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RESEARCH ARTICLE

THE DYNAMICS IN RAINFALL AND ITS IMPLICATIONS ON HUNTING LIVELIHOOD IN THE LITTORAL ECOLOGICAL ZONES OF NIGER DELTA

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ABSTRACT

This study evaluates the space-time dynamics in rainfall and its implications on hunting livelihood in the littoral ecological zones (LEZs) of Niger Delta. The specific objectives include to: the trends, oscillations, and level of variations in rainfall patterns among the distinct LEZs and; statistically compare and model the variations in rainfall indices in the distinct LEZs. The study area was stratified into three, comprising the Eastern, Central and Western LEZs. Rainfall data were collected from the three zones using gridded method from 1901 to 2021 (121) climatic years and analyzed descriptively and inferentially. The results of monthly and annual distribution patterns of rainfall depicted disparities among the sampled LEZs. The linearized model using regression with time series revealed that the Western LEZ sustained a positive trend with the annual increase rate of 0.369, while the Eastern and Central LEZs maintained a negative trend with the annual decrease of 3.228 and -1.716 respectively. ANOVA model of variations in rainfall distributions across climatic year intervals give 8.112 and 3.659 that are statistically significant at 0.05 confidence level for the Eastern and Central LEZs. This study concluded that rainfall distribution remained highly dynamics in LEZs over time sequence, with the corresponding negative and positive implications on hunting livelihood and the regional ecosystem. Also, the volatile nature of the study area driven by varying types of water induced geomorphic hazards such as erosion, flood and soil water intrusion on marginal land and it ecosystem have and will continue to affect hunting activities and threaten food security dimensionally. This paper is calling for more proactive actions to mitigate or avert the impacts of climate change-induced rainfall disasters in the Niger Delta.

Keywords: climate change, rainfall, livelihood, hunting, littoral ecological zones, Niger Delta

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INTRODUCTION

There are indications that uncertainties in global and regional rainfall patterns have exerted enormous stress on the unity and sustainability of ecosystems, agriculture, environment, and human population in this (Anthropocene age) due to the impacts of climate change especially in the Tropic. Moreover, the past human efforts to mitigate the rainfall dynamics through periodic monitoring, forecast, and/ or predict the future rainfall scenarios with a view to assuaging the devastating negative consequences on agriculture and allied livelihoods tend to attract diverging opinions and responsiveness among the observers of space, researchers, and other stakeholders across distinct geographical locations, (contextualized here as agro-ecological zones). Generally, biodiversity is sustainably at peril, while the future of human population, land resources and environmental potentials remain insecure.

Dimensionally, the identified effects of past rainfall triggered trends on crop production are evident in several regions of the world (Porter, Xie, Challinor, Cochrane, Howden, Iqbal, *et al.*, 2014), with negative impacts more common than positive ones, including several periods of price spikes following climate extremes in key producing regions (Food and Agricultural Organization (FAO, 2015)). There are evidences that the impacts of climate change-induced rainfall uncertainties have already negatively affected wheat and maize yields at regional and global level (Lobell, Schlenker, and Costa-Roberts, 2011). The upsurge in periodic (daily, weekly, monthly and annual) rainfall frequency, density, and intensity had accelerated the unusual incidences of flood and erosion in most tropical regions with the damaging effects on staple crops (e.g. root/ tubers, cereals, and legumes) yields that sustain human survival.

According to Hänsel, Schucknecht and Matschullat (2015), the observed and projected increases in precipitation extremes, such as intense rain, snow, sleet, or hail as well as severe dry and wet phases impacts many economic sectors (e.g. aquaculture, crop production, animal husbandry). Related potential effects of climate change-induced dynamics in rainfall have been extensively discussed in literature, (e.g., on precipitation by Easterling et al. 2000; on heatwaves and drought –synoptic diagnosis by Fink, Brücher, Krüger, Leckebusch, Pinto & Ulbrich. 2004; on drought and desertification by Lehner, Döll, Alcamo, Henrichs & Kaspar, 2006; on precipitation extremes in Europe by Kundzewicz, Radziejewski, & Pińskwar, 2006; as well as on heat and drought by Rebetez, Mayer, Dupont, Schindler, Gartner, Kropp & Menzel, 2006). Although disparities existed based on locations, methods, researchers' interests, the regional-scale analyses and consequently societal adaptation to the inevitable consequences of changing local and regional climatological conditions are needed, since effects of global climate change vary notably on spatial and temporal scales.

Research evidences have shown the over within the last two decades, concerted efforts had been directed to enhance global food production and mitigate hunger and death especially within the Tropics, but with limited level of successes. A case report indicates that approximately '800 million people were chronically undernourished, while 161 million children under five years are stunted and two billion people lack the essential micronutrients they need to lead healthy lives' (FAO, 2015:ix) thereby posing threat to most countries population in this anthropocene. Amidst the uncertainties, FAO notes that, to satisfy the growing demand driven by population growth and dietary changes, food production will have to increase by 60 percent by 2050 (FAO 2015).

More seriously, the United Nation Sustainable Development Goal (UNSDG 13:1) of 2015 emphasizes thus: 'Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries'. Similarly, UNSDG (13:2) stresses the importance of this: 'integrate climate change measures into national policies, strategies and planning'. Yet, the phenomenal dynamics in rainfall distributions in the world's vulnerable littoral ecological zones are grossly neglected. The highlighted scenarios are pointers to key indicators of threats to global food security as accelerated by the growing impacts of climate change-triggered rainfall and temperature anomalies especially in the rural communities of various developing countries.

From the regional assessments, Garai (2014) identified severe impacts of extreme climate (rainfall and temperature) stressors on the livelihoods of coastal residents in Bangladesh's south-western area, with potentials of limiting the peoples' socio-economic productivities and diminishing employment options. Comparatively, Kabir, Khan, Hasan, & Aftab (2022) reported that residents in the same region adopted seasonal migration as a way of adaptation to climate-instigated disasters agriculture and allied means of livelihoods. A further exploration revealed that households in Bagali and Koyra had higher livelihood vulnerability due to a lack of support from relatives or friends, while limited access to local government services in Dakshin Bedkashi increased livelihood vulnerability (Khan et al., 2022).

