic Zone, Crop Yield, Food Security

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Received: 27 April 2026; **Accepted:** 25 July 2026; **Published:** 2 September 2026

1. Introduction

Although the concerted efforts of the government, donor agencies, and other stakeholders to cope with the uncertainties in climate change indicators at the global level have yielded positive level of successes [1, 2], variations exist at both the regional and community levels as observed in Ezemonye et al [2], Umo et al [3]. The multiplier impacts of climate change-instigated uncertainties in rainfall cessations can alter farmland capability for optimum crop yield, food production, and food security. Such alteration had posed serious threats to food security in most local communities and regions, especially in the sub-Saharan African and Asian countries (Food and Agricultural Organization (FAO) [4].

The uncertainty in rainfall cessation (i.e., anomalies), represents the deviations of annual rainfall from long-run averages, is an old and recurring challenge [5, 6], usually with devastating impacts on crop yield per farmland, food production/ security; especially in the developing countries characterized by small farm-holdings and limited adaptive capacities [7]. Within the developing countries, Zaveri, Russ & Damania [8] established that on the average 'dry anomalies account for ~7.4 percent of global cropland expansion and 9 percent of cropland expansion in the developing world'. A two-stage assessment of the impact of rainfall-instigated uncertainties reveals that increase anomalies reduced crop productivities and a resultant increase in cropland expansion, with 1- to 2- and 3-y lags [8].

Aryal, Maharjan, Talchabhadel, & Thapa [9] observed that early rainfall cessation is associated with meteorological drought and it attendant effects of declining soil moisture and consequent crop failure without reference to surface water resources (agricultural drought). Empirical evidences have shown that uncertainties in rainfall cessation defined by precipitation deficiency constituted serious emerging dangers crops, water resources, economies, and human lives [10] across geographical regions over time scale. The prevalence of drought-induced early rainfall cessation is directly linked to deficit in soil moisture leading to force harvest of premature crops, poor crop output/ return per farmland, and increase food insecurity.

It has been observed that high variations in rainfall onset and cessation often cause discrepancies in interpreting seasonal characteristics, such as length of the rainy season, precipitation amount, and length dry days as envisioned in Ferijal, Batelaan, Shanafield, & Alfahmi [11]. Hence, distinct methods have been employed by researchers in determining rainfall onsets and cessations. The methods encompass the precipitation-based Agronomy method, which is an adaptive method as its parameters are locally adjustable with wide applications in Robertson *et al.* [12], and Moron *et al*. [13]. A study succinctly enumerates three onset estimation methods as agronomy, anomalous accumulation, and a modified local method [11], that is mostly used in climatological researches, yet applicability may differ due to the researcher's interest or context.

Within the humid Tropics and Imo State in particular, a combination of agronomic method, backed by Harris et al [14] geospatial resolution models can offer a more robustic avenue to generate data and used to predict crop specific growth, timing of yield, and mitigate adverse water shortage at the ecological level since the methods relied on local, seasonal, and annual rainfall data. The existing lacunas constitute major sources of concern, especially when considering the multitude and complex nature of phenomena modern physical geographers and allied earth scientific works by (Umo, Enwereuzor & Ezemonye [15], Mondal [16], to clearly comprehend and elucidate their interactions for informed ecosystem service [15], demand valid descriptive statistical comparisons and appropriate inferential statistical modellings in space and time.

The activities of the bandits (unknown-gunmen) constitute one of the cardinal threats to rural farmer's commitments to sustainable food production in Southern Nigeria. Also, increase in geophysical hazards such as meteorological droughts and extreme uncertainties in rainfall events reported in Umo *et al* [1, 2], Hubertus *et al* [17], coupled with limited farmers' awareness and drought-specific adaptation capacity at both community and farm level are expediting more devastating impacts on specific crop yield and food security in this Anthropocene Age due to the multiplier effects of climate change. The highlighted treatise collaborate diverse recent studies whose notions depict that the length of a given season naturally exhibits spatial and temporal variations due to shifts in onset and cessation' as exemplified by Ferijal *et al* [11] Goswami and Xavier [18], Fu *et al* [19], Misra & DiNapoli [20]; Duru et al [21]; Marjuki *et al* [22].

Geoscience and other scientific disciplines are seriously saddle with how it can best addressed vital global issues, such as climate change, food insecurity, human conflict, and persistent poverty [2, 23, 24]. Yet, current trends and directions in physical Geography researches (e.g. climate change, landforms, and food security) depict areal differentiations (from household, community, countries, regional, to global levels), due to dynamisms in stakeholders' awareness, perception, responsive capacity, and adaptation [1]. The cardinal issues of research interest in this context are highlighted thus: What are the underlying characteristics of annual rainfall cessations? Are there differences in annual trends of rainfall cessations over space-time? Do changes in geographical locations have statistically significant influence on rainfall cessation across the study agro-climatic zones? A clear elucidation of the issues will offer a better understanding of historical dimensions of how climate change-instigated uncertainties in rainfall cessations influence food production and security in the Imo agro-climatic zones.

The central purpose of this study is to examine the patterns in rainfall cessation from 1981 to 2023 (43 climatic years) and its implications on food security in Imo State agro-climatic zones of Nigeria. To achieve the stated central target, the following specific objectives were explored.

1) To identify and assess the characteristics of uncertainties in annual rainfall cessations among the three (Imo North, Imo East, and Imo West) agro- climatic zones.
2) To comparatively evaluate the space-time trends in rainfall cessations in the three agro- climatic zones of Imo State.
3) To determine whether of changes in geographic locations have statistically significant impacts on rainfall cessation across the agro-climatic zones in Imo State.

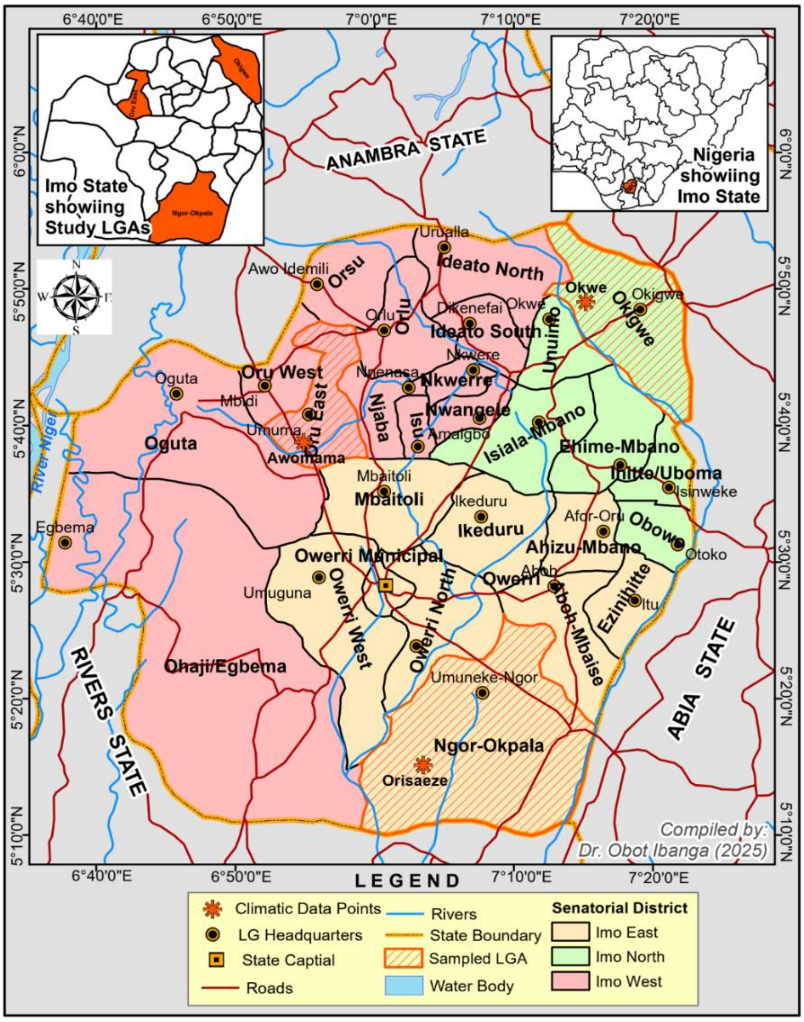
2. The Study Area

2.1. Location

Imo State is situated between Longitudes $6°5^1$ and $7°25^1$ East of Greenwich Meridian and Latitudes $4°5^1$ and $7°15^1$ North of Equator. In context of relative geographical positions, Imo State share boundary with Anambra State on the East, Abia State on the West, and Rivers State on the South [2] as indicated in Figure 1. Moreover, the State has an approximated total land mass of about 5,100 km^2, traverse by three agro-climatic zones (comprising Okigwe, Owerri, and Orlu).

2.2. Climate

The climate of the study area is generally classified as Af climate based on Köppen's classification scheme cited in [1-3]. The dynamics in seasonality led to their stratifications into four dimensions, comprising long rainy, short rainy, long dry and short dry seasons observed in Umo [25, 26]. The degrees of dynamisms in climatic seasons usually exert divergent influences on rainfall onset and cessation across geographic space and time. The mean annual rainfall is over 2500 mm and a mean temperature of approximately 26.9^0 Celsius [27]. The relative humidity varies within the range of between 72 percent for dry season and 92 percent for rainy seasons [2, 25]. Recently, there are marked evidences of rising temperature and rainfall in the area [2] due to the compounding effects global warming and climate variability.



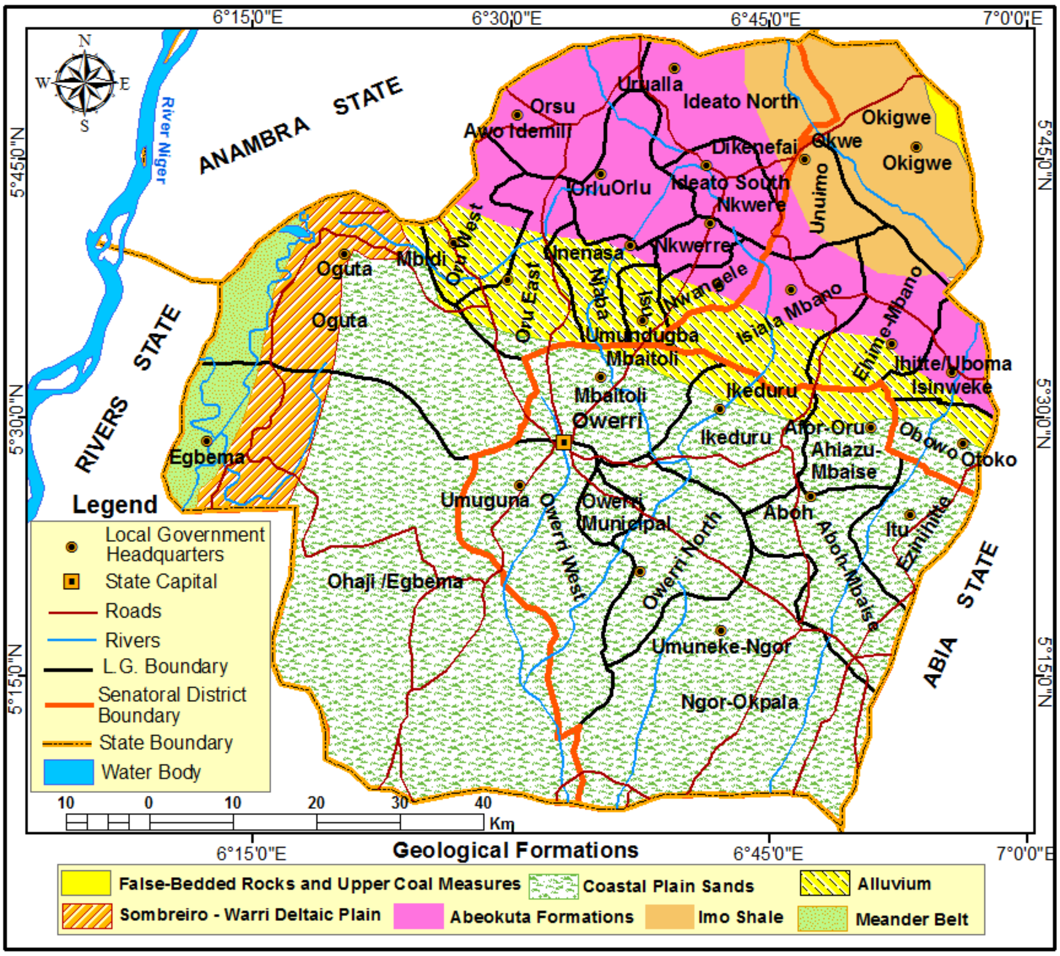
Source: Authors' Fieldwork (2025).