In a quantitative modelling, Hänsel et al. (2015) found that between the frequency distribution of the SPI and of the mRAI was made for the period 1961–2000, which was also used as the validation period for the RCMs. The results of Kolmogorov-Smirnov test established no statistical significant differences existed in the 289 distributions between SPI and mRAI, while the frequency distribution of mRAI classes is not fully symmetrical, yet the statistical tests depicted no statistical significant deviation. For a specific evaluation of the future drought risk, purely precipitation-based indices like the tested SPI and mRAI bear some limitations and tend to underestimate the real drought risk (Hänsel *et al.*, 2015).

The districts of Dakshin Bedkashi and Bagali demonstrated higher livelihood vulnerability to climate induced disasters with illiterate household heads, where earlier studies had already identified the educational status of the household head as the significant driver of vulnerability in both Nepal (Sujakhu, Ranjitkar, Niraula, Salim, Nizami, Schmidt-Vogt, *et al.* 2018), while in South Africa, (Baiyegunhi & Fraser, 2014) established collaborated pattern. Similarly, a study revealed that residents without a male as head are often faced with livelihood vulnerability due to limited ability to adapt to extreme climate-induced hazards and lower access to livelihood resources and strategies (Islam, Sallu, Hubacek, & Paavola, 2014).

Recent studies have devoted much research efforts at determining the vulnerability of livelihoods to extreme climate change indicators (precipitation and temperature) especially in Euro-Asia and African morpho-climatic zones. The place-centered evidences reveal the dominance of agricultural (farming) productivities in the rural communities, with emphasis on small holdings. However, pattern established based on rainfall and/ or temperature dynamics depicted variances and homogeneities in the findings, defined by complexities in the choice of methods, ideas and content of the researchers' interests.

From a recent empirical study, Khan *et al.* (2022) established that gender and education of household heads, presence of dependents, crop growing, agriculture as major income source income, access to supports, government services, and social organizations as key indicators of adaptive capacity that determine vulnerability. Accordingly, partnership between government and the community might lead to new perspectives on climate risk mitigation measures and improved livelihood opportunities (Khan et al., 2022).

In the highly vulnerable region such as the littoral belt or coastal belt of the world, human populations that are dependent on agriculture and natural resources, with livelihoods that are highly exposed to climate change-induced extreme rainfall impacts, and who have very limited capacity to respond (FAO, 2015). In Niger Delta region with high levels of food insecurity and inequality, increased scenarios of floods and saltwater intrusion had continued to affect households with limited capacities, given their restricted access to resources to response (Omonigho, 2022). Also, gender and social differences discriminate people's access to adaptation options, or even information, such as weather and climate data (FAO, 2015).

Within the Littoral Ecological Zones (LEZ) of Niger Delta, rainfall uncertainties tend to exercise both constraining and enabling influences on the functionalities of crops and ecosystems which humans and their livelihoods depend. Moreover, recent treatises on climate change-induced rainfall rise in the littoral zones of the Africa and Nigeria in particular have been either neglected or only received a passing attention in research. Such neglects create an urgent need for adoption of both qualitative and quantitative tools in evaluating the regional dynamics in rainfall especially in highly vulnerable littoral ecological zones of Niger Delta.

Aim and Objectives

The aim of this study is to evaluate the space-time dynamics in rainfall and its implications on hunting livelihood from 1901 to 2021 (121) climatic years in LEZs of Niger Delta, Nigeria. The following specific objectives were formulated to guide this study:

i. To compare and describe the disparities in monthly and annual rainfall characteristics across distinct LEZs of Niger Delta.
ii. To evaluate the trends, oscillations, and level of variations in rainfall patterns among the different LEZs of Niger Delta.
iii. To statistically compare and model the variations in rainfall indices in the distinct littoral ecological zones of Niger Delta.
iv. To assess the policy implication of dynamics in rainfall patterns on hunting activities in LEZs of Niger Delta.

THE STUDY AREA

Location and Physiographic Provinces

The study area is situated within the coastal belt of Niger Delta region of Nigeria. It is located between Latitudes 5^0 28^1 and 8^0 26^1 North of the Equator and Longitudes 4^0 14^1 and $7^0 25^1$ East of Greenwich Meridian. Relatively, the entire southern flange is a transitional coast zone that separates Atlantic Ocean and the landmass of Southern Nigeria, the hinterland are interwoven with varying States and outcrop of elevation of different types (Figure 1). It covers an approximate land area of about of 70,000 square kilometers, representing 7.5 percent of the country's landmass (Omofonwan, 2013, Umo and Ike, 2020).

The climate is dominated by the humid Tropical (Af) classification based on Köppen's scheme. Contextually, the central region recorded rainfall all year round with potentials of complexities in temperature due to the influence of and proximity to the Atlantic Ocean (i.e. Ocean-land interactions). On the contrary, the upper borders of the Eastern and Western belts usually recorded comparatively low rainfall with clear incidences of peak and shot dry seasons, as well as long and short rainy seasons in each climatic year, given their distances away from the Ocean disparities in the level of vegetation cover (Umo and Ike, 2020).

Vegetation and Socio-economic Activities

The vegetation of the Littoral zone of Niger Delta region of Nigeria, vary across geographic location ranging from major atolls, islands, marine Swamps to freshwater Swamps. There are two dominant types of vegetation in the study area (Umo et al., 2021). The upper and middle areas are dominated by the tropical rainforest belt with both primary and secondary vegetation. The secondary vegetation types have been altered by diverse human occupations, excepting some pockets primary forests. These parts of the region are dominant source of water for domestic and agricultural uses (Umo, 2019; Umo *et al*., 2021). The soils are very rich in humus content and often favour diverging types of livelihoods.

The littoral belts adjourning the Atlantic Ocean exhibit two sequences of swampy vegetation type (i.e. fresh water swamp and salt water swamp) (Umo, 2019; Umo *et al*., 2021). The salt

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water is found in Creeks and usually possesses high salt content due to their proximity to and influence of the Atlantic Ocean (Figure 1).

The saltwater Swamps are dominant in Creeks and estuarine regions and usually possess high salinity content due to their proximities to the Atlantic Ocean (Figure 1). They are found within the estuarine belts especially where the Niger, Calabar, Ethiope, Imo, Kwa Iboe, and other major Rivers enter the Atlantic Ocean. The trees possess aerial root system due to Ocean water intrusion, but its resources are persistently altered by reckless human activities (Umo, 2019).