Figure 1. *Imo State Showing Agro-climatic Zones and Data Extraction Points.*

2.3. Geology, Vegetation, and Land Use

The geological formations of the studied Imo - climatic zones (Figure 2), depict diversities over geomorphic spaces. The Imo Northern agro- climatic zone possesses five vital geological formations, comprising the False-bedded Rocks of Coal and Upper Measures, the Imo Shale, the Abeokuta formation, the Quaternary Alluvium, and the Coastal Plains Sands Deposits of Tertiary Times [2, 29]. The dominant formations composed of the Imo Shale, occupying major parts of the Northern flank especially Okigwe and Onimo Local Government Areas, while the southern flank is a transitional zone with alternate formations of comprising dominantly Quaternary Alluvium region and traces of the Coastal Plains Sand Deposits of Tertiary Times [2, 27, 28].

In context of geologic sequence of Age stratification as indicator, Onwumerobi [29] identified the existent of the Paleocene, Eocene, Pleistocene formations in the Northern agro-climatic zone [2]. The complexities of geologic formations embedded in Imo North agro-climatic zone posed severe challenges to diverse engineering and allied construction works such as roads, bridges, and housing/ buildings. More so, the complexities in Geological formations coupled their complex sceneries (relief features) offer the soil diverse attributes that favour multiple agricultural practices such as unique rocky terrain that favours pastoral (animal) activities, multiple crop production such as tree crops (especially raffia, palm tree, pear, avocados, cashew, coconut, and orange), roots and tubers, plantain, and banana. Most recently the poor terrains in some areas within the Okigwe zone tend to offer sites criminal activities.



Source: Modified from the Nigeria Geological Survey Agency (2012).

Figure 2. *Imo State Showing the Geological Formations.*

The Imo East agro-climatic zone is traverse dominantly by the Coastal Plains Sands Deposits of Tertiary Times, (occupying over 90 percent of the entire land areas), while the Quaternary Alluvium region occupies a residual land areas of less than 10 percent in the zone. The residual areas are prevalence in the transition zone between the Imo North and Imo East especially at the boundary region around Ikeduru, Mbaitoli, and Isiala Mbano axis of the Imo State (Figure 2). The agricultural land uses have strong affinity with its soil and geological formations. The fairly uniform geological formation coupled with almost a homogenous flat-terrain offers the Imo East agro-climatic zone multiple options for diverse agricultural land uses, housing, industrial development, administration, and allied socio-economic activities.

The geological formations for the Imo West agro-climatic zone presented in Figure 2 depict spatial dynamics, with shared attributes from the Imo North and Imo East agro-climatic zones. In addition, the existent of the unique Sombreiro, Meaner Belt, Coastal Alluvium, and the Coastal Plains Sand Deposits of Tertiary Times [2] provide agricultural and allied land users multi-dimensional options for sustainable production of crops such as roots and tubers (e.g. yam, cassava, potatoes, cocoyam, water yam), fruits and vegetables (corn, pumpkin, cucumber, pineapple), tree crops (e.g. palm tree, pearl, avocados, coconut, cashew, and cocoa).

3. Materials and Methodology

3.1. Research Design, Area Demarcation, and Sampling

This study is employed descriptive survey design to with a view to presenting the phenomenon of rainfall cessation in the three distinct agro-climatic zones in Imo State based on the secondary data. To explore the uncertainties in rainfall cessations, the study area was stratified into three major divisions using senatorial zones (Northern, Eastern, and Western) as index (as exemplified in Figure 1 and their coordinates recorded as summarized in Table 1 with the aid of using Germaine Global positioning System (GPS) as contextualized and applied in Umo et al [2, 35].

The choices of locations for rainfall data extractions in each zone (stratum) were purposively selected to facilitate evenness in areal differentiations (i.e. temporal spread). The locational attributes of zone were primarily sourced though series of direct field studies (reconnaissance surveys) locations of (Longitudes and Latitudes) coordinates and determination of elevations.

3.2. Data Collection

On the contrary, data on rainfall cessations were extracted from the University of East Anglia Climatic Research Unit (Harris, Jones, Osborn, & Lister) [2, 14, 28], supported by CRU time series, version 4.05 of high resolution gridded data from January 1st, 1981 to December 31st, 2023 (43) climatic years using gridded method [2, 28, 35]. The gridded datasets were created with the grid cells' specifications of 0.5° × 0.5° in size to extract periodic rainfall onset at three distinct geopolitical zones in Imo State, Nigeria as applicable in Umo et al [2, 28]. The rationale was avert the constraints of fixed locational coverage embedded in rainfall data archival from distinct Nigerian Meteorological Agency (NiMet's) weather stations within the State [2, 3, 28].

To ascertain the reliability test of the rainfall data sets from NiMet Station (at Imo Cargo Airport) and that of CRU from Eastern agro-climatic zone (Orisaeze) point were carried out using Cronbache's test and the result attests very high level with a positive co-efficient of 0.97. It is worth emphasizing that the CRU raster data were collated monthly, with annual sum calculated using a raster calculator as demonstrated in recent researches such as Umo et al [2], Abeneme et al [28] Okoro, Chen, Chineke & Nwofor [30], Chen, Tian, Yao, & Ou [31], Omonigho [32].

Table 1. Data Sources and Extraction Methods.

Agro-land Zones	Data Site Extraction	Longitudes	Latitudes	Elevation	Durations
Eastern Agro-climatic Zone	Orisaeze	7.0807	5.2728	62.51 meters	1/1/1981 – 31/12/2023
Western Agro-climatic Zone	Awomama	6.9331	5.6884	68.31 meters	1/1/1981 – 31/12/2023
Northern Agro-climatic Zone	Okwe	7.2186	5.7766	116.22 meters	1/1/1981 – 31/12/2023

Source: Authors' Compilation (2025).

3.3. Methods of Data Analysis

Data generated on the dynamics in rainfall cessation across the three agro-climatic zones were analyzed using descriptive and inferential statistical tools. The descriptive statistics encompasses mean, media, standard deviation, range, variance, and sum for comparative purposes and description of the phenomena of rainfall cessation. Further still, Time series with linear regression models were used in elucidating the annual trends, variances, and oscillations in rainfall cessation between 1981 – 2023 (43 climatic years), and compare the models between and among the agro-climatic zones in the Imo State for informed policy framework and decision making. On the basis of explainable variances and test of variability in the mean pattern if rainfall cessations among the distinct zones, multiple linear regression and ANOVA models were used, while partial regression and T-test statistics were employed as surrogate for the determination of differences in independent variable on the linear combination of each dependent variable in the series.