On the basis of socio-economic activities, the study area is one of the largest fishing settlements in West African coastland. Similarly, the Freshwater Swamps offer unique landform scenery for diverse agricultural activities and allied means of livelihoods to support the growing population. Specifically, large-scale fish farming (aquaculture), intensive and extensive crop production (cassava, yam, maize, vegetables, and rice), animal production (goat, sheep, cow, pig and birds), commercial fishing and hunting are common (Umo, 2019; Omonigho, 2022). Similarly, population increase in the region tend to accelerate the scrambling for and colonization of land for housing, industrialization, administration, marketing, political, agricultural, and allied commercial activities.

Figure 1: Littoral Zones in Niger Delta showing Locations of Climatic Data Extraction.
Source: Authors' Extraction (2022).

On the basis of industrial activities, the region possess a low lying terrain highly rich in hydrocarbon, clay and gravel deposits and has formed a viable unit for the exploitation and exploration of crude oil by both national and multinational companies and oil servicing firms within various locations such as Bonny, Eleme, Nembe, Warri, Onne, Brass, Eket, and Ibeno including Chevron, Shell, ExxonMobil, Trebelyn Oil and Gas (Umo *et al.*, 2021). More so, the Eleme and Warri petroleum refineries as well as the Onne, Calabar, and Warri sea ports are situated in the region.

METHODOLOGY

Sampled Locations for data

The littoral zone of Niger Delta was stratified into three distinct belts using State as index. The sampled States comprise the Eastern agro-ecological zone (Edo and Ondo), Central agro-ecological zone (Bayelsa, River, and Delta), and Eastern agro-ecological zone (Akwa Ibom, Cross River) respectively. In each belt, one climatic point was randomly sampled using simple balloting and details of the as depicted in Table 1.

Table 1: Geospatial Characteristics of Rainfall Data Extraction Points in the Littoral Zones

Littoral Zones	Nearest Community	Longitudes	Latitudes
Eastern	Gburudu, Ovia LGA, Edo State	4.121452	5.128413
Central	Jounkiri, Nembe LGA, Bayelsa State	4.560778	6.695616
Western	James Town, Calabar Southm, Cross River	4.831065	8.255551

Source: Authors' Fieldwork (2024).

Climatic Data Extraction

Although the methods used in determining rainfall onsets differ based on researchers' interests, choices, contents, contexts, and ideologies, this study employed the precipitation-based Agronomy method because of its amenability and adjustability to rainfall characteristics (indices) in the Niger Delta region of Nigeria. In term of context, the method offer one of the most intuitive threshold values of rainfall parameters within the stipulated climatic period and the planning and execution of hunting activities and allied livelihoods.

The extraction of seasonal rainfall indices for period of one hundred and twenty-one (121) climatic years (1901 to 2021) was carried out using gridded method. The gridded datasets were created with the grid cells' specifications of 0.5° × 0.5° in size to extract periodic rainfall characteristics from three distinct littoral ecological zones in Niger Delta, Nigeria. The extractions were carried out using the University of East Anglia Climatic Research Unit (Harris, Jones, Osborn, & Lister, 2020) model, supported by CRU time series version 4.05 of high resolution gridded data from January 1st, 1901 to December 31st, 2021 for 121 climatic years. The rationale was to avert the constraints of spatial/ locational coverage embedded in rainfall data archival from distinct Nigeria Meteorological Agency (NiMet's) weather stations in the Littoral ecological zones of Nigeria.

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To ascertain the reliability of the rainfall data, rainfall data series of NiMet Stations within the sample States and localities (see Table 1) for the three littoral ecological were obtained and that of CRU from the University of East Anglia Climatic Research Unit were tested using Cronbache model 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 propagated and applied in recent studies such as Okoro *et al*. (2014), Chen *et al*. (2016), and Omonigho (2022).

Methods of Data analysis

Data generated from the field survey were analyzed using descriptive and inferential statistics. The descriptive statistical tools used include graph, bar, mean, range, standard deviation, and variance for easy perusal and comparisons of patterns in the results. On the contrary, the inferential statistics compose of time series, regression, and Analysis of variance (ANOVA) respectively to create bases for statistical tests and assessments of variations, similarities, relationships, trends and oscillations within and among the littoral agro-ecological zones in Niger Delta. The statistical analyses were carried out using Statistical Packages for Social Sciences (SPSS) version 22.0, while test of significance was done at 0.05 confidence level.

PRESENETATIONS OF RESULT AND DISCUSSIONS

The results of the characteristics, patterns, trends, oscillations, and variations in monthly and annual rainfall distributions within and across distinct littoral ecological zones of Niger Delta are thematically presented and sequentially discussed in what follow.

Assessment of Monthly and Annual Rainfall Characteristics in Littoral Zones

The descriptive assessment of monthly rainfall characteristics from 1901 to 2021 (representing 121) climatic years is presented in Figure 2 using bar chart. The result clearly show spatial and temporal variations based on LEZ and monthly distributive patterns. From the dimension of Eastern LEZ of Niger Delta, the results reveal that the highest mean monthly rainfall amount of 396.7 mm was recorded in September, while a lowest mean value of 34.1 mm is associated with the month of January. In context of Central LEZ, the highest monthly mean score value of 381.4 mm is associated with the month of September, while a lowest monthly mean value of 37.1 mm was recorded in the December. In the Western LEZ, a highest mean monthly rainfall value of 347.3 mm was recorded in July while a lowest mean value of 16.9 mm was recorded in January.

The comparative assessments of the monthly mean rainfall distributions for 121 years depict some attributes of uniformities and heterogeneities years in LEZ of Niger Delta. In the perspective of maximum, the Eastern LEZ possesses a dominance highest mean rainfall

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values for eight climatic months, persistently from April to December (Figure 2). On the contrary, Central LEZ took a leads with highest mean monthly rainfall distributions, only for the months of January, February, and March. A further extrapolation of the monthly rainfall distributive patterns for 121 climatic years using lowest mean as surrogate clearly reveal a unilateral homogenous lowest pattern recorded in the Western LEZ, excepting the month of June and July where the Western LEZ exhibited the lowest distributive pattern. The strikingly high mean monthly rainfall coupled with the generalized incidences of rainfall in the study area is directly due to their proximities to and influence of Atlantic Ocean. The patterns, when compared with Hänsel *et al*. (2015) depicted contradictions based on the report that SPI and mRAI deliver a similar spread and mean of all ensemble members, regarding the frequency of certain anomaly classes on time scales of 1 to 12 months.