4. Results and Discussions

The quantitative and thematic evaluations of uncertainties in the characteristics, trending patterns, and model predictive powers of rainfall cessations within and across diverse agro-climatic zones in Imo State are chronologically presented in the discourses that follow.

4.1. Assessments of Distributive Patterns in Rainfall Cessations in Imo State

The results of the distributive pattern of rainfall cessation at distinct agro-climatic zones of Imo State are descriptively summarized in Table 2 for easy perusal and comparison. From the results, the minimum and maximum range for Imo West and Imo North maintains the homogenous values of 296.00 mm and 360.00 mm respectively, while the scenario in Imo North gives different values of 294.00 mm and 358.00 mm for minimum and maximum. A further exploration of the result using sum as index reveals differentiations. A highest sum of 13813.00 mm is recorded in Imo East, followed by a value of 13802.00 mm for Imo West, while a lowest sum of 13683.00 mm is associated with Imo North agro-climatic zone. The mean distributions indicate disparities based on geographic locations. Specifically, a highest mean score of 321.232mm is recorded in Imo East, followed by a value of 320.977 mm for Imo West, whereas a least mean score value of 318.209 occurs in Imo North agro-climatic zone.

To elucidate the pattern of discrepancies from the mean score, standard deviation is employed and the results in Table 2 further reveal that a peak value of 13.898 is recorded at the Imo West agro-climatic zone, the value is closely followed by 13.815 mm for Imo East, while Imo North agro-climatic zone recorded a least standard deviation of 13.041 mm in the series. On the basis of variance, the results in Table 2 clearly indicate that a highest value of 193.166 mm is obtained for Imo West, followed by 190.849 mm in Imo East while a lowest score value of 170.074 mm is associated with the Imo North agro-climatic zone of Imo State.

Table 2. *Descriptive Analysis of the Uncertainties in Rainfall Cessations.*

Location	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Imo_North	43	294.00	358.00	13683.00	318.209	13.041	170.074
Imo_West	43	296.00	360.00	13802.00	320.977	13.898	193.166
Imo_East	43	296.00	360.00	13813.00	321.232	13.815	190.849

Source: Authors' Analysis (2025).

The comparative assessment of the discrepancies in rainfall cessations across the agro- climatic zones and dates of occurrences as indicators, the results summarized in Table 3 depict variations. From the results, the earliest rainfall cessation was recorded In Imo North agro-climatic zone on 21st October, 1998, followed by the homogenous events on 22nd October, 2008 recorded both at Imo East and Imo West agro-climatic zones respectively. In another dimension, Imo East and Imo West agro-climatic zones recorded a uniform late rainfall cessation date of 26th December, 1990, while Imo North agro-climatic zone recorded a late rainfall cessation date on 12th December, 1990. The marked deviations in rainfall early cessation and late cessation at the Imo North from other agro-climatic zones can partly be attributed to its exposure to and influence of the Guinea Savannah climate especially around the boundary of Okigwe in Imo State and Enugu State.

Table 3. *Descriptive Analysis Characteristics of Rainfall Cessation in Imo State.*

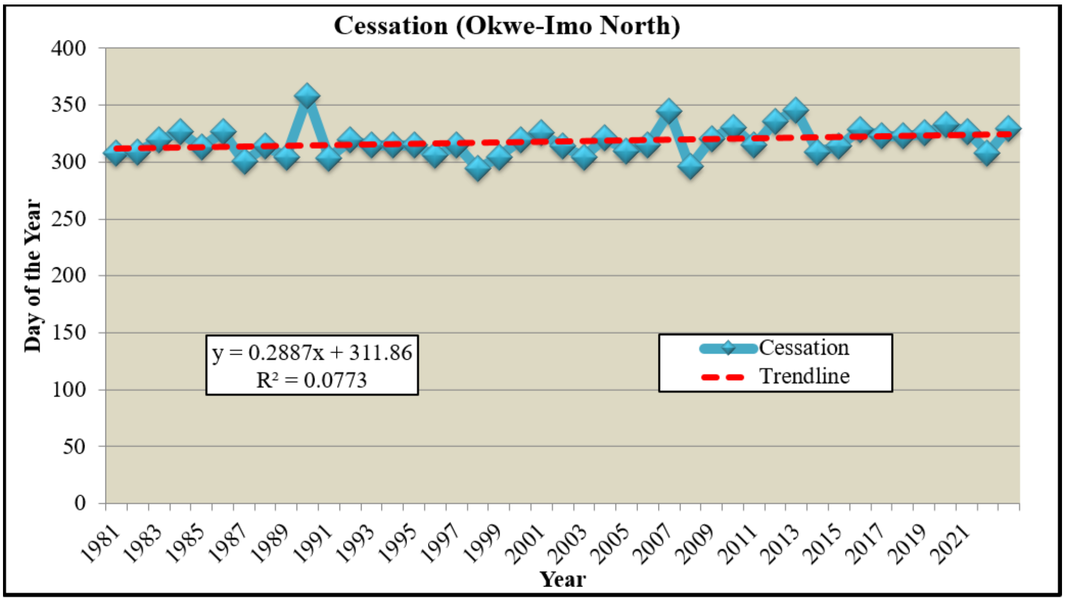
Agro-climatic Zones	Rainfall Data Points	Early cessation	Late cessation
Imo North	Okwe	21st Oct. 1998	12th Dec. 1990
Imo East	Orisaeze	22nd Oct. 2008	26th Dec. 1990
Imo West	Awomama	22nd Oct. 2008	26th Dec. 1990

Source: Data Analysis by the Researcher (2025).

4.2. Comparative Evaluations of Space-time Trends in Rainfall Cessations in Imo State

Time series with regression model were adopted as surrogate for determining the periodic trend in rainfall cessations across agro-climatic zones of Imo State and the results summarized in Figures 3, 4 and 5 indicate elements of consistency based on generalized positive trends and divergence based on the annual events. In the context of rainfall cessation in Imo North agro-climatic zone, the total positive anomalies of 15 climatic years is recorded and a total negative anomalies of 17 climatic years, while a total of 11 converges within the regression line.

On the basis of extreme events the results in presented in Figure 3 reveals that a highest positive trend in cessation of 358 mm was recorded in 1998 climatic year, this is followed by 345 mm in 2013 climatic year. On contrary, a lowest cessation event of 294 mm is associated with the 1998 climatic year, accompanied by 295 mm for 2008 climatic year. A juxtaposition of the pattern exhibited in Imo North agro-climatic zone indicate the dominant negative convergence of annual rainfall cessation below the average regression value over the positive annual rainfall trends. Furthermore, though the annual anomalies sustain positive trends in the Imo North agro-climatic zone (Figure 3), it very clear that the actual annual deviations from the average (regression) line are rather eclipsing due to the influence of climate change and local geography.



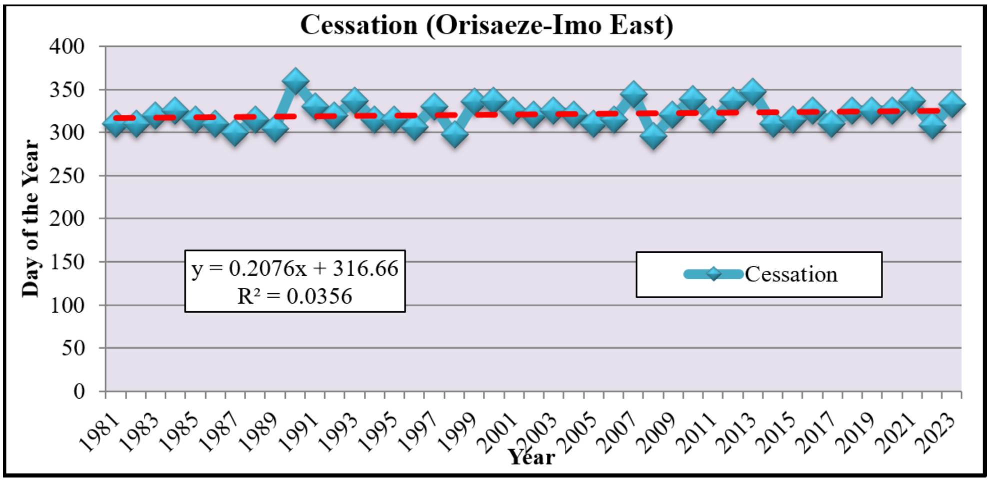
Source: Data Analysis by the Researcher (2025).

***Figure 3**. Temporal Trend of Rainfall Cessation in Okwe (Imo North).*

The results of the linearized model of rainfall cessation in Imo East agro-climatic zone presented in Figure 4 depict variations in events and a positive trending pattern. In context of anomalies, the result reveals that a total of 13 climatic years trend above the average (regression) line, which suggest excess scenarios. Furthermore, a total of 14 climatic year trend below the average (regression) line, are the indicators of dominant of early cessation and a corresponding early cessation in optimum crop growth and yield, leading to premature harvest.

Contrarily, highest proportions of 16 climatic years were rather converging on the line of best fit in the Imo East agro-climatic zone of Imo State. The pattern in the uncertainties suggest possible adverse effects on crop production which Umo, Okoroafor, and Ukwe report that 'farmers remain concerned about an increasing intensity of extreme weather events that will and has continued to occur as a result of climate variability' [1].

On the basis of extreme events, the results presented in Figure reveal that a most outstanding cessation in rainfall event of 360 mm is associated with 1990 climatic year, followed by 348 mm recorded in 2003 climatic year. A further juxtaposition of the results on the account of extreme events indicate that a least scenario of 296 mm is recorded in 2008 climatic year, and this closely followed by 297 mm recorded in 1998 climatic year of the Imo East agro-climatic zone. Moreover, the implication of focal convergent of rainfall cessation within the average is that the events sustain fairly uniform (normal) patterns in the series, partly due to the relative position of ITCZ that controls the two regional climate notably rainfall and temperature characteristics.

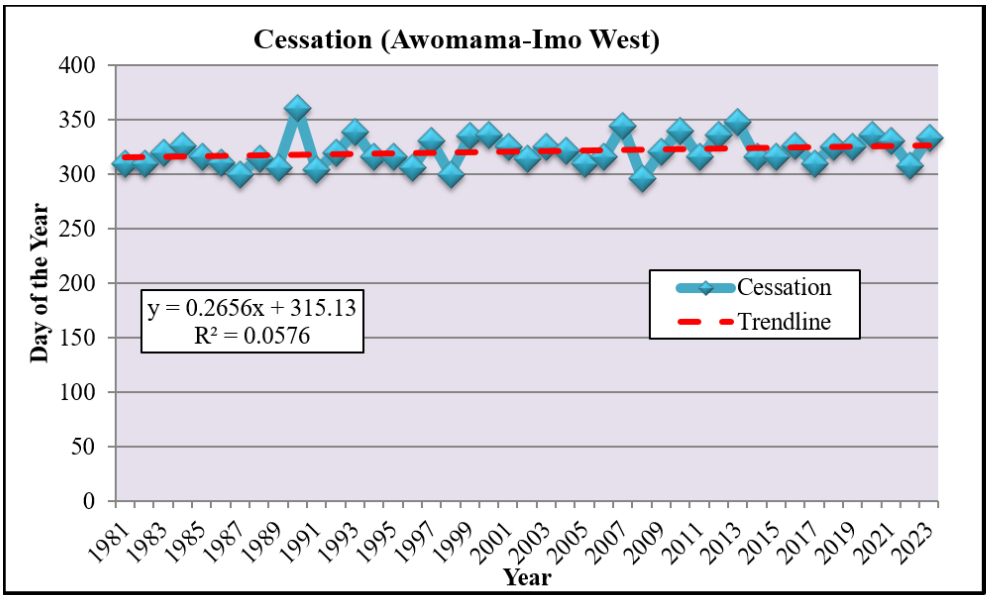


Source: Authors' Analysis (2025).

Figure 4. *Temporal Trend of Rainfall Cessation in Imo East.*

The linearized model of the cessation pattern in annual rainfall in Imo West agro-climatic zone is presented in Figure 5 and the results differ based on climatic years. On the dimension of positive anomalies, the results show that the most dominant trend of 17 climatic years converge below the regression line while the total cessation periods of 15 climatic years exceeded the average line in the series. However, the residual cessation events of 11 climatic years fall within the average line in the series. The high incidences of early cessation in annual rainfall over other patterns can be attributed to increase in intervening influences of climate change impacts, deforestation and urbanization.