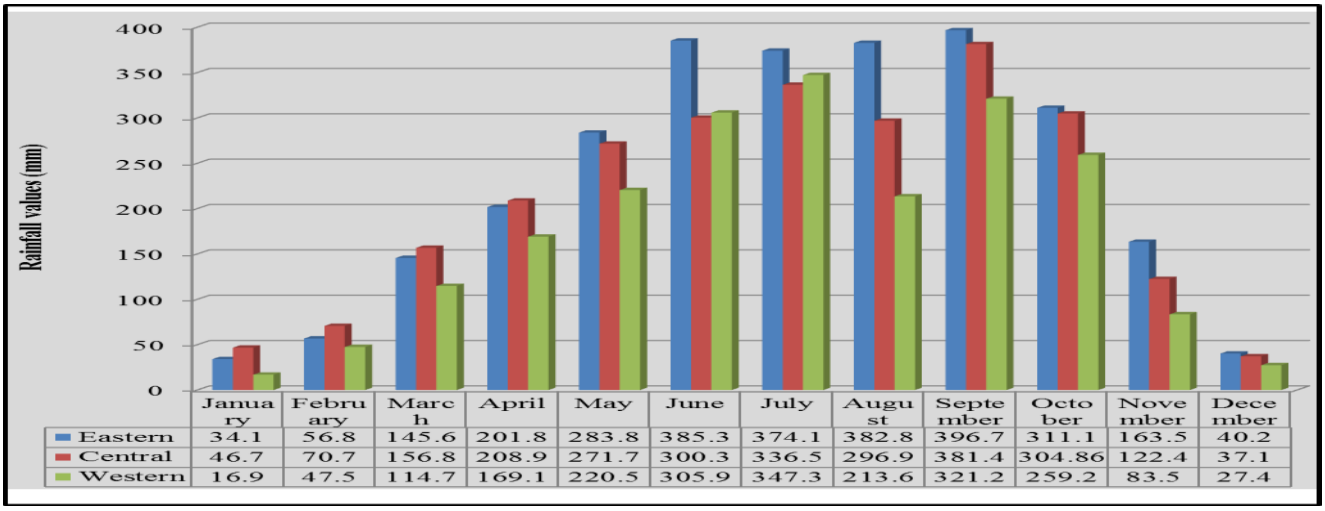

Figure 2: Analysis Monthly Rainfall Pattern in Littoral Ecological Zone of Niger-Delta.
Source: Authors' Analysis (2024).

The assessment of annual rainfall characteristics in LEZ of Niger Delta for 121 (1901 - 2021) climatic years using descriptive statistics is presented in Table 2 and the results reveal disparities. In the Eastern LEZ of Niger Delta, the results give a mean value of 2776.02 mm and a standard deviation of 263.55 mm. Furthermore, the variance is 9457.86 mm while range gives a value of 1187.9 mm respectively. On the basis of annual events, a lowest annual rainfall amount of 2259.2 mm was recorded in 1983 climatic year while a highest annual rainfall amount of 3447.1 mm was recorded in 1969 climatic year.

In context of the Central LEZ of Niger Delta, the results presented in Table 2 show a mean annual rainfall of 2534.28 mm with a standard deviation of 204.76 mm. The values for variance and range are 41927.21 and 1147.1 mm respectively. More so, a lowest rainfall amount of 1979.5 mm was recorded in 1983 while a highest amount of 3126.6 mm was recorded in 1905 climatic year within the Central LEZ of the Niger Delta. The intra-zonal divergences in rainfall amount attest the uniqueness of spatial location and local geographies of the littoral zone.

The descriptive explorations of rainfall characteristics for 121 years in the Western LEZ of Niger Delta presented in Table 2 equally depict divergences with respect to analytical tools. Specifically, the mean and standard deviation convey the values 2126.80 mm and 292.02 respectively. The result of variance and range give 85274.22 mm and 1686.7 mm in that order. A further descriptive evaluation based on minimum and maximum events reveal that a lowest rainfall mount of 1494.1 mm was recorded 1946 climatic years while a highest amount of 3180.8 mm was recorded in 1901 climatic year, accordingly.

Retrospectively, the comparative evaluations of the results at LEZ levels in Niger Delta reveal divergences in the results. Specifically, a highest mean monthly value of 2776.02 mm is associated with the Eastern LEZ, while a lowest monthly mean value of 2126.80 mm is recorded in the Western belt. On the domain of standard deviation, the lowest deviation from the mean is recorded in the Central LEZ with a value of 204.76 mm, while the highest deviation of 292.02 mm is recorded in the Western LEZ. The disparities in proportions standard deviation is an indication of uncertainties in annual rainfall characteristics across the climatic years (1901 – 2021).

Table 2: Descriptive Analyses of Characteristics of Annual Rainfall in LEZ of Niger-Delta

Descriptive Statistics	**Ecological zones**		
	Eastern	Central	Western
Mean (mm)	2776.02	2534.29	2126.80
Standard Deviation (mm)	263.55	204.76	292.02
Variance (mm)	69457.86	41927.21	85274.22
Range (mm)	1187.9	1147.1	1686.7
Minimum (mm/year)	2259.2 (1983)	1979.5 (1983)	1494.1 (1946)
Maximum (mm)	3447.1 (1969)	3126.6 (1905)	3180.8 (1901)
N (Years)	121	121	121

Source: Authors' Analysis (2024).

Patterns, Convergences and Oscillations of Annual Rainfall in LEZ of Niger Delta

The results of statistical assessments of annual rainfall trend and oscillation from 1901 to 2021 climatic in the three Littoral ecological zones of Niger Delta are presented in Figures 3, 4, and 5 respectively. The results show elements of homogeneity and heterogeneity among LEZ. In the Eastern LEZ of Niger Delta, the results presented in Figure 3 reveal that a highest rainfall amount of 3447.11 mm was recorded in 1969, followed by 3332.18 mm and 3294.35 mm in 1905 and 1963 climatic years respectively. On the contrary, the lowest rainfall of 2259.19 mm was recorded in 1983, followed by 2278.65 mm in 1984 climatic years.

On the basis of oscillation of events, the results reveal that a total of 56 climatic years recorded rainfall events above the regression line which are indication of excess rainfall amount with potential incidences of hydrological and geomorphological hazards such as flood and erosion with devastating impacts on hunting, fishing, and farming if appropriate adaptation option were not adopted. On the contrary, a total of 55 climatic years of rainfall events converge below the average line which implies that hunting activities were not negatively impacted or hindered in the Eastern LEZ of Niger Delta. A further evaluation of the results presented in Figure 3 clearly reveal that the residual of 10 climatic years converge within the regression line which symbolizes moderate incidences of annual rainfall amount with possible moderate impacts on hunting and allied socio-economic livelihoods.

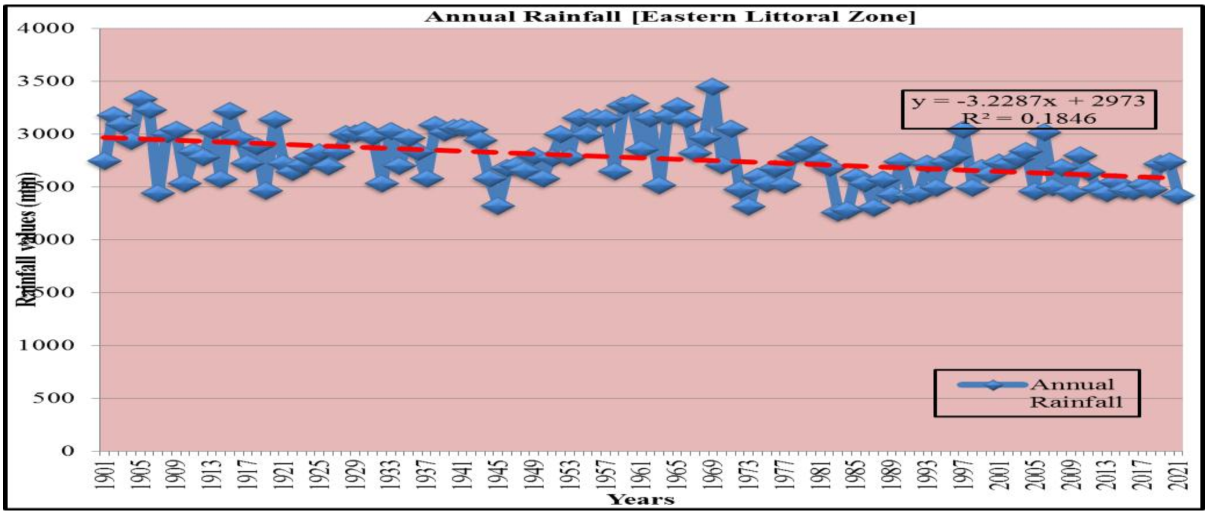

Figure 3: Temporal Trend of Annual Rainfall in Eastern LEZ of Niger Delta.
Source: Authors' Analysis (2024).

The time series model of annual rainfall distributions from 1901 to 2021 (121) climatic years in the Central LEZ is presented in Figure 4 and the results reveal dynamics in the amount received and convergence patterns. A retrospection of the results based on incidences reveal that a historic highest annual rainfall amount of 3126.63 mm was recorded in 1901, followed by 3015.00 mm recorded in 1954, and 2974.59 mm recorded in 1974 climatic year. Contrarily, a historic lowest rainfall amount of 1979.50 mm was recorded 1983 climatic year, followed by 2196.10 mm and 2215.94 recorded in 1977 and 1973 climatic years respectively.

The evaluation of the oscillation patterns presented in Figure 4 show that a total 50 climatic years recorded rainfall amount above the line of best fit which implied high negative influences (high vulnerability) to hunting and allied livelihoods on the people with the Central LEZ of Nigeria Delta. The high hunters' vulnerability to rainfall incidences suggests urgent need to build capacity for sustainable adaptation. On the contrary, a total of 44 climatic years recorded annual rainfall amount oscillating below the regression (average) line with obvious limited negative implication (low vulnerability) to hunting and allied livelihood in the Central LEZ of Niger Delta. Finally, a total of 27 climatic years recorded annual rainfall amount that converge within the trending (regression) line with a possible outcome of low to moderate vulnerability to crop production, aquaculture, and allied livelihoods in the sampled area.

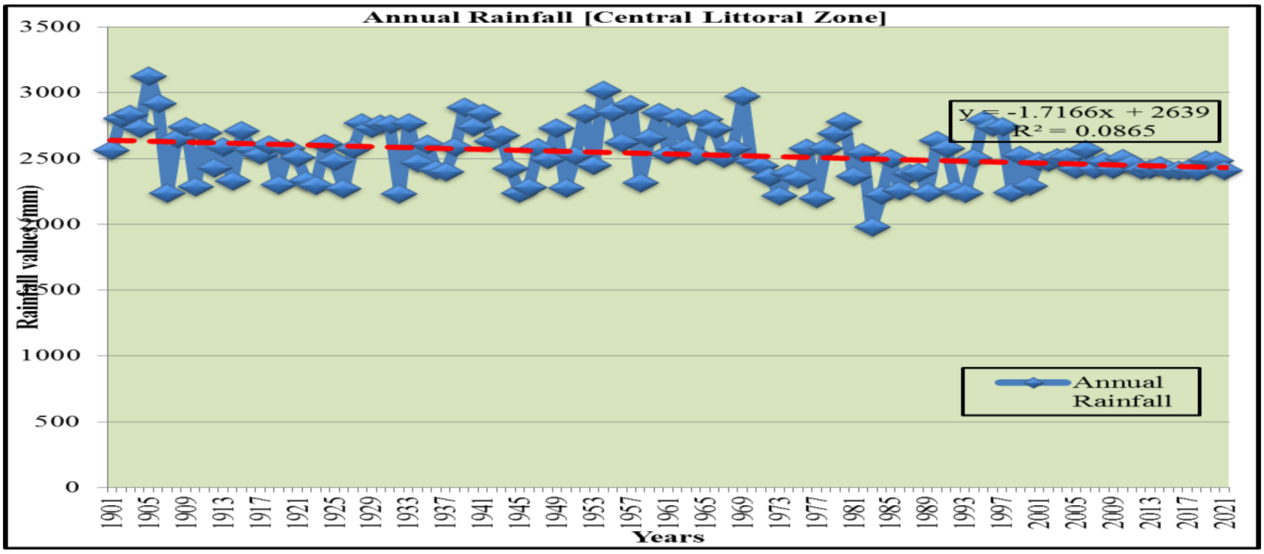

Figure 4: Temporal Trend of Annual Rainfall in Central LEZ of Niger Delta.
Source: Authors' Analysis (2024).