In the context of extreme cessation events, the results in Figure 5 reveal that a highest amount of 360 mm is recorded in 1990 climatic year, followed by 348 mm for the 2013 climatic year. On the contrary, a least cessation amount of 296 mm is associated with the 2008 climatic year and this is accompanied by 300 mm recorded simultaneously during the 1987 and 1998 climatic tears, respectively. The high concentration of mean rainfall cessation amount on an around the regression line in the Imo West agro-climatic zone attests the homogenous nature the combine regional climatic stressors (especially anthropogenic and natural interventions) thereby constraining sustainability in annual and biannual crop yield as well as food security. This will become very eminent when juxtapose with the uproar in issues of internal insecurity and kidnapping cases that are threatening residents, farmers, and livelihoods in the region.



Source: Data Analysis by the Researcher (2025).

Figure 5. *Temporal Trend of Rainfall Cessation in Awomama (Imo West).*

To elucidate the predictive powers variations between of rainfall cessation and climatic years, regression model with time series were used and the results of the equation s are summarized in Table 4 offer homogeneities and differences across the climatic years and agro-climatic zones. On the dimension of homogeneity, trending patterns uphold a unilateral positive increase across the distinct agro-climatic zones, while heterogeneities are observed annual trending values across the climatic years and the distinct agro-climatic zones in Imo State.

The Imo North agro-climatic zone exhibit a highest positive predictive value of 0.288x + 311.8 and a corresponding maximum positive regression co-efficient of 0.077 that explains 7.7 percent of the proportion of uncertainties in annual rainfall cessation in the sampled location. The implication of the result is that most of the uncertainties are driven by geographic space and climatic factor itself. The Imo West possesses closely related high positive predictive power with a linearized regression equation of 0.265x + 315.1 and a comparative low positive regression co-efficient of 0.057 that accounted for a total of 5.7 percent of the total proportion of uncertainties in rainfall cessation in the agro-climatic zone as evidence in Table 4.

A further comparison based on findings from the Imo East agro-climatic zones depict marked disparities. Specifically, the linearized regression equation reveals a lowest predictive positive power of 0.207x + 316.6 and a corresponding least positive regression co-efficient of 0.035 that expressed a total of 3.5 percent of the proportion of uncertainties in annual rainfall cessation in Imo East agro-climatic zone. A generalized comparison of the results of the three agro-climatic zones led to a deduction that the leading positive predictive power and an affiliated dominant explainable variance in the regression co-efficient of rainfall cessation has strong affinity with the dynamics in relief and depletion of natural forest vegetation and land use types in Imo North agro-climatic zone. In context of literature, the results differ from Hubertus et al. whose study ‘shows the importance to analyze rainfall changes locally and seasonally as they are mainly perceived in how they affect agricultural activities’ [17]. The observed difference is directly linked to the choice methods and locations.

Table 4. *Analysis of Trend Patterns in Rainfall Cessation at Imo Agro-climatic Zones.*

	Rainfall Data Points	Regression Equation	Regression Coefficient (R)	Pattern of Trend
Northern	Okwe	y = 0.288x + 311.8	0.077	Increasing
Eastern	Orisaeze	y = 0.207x + 316.6	0.035	Increasing
Western	Awomama	y = 0.265x + 315.1	0.057	Increasing

Source: Authors’ Analysis (2025).

4.3. Evaluation of the Locational Impacts on Rainfall Cessations in Agro-climatic Zones

To elucidate the multiple proportion of explainable variance and test for variation in the impact geographic locations on uncertainties in rainfall cessation among three agro-climatic zones of Imo State, multiple linear regression, ANOVA, and T-test model were used and the results are presented in Tables 5, 6 and 7 for easy perusal, comparison, and chronological assessments.

In Table 5 the results of multiple regression models indicate that the regression co-efficient is 0.301 and the regression square of 0.090 while the standard error associated with the model is offers 0.82212. Dimensionally, the low positive regression co-efficient 0.301 implies that 3.01 percent of the impact of variations in geographic locations is attributed to the uncertainties in annual rainfall cessation in Imo State agro-climatic zones. In another perspective, the regression results suggests that uncertainties in rainfall cessation among the distinct agro-climatic zones can be better explain by factors such as spatial spread, relief, vegetation, but accelerated by multi-purpose land uses and abuses as triggered by urbanization as envisaged in Umo *et al.* [28], Montgomery [33], Ackerman and Knox [34].

Table 5. *Regression Analysis of Multiple Impacts of Locations on Rainfall Cessations.*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.301[a]	0.090	0.020	0.82212

a. Predictors: (Constant), Cess_Imo_West, Cess_Imo_North, Cess_Imo_East

To test for the multiple effect of impact of variations in geographic location on the combination of uncertainties in rainfall cessation among the three distinct agro-climatic zones, ANOVA model was employed and the results summarized in Table 6 reveal that the sum of squares associated with the model is 2.617 while the sum of squares of the residual offers 26.359.

Furthermore, the mean square of regression gives 0.872 while the mean square of residual reveals a value of 0.676 in the series. When the model was subjected to statistical test, the result gives a calculated low positive ANOVA value of 1.291 that is statistical insignificance at 0.05 confidence level. The results contradicted Umo and Enwereuzor [27] report in the wetland area of Kwa Iboe River whose pattern maintained statistical significant variations. It is therefore inferred from the result that of dynamics in geographic locations have no statistically significant impacts in uncertainties in rainfall cessation among the agro-climatic zones.

Table 6. *ANOVA[a] Model of Impact of Location on Annual Rainfall Cessations in Imo State.*

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.617	3	0.872	1.291	0.291[b]
	Residual	26.359	39	0.676		
	Total	28.977	42			

a. Dependent Variable: Geographic Location.
b. Predictors: (Constant), Cess_Imo_West, Cess_Imo_North, Cess_Imo_East

Discounting the results in the multiple models presented in Tables 5 and 6, partial regression model and T-test statistics were employed. The model results of rainfall cessations for Imo North, Imo East, and Imo West summarized in Table 7 reveal that the standardized partial regression co-efficient of 0.129, 0.870, and -0.945 respectively. The logical comparison of the results show that the highest proportion of variance associated partial regression model of -0.945 is recorded in the Imo West agro-climatic zone, followed by a high positive value of 0.870 in the Imo East, while the least value of 0.129 is accrue to the Imo North agro-climatic zone. Indeed, Umo, Okoroafor & Ukwe whose work the promotion of sustainable development and creation of ecological smart future with limited or zero flood disaster risk is useful in this regard [1]. However, such actions demand developing, working, and sustaining preliminary ecological disaster plans blueprint whose principles, methods, and applications in Nigerian environment need be people-society friendly is necessary in this context [1].