The evaluation of oscillation of annual rainfall amount in in the Western LEZ is presented in Figure 5 and the results depict disparities across the climatic years. Contextually, the results reveal that a highest historic rainfall amount of 3180.74 mm was recorded in 1901 climatic year. Other high historic records are associated with 1968 with a value of 3105.00 mm and 1917 with a value of 2971.10 mm respectively. Contrarily, a lowest historic annual rainfall amount of 1494.09 mm was recorded in 1946 climatic year. Other climatic years with very low annual rainfall amount are recorded in 1983 with an amount of 1597.53 mm and 1977 with a value of 1633.87 mm respectively.

From dimension of annual oscillation of rainfall amount, the time series model reveals presented in Figure 5 show that a total of 54 climatic years converge above the average line in the series which suggests that very high probability of vulnerability of hunting and allied livelihoods to climate change-induced rainfall excesses and the corresponding hazards in the Western LEZ of Niger Delta. In another perspective, the results further reveal that a total of 53 climatic years recorded an annual rainfall amount below the regression line which attests that low vulnerability of hunters and livelihoods to rainfall and allied climate change impacts in the study area. Further still, a total of 14 climatic years recorded annual rainfall amount as converging on the average (regression) line in the sampled allocation.

A retrospection of the results of the trending pattern in Figure 5 led to a deduction that the high level of oscillation of annual rainfall amount varied between the 20th century and 21st century, with a comparative higher level of hunters' vulnerability to rain-induced climate change stressor in 20th C than the present century. The inference can be attributed animal responsive to stressors via migration.

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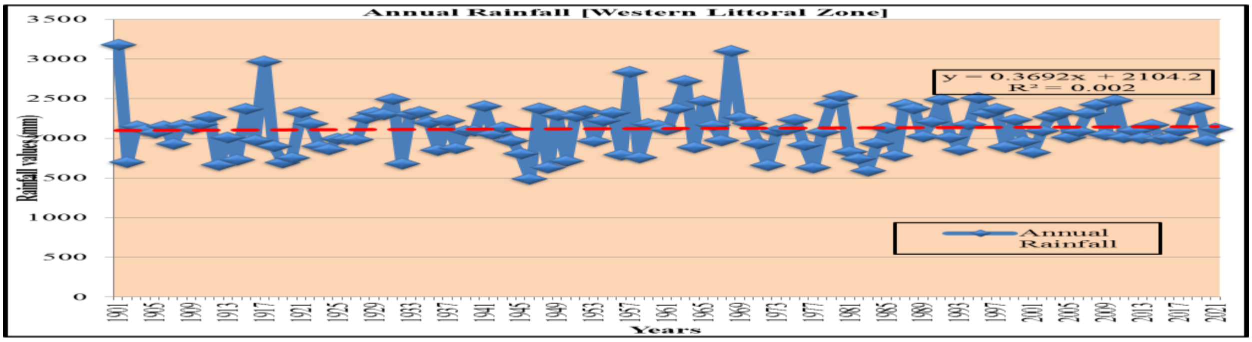

Figure 5: Temporal Trend of Annual Rainfall in Western LEZ of Niger Delta.
Source: Authors' Analysis (2024).

Assessments of Spatio-temporal Changes in Annual Rainfall in LEZs of Niger Delta

Linear regression was employed a as surrogate for assessing the variances and predicting changes in annual rainfall across the 121 (i.e. 1901 – 2021) climatic years in the three LEZ of Niger Delta. The results summarized in Table 3 depict divergences in terms of predictive powers and trending patterns. In Eastern LEZ, the model gives a negative predictive power of -3.228x which directly accelerates the downward trending pattern of regression (average) line as the climatic years increase (details in Figure 3). The regression coefficient gives a value of 0.184 which explained 18.4 percent of the proportion of variance in annual rainfall amount in the Eastern LEZ of Niger Delta.

In the Central LEZ of Niger Delta, the results of the linearized models of spatio-temporal variations in annual rainfall amount for 121 climatic years are summarized in Table 3. The results give a negative annual predictive value of -1.716x which triggers the downward tending pattern of the average (regression) line as the climatic years change from 1901 to 2021 (details in Figure 4). Also, the regression coefficient gives a positive value of 0.086 which account for 8.6 percent of proportion of variance in annual rainfall in the Central LEZ of Niger Delta.

In context of Western LEZ of Niger Delta, the results of statistical model summarized in Table 3 indicate disparities in the results. Specifically, the predictive power of annual change in rainfall gives a positive value of 0.369x which revolutionizes the upward tending pattern of the average (regression) line with changes in climatic years (from 1901 to 2021) as depicted in Figure 5. Furthermore, the regression coefficient gives a positive value of 0.002 which expressed a relatively low proportion of variance of 2.0 percent in annual rainfall in the Western LEZ of Niger Delta.

A general comparison of the results of inter-littoral ecological zones trends reveals that both the Eastern and Central LEZ possess a homogenous decreasing (negative) pattern. However, the Eastern LEZ is more pronounce than that of the Central. On the contrary, only the

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Western LEZ exhibits an increasing (positive) trend in the sequence. In context of regression coefficients, the results reveal a unilateral positive coefficient, but the Eastern LEZ is most dominance in the area.

Table 3: Regression and Time Series Models of Annual Rainfall in LEZ of Delta State.