Table 7. *Partial Regression and T- Test of Variations between Parameters in Imo State.*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.698	3.212		0.217	0.829
	Cess_Imo_North	0.008	0.017	0.129	0.476	0.637
	Cess_Imo_East	0.052	0.028	0.870	1.895	0.066
	Cess_Imo_West	-0.056	0.030	-0.945	-1.866	0.070

a. Dependent Variable: Location

On the contrary, the T-test models of the level of significance summarized in Table 7 indicate a unilateral statistically insignificant impact between the dependent and independent variables at 0.05 confidence level. The finding led to a deduction that there is no statistically significant impact of uncertainties between geographical location and rainfall cessation in each agro-climatic zone of Imo State. The result collaborates Abaneme *et al.* whose study on fluxes in rainfall during length of growing established statistical insignificant locational effect [35].

5. Conclusion

The preceding discourses on space-time uncertainties in rainfall cessations across agro-climatic zones in Imo State have exercised diverging effects on crop yield, production and food security. The pre-mature harvests due to rainfall deficit and low soil moisture that lead to reduction in farmers' net crop outputs accelerated by adverse weather changes. The established patterns vary from Moron et al [13, 36] whose finding partly depicts 'that daily intensities are largely spatially incoherent except at short distances, while daily occurrence tends to exhibit larger spatial scales.

The collective efforts in tackling climate change impacts have gained popularity at the global level. The small farm holders in the rural and local agro-land users are worst hit due to limited capacity to adapt to the uncertainties associated with early annual rainfall cessation leading to meteorological and hydrological droughts in diverse zones of Imo State.

The existing hydrological potentials such as Oguta Lake, Imo River, Orashi River, Njaba River and others are generally under-utilized with respect to damming technologies and irrigation facilities leading to over-reliance on rainfall indices (onsets, length of growing season and cessations). Hence there need to optimally develop hydrological potential along the ongoing power projects for to boost the State and regional agricultural production promote sustainability in security for the rising population.

6. Public Policy Recommendations

In consideration of the results discussed in the preceding subsections and conclusion drawn, this study recommend as following.

1) Establishments of zonal agro-climate change education centers. The establishments of three agro-climatic zones in Imo State with modern meteorological equipment and personnel can offer naissance services such as recording, monitoring, forecasting, and educating the rural and urban residents on the past, present, and possible future weather and climatic events. Such actions can help to mitigate or eradicate people level ignorance on the dangers of adverse weather climate indices on agricultural production and food security in the State.
2) Capacity building for sustainable farmers' adaptation to uncertainties in and synoptic weather changes. There is urgent need for advocacy planning and farmers' education on how to response to extreme rainfall and temperature events in their localities. Damming technologies and irrigation facilities especially in the wetland regions of Okigwe and Oguta can offer sustainable and people friendly options for the management of meteorological drought due to early rainfall cessation or late rainfall onset in the study area.
3) Crop production in each agro-climatic zone is constraint by limited family land due to land fragmentation. Therefore, government and communities should acquire acres of land across different zones in the rural areas and use as public demonstration farms for commercial agriculture. Such intervention will aid commercial and irrigation agriculture for enhance crop production and food security.

Abbreviations

ANOVA	Analysis of Variance
R	Regression
Cess	Cessation
Std	Standard

Acknowledgments

The authors acknowledged the University of East Anglia Climatic Research Unit (Harris, Jones, Osborn & Lister, 2020), CRU time series version 4.05 of high resolution gridded and the technical service offered by Obot Akpan Ibanga during climatic data extraction phase.

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Funding

The authors acknowledge the financial support of the Tertiary Education Trust Fund (TetFund) Institutional-based research (2024 intervention) for the procurement of equipment and execution of the field work.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Umo, I. S., Okoroafor, P. E. N., and Ukwe, I. G. (2021). Climate variability and the issues in flood disaster risk awareness in Nigerian communities. NIPES Journal of Science and Technology Research, 3(4), 271–282. https://doi.org/10.37933/nipes/3.4.2021.27

[2] Umo, I. S., Keke, I. C. & Enwereuzor A. I. (2026). Spatio-temporal models of maximum surface temperature in context of human comfort in Imo State ecological provinces. Alvan Journal of Social Sciences, 3(1), 682-692. https://www-ajsspub-org.b12sites.com

[3] Ezemonye M. N., Ibanga, O. A., et al. (2025). The dynamics in rainfall and its implications on hunting livelihood in the littoral ecological zones of Niger Delta. Alvan Journal of Social Sciences, 2(3), 671-692. https://www-ajsspub-org.b12sites.com

[4] Food and Agricultural Organization (2015). Climate change and food security: Risks and responses. Accessed 22/4/2023 from https://www.fao.org/publications

[5] Pendergrass, A. G., Knutti, R., Lehner, F., Deser, C., & Sanderson, B. M. (2017). Precipitation variability increases in a warmer climate. Science Report 7, 17966.

[6] Barbier, E. (2019). The Water Paradox: Overcoming the Global Crisis in Water Management. Yale University Press.

[7] Hall, J. W., et al. (2014). Water Security. Coping with the curse of freshwater variability. Science, 346, 429–430.

[8] Aryal, A., Maharjan, M., Talchabhadel, R., & Thapa, B. R. (2022). Characterizing meteorological droughts in Nepal: A comparative analysis of standardized precipitation index and rainfall anomaly index. Earth, 3, 409–432. https://doi.org/10.3390/earth3010025

[9] Zaveri, E., Russ, J. & Damania, R. (2020). Rainfall anomalies are a significant driver of cropland expansion. Edited by Anthony J. Bebbington: PNAS Sustainability Science), 117(19), 10225 – 10233. Proceedings of the National Academy of Sciences, 2020. https://www.pnas.org/cgi/doi/10.173/pnas.1910719117

[10] Kundu, A., Patel, N. R., Denis, D. M., Dutta, D. (2020). An estimation of hydro-meteorological drought stress over the central part of India using geo-information technology. Journal of Indian Society for Remote Sensing, 48, 1-9.

[11] Ferijal, T., Batelaan, O., Shanafield, M., & Alfahmi, F. (2022). Determination of rainy season onset and cessation based on a flexible driest period. *Theoretical and Applied Climatology, 148*, 91–104. https://doi.org/10.1007/s00704-021-03917-1

[12] Robertson AW, Moron V, Swarinoto Y (2009). Seasonal predictability of daily rainfall statistics over Indramayu district, Indonesia. *International Journal of Climatology, 29,* 1449–1462.

[13] Moron, V., A. W. Robertson, and M. N. Ward, 2006: Seasonal predictability and spatial coherence of rainfall characteristics in the tropical setting of Senegal. *Mon. Wea. Rev.*, 134, 3248–3262.

[14] Harris, I., Osborn, T. J., Jones, P. & Lister, D. (2020). Version 4 of the CRU/TS monthly high resolution gridded multivariate climate dataset. Data, 7 article 109. Retrieved online from https://doi.org/10.1038/s41597-020-0453.3

[15] Umo, I. S., Enwereuzor, A. I. and Ezemonye, M. N. (2021). Mathematical modelling of seasonal dynamics of bedload sediments in eco-geomorphologic units of humid tropical Rivers, Southeastern Nigeria. *NIPES Journal of Science and Technology Research, 3*(4), 259–270. https://doi.org/10.37933/nipes/3.4.2021.26

[16] Mondal, P. (2014). A review study of eco-geomorphology an interdisciplinary approach to River science. Gideon Research Thoughts, 3(8), 1 – 7.

[17] Hubertus, L., Groth, J., Teucher, M. & Hermans, K. Rainfall changes perceived by farmers and captured by meteorological data: Two sides to every story. Regional Environmental Change (2023) 23: 75, 1-15. https://doi.org/10.1007/s10113-023-02064-9

[18] Goswami, B. N. & Xavier, P. K. (2005). ENSO control on the south Asian monsoon through the length of the rainy season. *Geophysical Research Letter*, 32, L18717.

[19] Fu, R., Yin, L., Li, W., Arias, P. A., Dickinson, R. E., Huang, L., Chakraborty, S., Fernandes, K., Liebmann, B., Fisher, R. & Myneni, R. B. (2013). Increased dry-season length over southern Amazonia in recent decades and its implication for future climate projection. *Proceeding of the National Proceeding of the National Academy of Sciences*, 110, 18110-18115.

[20] Misra V, Dinapoli S (2014). The variability of the Southeast Asian summer monsoon. *International Journal of Climatology, 34*, 893 – 901.

[21] Duru, P. N., Umo, I. S. & Ojinma, C. C. (2015). Enhancing the capability of rural farmers towards effective soil management in Amucha community of Njaba, Imo State. Journal of Emerging Trends in Economics and Management Sciences, 6(8), 381-385. Retrieved online on 28/7/2025 from https://doi.org/10.10520/EJC174483

[22] Marjuki, Schrier G. V. D., Tank, A. M. G. K., Besselaar E. J. M. V. D., Nurhayati & Swarinoto, Y. S. (2016). Observed trends and variability in climate indices relevant for crop yields in Southeast Asia. *Journal of Climatology, 29*, 2651-2669.

[23] World Science Forum. Declaration of the 10th World Science Forum on Science for Social Justice. 2022: https://worldscienceforum.org/contents/draft-declaration-of-worldscience-forum-2022-is-now-open-for-comments-110144

[24] Stewart I, Capello M A, Mouri H, Mhopjeni K, Raji M. (2023). Three horizons for future geoscience. Earth Science System and Society, 3, 10079. Retrieved 2/3/2024 online from https://doi.org/10.3389/esss.2023.10079

[25] Umo, I. S. (2019). *The dynamics of sediments, heavy metals and nutrients in the Kwa Iboe River, southeastern Nigeria.* Unpublished Ph.D. Thesis, Department of Geography and Regional Planning, University of Benin, Nigeria.

[26] Umo I. S. (2025). An expanded synopsis on the dynamics of sediments, heavy metals, and nutrients in the Kwa Iboe River Basin, Nigeria. *Alvan Journal of Social Sciences, 2*(2), 1-15. https://www-ajsspub-org.b12sites.com

[27] Umo, I. S. and Enwereuzor, A. I. (2021). The implications of area morphology and particulate matters' distributions on the Kwa Iboe River Basin restoration, Southeastern Nigeria. *Journal of Water Resources and Ocean Sciences*, 10(3), 53 – 60. Retrieved on 20/4/2025 from https://doi.org/10.11648/j.wros.20211003.13

[28] Abeneme, A. O., et al. 2026. Space-time oscillations in rainfall onsets and implications on sustainable staple crop production in Imo State, Nigeria. *Journal of Atmospheric Science Research, 9*(2), 92 – 105. https://doi.org/10.30564/jasr.v9i2.13001

[29] Onwumerobi, A. C. 2004. A synopsis of geomorphology. 2nd Edition. Owerri, CRC Publication.

[30] Okoro UK, Chen W., Chieke C., & Nwofor 2014. Comparative analysis of gridded datasets and gauge k measurements of rainfall in the Niger Delta Regio. *Research journal of Environmental Science*, *8*(7), 373-390. https://doi.org/10.3923/rjes.2014.373.390

[31] Chen, D. L., Tian, Y. D., Yao, T. D., & Ou, T. H. (2016). Satellite measurements reveal strong anisotropy in spatial coherence of climate variations over the Tibet Plateau. *Scientific Reports*, *Number 6*, 484 – 504.

[32] Omonigho, G. M. (2022). A Comparative Analysis of Rural Livelihoods Vulnerability and Adaptation Strategies to Climate Change in the Mangrove Swamp and Freshwater Swamp Ecological Zones of Delta State, Nigeria. Unpublished PhD Synopsis, Department of Geography and Regional Planning, University of Benin.

[33] Montgomery, C. W. (2003). *Environmental geology*. 6th edition. Boston, McGraw Hill.

[34] Ackerman, S. A. and Knox, J. A. (2003). *Meteorology: Understanding the atmosphere*. United State, Thomson Book/Cole.

[35] Abaneme, A. O., Umo, I. S**.**, Ukwe, I. G. & Ogu, C. (2025). Spatio-temporal fluctuations in rainfall during the growing seasons and its implication on sustainable agro-land use and practices in Imo State. *Alvan Journal of Social Sciences, 2*(2), 1 – 21. https://www-ajsspub2.org

[36] Moron V., Robertson AW., Ward MN. & Camberlin P. 2007. Spatial coherence of tropical rainfall at the regional scale. Journal of Climate, 20(21), 5244 – 5263. https://doi.org/10.1175/2007JCLI1623.1