Ecological zones	Regression Equation	Regression Coefficient	Pattern of Trend
Eastern	y = -3.228x + 2973	$R^2 = 0.184$	Decreasing
Central	y = -1.716x + 2639	$R^2 = 0.086$	Decreasing
Western	y = 0.369x + 2104	$R^2 = 0.002$	Increasing

Source: Authors' Analysis (2024).

Examinations and Tests of Interval Variances in Rainfall Amount

The temporal changes in rainfall attributes at interval of thirty years in the three distinct LEZs' of Niger Delta region were conducted using both descriptively examined using mean and standard deviation and the result presented in Table 4 revealed disparities in the score values with respect to climatic years and spatial locations. Within the Eastern LEZ of Niger Delta, the highest mean score of 2879.59 mm is recorded during 1901 – 2030 climatic years, while a lowest mean score of 2622.28 mm is associated with the 1991 – 2021 climatic years which strongly affirmed progressive declines in annual rainfall with increase in climatic years as established in the preceding subsections of this study. In context of standard deviation, the results presented in Table 4 showed that the highest deviation of from the mean of 307.44 mm is recorded in 1961 – 1990 climatic years. The result affirmed

The assessment of mean rainfall characteristics for the Central LEZ of Niger Delta gives a highest mean value of 2602.54 mm for 1931 – 1960 climatic years. This is followed by 2584.77 mm for 1901 – 1930 climatic years, while a highest standard deviation from the mean periodic rainfall amount of 220.66 mm is recorded for 1931 – 1960 climatic years. The value of standard deviation is followed by 213.33 mm recorded during 1961 – 1990 climatic years respectively.

A further temporal assessment based on the Western LEZ of Niger Delta clearly depicts the dominant mean value of 2161.91 mm recorded during 1991 – 2021 mm climatic years, followed by 2134.63 mm recorded for 1961 – 1990 mm climatic years. On the basis of standard deviation the results indicate that a highest value of 334.80 mm is associated with 1961 – 1990 climatic years while a lowest standard deviation of 196.19 mm is associated with 1991 – 2021 climatic years. The pattern deviates from Lloyd-Hughes and Saunders (2002) report that SPI reacts very sensitive to low precipitation totals and may yield unrealistically low values.

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Table 4: Descriptive Analyses of existence of changes in Periodic Rainfall in Niger Delta Region

Littoral Ecological Zone/Climatic Period		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Mini	Maxi
						Lower Bound	Upper Bound		
Eastern	1901 – 1930	30	2879.59	231.82	42.32	2793.03	2966.2	2439.6	3332.2
	1931 – 1960	30	2878.36	243.18	44.40	2787.56	2969.2	2321.2	3294.3
	1961 – 1990	30	2728.98	307.44	56.13	2614.18	2843.8	2259.2	3447.1
	1991 – 2021	31	2622.28	171.78	30.85	2559.27	2685.3	2420.0	3038.9
	Total	**121**	**2776.02**	**263.55**	**23.96**	**2728.59**	**2823.5**	**2259.2**	**3447.1**
Central	1901 – 1930	30	2584.93	213.86	39.05	2505.07	2664.8	2238.3	3126.6
	1931 – 1960	30	2602.49	220.66	40.29	2520.10	2684.9	2232.6	3015.0
	1961 – 1990	30	2486.47	217.33	39.68	2405.32	2567.6	1979.5	2974.6
	1991 – 2021	31	2465.54	127.99	22.99	2418.59	2512.5	2236.8	2791.6
	Total	**121**	**2534.29**	**204.76**	**18.61**	**2497.43**	**2571.1**	**1979.5**	**3126.6**
Western	1901 – 1930	30	2110.11	332.25	60.66	1986.05	2234.2	1669.6	3180.8
	1931 – 1960	30	2099.38	296.84	54.20	1988.54	2210.2	1494.1	2841.2
	1961 – 1990	30	2134.63	334.80	61.13	2009.62	2259.7	1600.0	3105.6
	1991 – 2021	31	2161.91	196.19	35.24	2089.94	2233.9	1827.5	2513.3
	Total	**121**	**2126.80**	**292.02**	**26.55**	**2074.24**	**2179.4**	**1494.1**	**3180.8**

Source: Authors' Analysis (2024).

The extrapolation of the results presented in Table 4 using inter-littoral ecological zones of Niger Delta as indices reveal widespread disparities in context and content. Comparatively, the Eastern LEZ record a most dominant mean value of 2776.02 mm, followed by Central LEZ of Niger Delta with a mean score of 2534.29 mm while the Western LEZ record a least mean value of 2126.80 mm. A further comparison of the results using standard deviation as basis shows that a highest value of 292.02 mm is recorded in the Western LEZ. This is followed by the Eastern LEZ with a value of 263.55 mm while a lowest value of 204.76 mm is associated with the Central LEZ. The implication of the pattern in the results is that the Central LEZ of Niger Delta depict strong allegiance to the principles of uniformity of rainfall in the Tropics, whereas the Western and Eastern LEZs' of Niger Delta were under a strong and directly influence of the local and geographical factors such as proximity to the Ocean/ other water bodies, vegetation, land use, seasonal changes, climate change, and relative position of ITCZ a period of time.

Evaluation of Spatial and Temporal Variances of Rainfall Patterns in Niger Delta

The comparative evaluation of variations in periodic rainfall for each LEZ of Niger Delta region is carried out using ANOVA and the results presented in Table 5 differs. At the Eastern LEZ, the results reveal that the sum of squares between groups gives 1435089.07, while within groups gives 689945.38 and a grand total of 8334943.38 respectively. Furthermore, the mean sum of squares between groups gives 478363.02, while within groups give 58973.11. When the result is further aggregated, the calculated F value gives a high value of 8.112 that is significant at 0.000 confidence level. The high F-value led to an inference that there is statistical significant variation in rainfall dynamics at periodic intervals in the Eastern LEZ of Niger Delta.

In context of the Central LEZ, the ANOVA model of the sum of squares between groups gives 431592.71, within groups gives 4599673.01, while the total sum squares is 5031265.72. More so, the mean squares between groups gives. A test of variation at varying intervals gives an F-statistic of 3.659 that is significant at 0.015 confidence level. It is affirmed that there is statistical significant variations in rainfall at varying intervals in the Central LEZ of Niger Delta. A further retrospection based on the results summarized in Table 5 for Eastern and Western LEZ indicate that though statistical significant variations across each interval, the F-statistical value is more dominance in Eastern LEZ than the Central LEZ of Niger Delta.

From the Western LEZ, the ANOVA assessment gives 70953.52 for variation between groups, 10161953.27 for between groups, and a total sum of squares of 10232906.78 respectively. Also, the mean square between groups gives a value of 23651.17 and within groups gives a value of 86854.30 accordingly. However, the calculated F- statistics gives an abysmal low value of 0.272 that is statistically insignificant at 0.05 confidence level. This study established that there are no statistical significant variations in rainfall intervals in the Western LEZ of Niger Delta. The pattern collaborated Hänsel *et al.* (2015) report of slight deviations in the magnitude and statistical non-significance of the observed and projected trends in rainfall indices.

Table 5: ANOVA Model of Variations in Periodic Rainfall in Each LEZ of Niger Delta

		Sum of Squares	df	Mean Square	F	Sig.
Eastern	Between Groups	1435089.07	3	478363.02	8.112	0.000
	Within Groups	6899854.31	117	58973.11		
	Total	8334943.38	120			
Central	Between Groups	431592.71	3	143864.24	3.659	0.015
	Within Groups	4599673.01	117	39313.45		
	Total	5031265.72	120			
Western	Between Groups	70953.52	3	23651.17	0.272	0.845
	Within Groups	10161953.27	117	86854.30		
	Total	10232906.78	120			

Source: Authors' Analysis (2024).

Evaluations of Multiple Differences in Rainfall Patterns in Niger Delta

The test of multiple differences in the mean rainfall pattern at varying intervals in each LEZ of Niger Delta is carried out using Turkey HSD and the results presented in Table 6 differs based on the climatic year intervals. In the Eastern LEZ, the multiple comparisons of the mean values reveal that the climatic years 1991 – 2021 exhibited persistent high mean values across distinct climatic year intervals on the order of 257.31, 256.08, 256.08, and -257.31 respectively. However, the positive differences in the mean depicts a proportionate increase on rainfall during the climatic year intervals, while the negative differences in the mean values represents a proportionate decrease in rainfall during the climatic year intervals.

Table 6: Tukey HSD Multiple Models of Mean Differences in Rainfall Dynamics

Dependent Variable			Mean Difference (I-J)	Standard Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Eastern	1901 - 1930	1931 - 1960	1.22	62.70	1.000	(162.20)	164.65
		1961 - 1990	150.60	62.70	0.082	(12.82)	314.03
		1991 - 2021	257.31*	62.19	0.000	95.21	419.41
	1931 - 1960	1901 - 1930	(1.22)	62.70	1.000	(164.65)	162.20
		1961 - 1990	149.38	62.70	0.086	(14.04)	312.80
		1991 - 2021	256.08*	62.19	0.000	93.98	418.18
	1961 - 1990	1901 - 1930	(150.60)	62.70	0.082	(314.03)	12.82
		1931 - 1960	(149.38)	62.70	0.086	(312.80)	14.04
		1991 - 2021	106.70	62.19	0.320	(55.40)	268.80
	1991 - 2021	1901 - 1930	-257.31*	62.19	0.000	(419.41)	(95.21)
		1931 - 1960	-256.08*	62.19	0.000	(418.18)	(93.98)
		1961 - 1990	(106.70)	62.19	0.320	(268.80)	55.40
Central	1901 - 1930	1931 - 1960	(17.56)	51.19	0.986	(151.00)	115.87
		1961 - 1990	98.45	51.19	0.224	(34.98)	231.89
		1991 - 2021	119.39	50.78	0.093	(12.96)	251.74
	1931 - 1960	1901 - 1930	17.56	51.19	0.986	(115.87)	151.00
		1961 - 1990	116.02	51.19	0.112	(17.41)	249.45
		1991 - 2021	136.95*	50.78	**0.040**	4.60	269.30
	1961 - 1990	1901 - 1930	(98.45)	51.19	0.224	(231.89)	34.98
		1931 - 1960	(116.02)	51.19	0.112	(249.45)	17.41
		1991 - 2021	20.93	50.78	0.976	(111.42)	153.28
	1991 - 2021	1901 - 1930	(119.39)	50.78	0.093	(251.74)	12.96
		1931 - 1960	-136.95*	50.78	**0.040**	(269.30)	(4.60)
		1961 - 1990	(20.93)	50.78	0.976	(153.28)	111.42
Western	1901 - 1930	1931 - 1960	10.73	76.09	0.999	(187.60)	209.05
		1961 - 1990	(24.52)	76.09	0.988	(222.85)	173.81
		1991 - 2021	(51.80)	75.48	0.902	(248.52)	144.92
	1931 - 1960	1901 - 1930	(10.73)	76.09	0.999	(209.05)	187.60
		1961 - 1990	(35.25)	76.09	0.967	(233.57)	163.08
		1991 - 2021	(62.52)	75.48	0.841	(259.24)	134.20
	1961 - 1990	1901 - 1930	24.52	76.09	0.988	(173.81)	222.85
		1931 - 1960	35.25	76.09	0.967	(163.08)	233.57
		1991 - 2021	(27.28)	75.48	0.984	(224.00)	169.44
	1991 - 2021	1901 - 1930	51.80	75.48	0.902	(144.92)	248.52
		1931 - 1960	62.52	75.48	0.841	(134.20)	259.24
		1961 - 1990	27.28	75.48	0.984	(169.44)	224.00

*Denotes a mean difference that is statistically significance at the 0.05 level.

Source: Authors' Analysis (2024).

However, the highlighted mean affirmed statistical significant difference at 0.05 confidence level. The variations in the mean pattern affirms Porter *et al.*, 2014) observation that the of past rainfall uncertainties has triggered regional trends in crop production across the world, and FAO (2015) report of over-riding negative impacts than positive ones, including dimension periods of price spikes.

The comparisons of multiple mean in Central LEZ reveal that the climatic year intervals 1931 – 1960 maintain a high positive mean difference with the values of 136.95. This is followed by 1991 – 2021 climatic years interval with a negative value of -136.95. Apart from the differences in positive and negative values, each score difference is statistical significance at 0.040 confidence level. Contrarily, other climatic year intervals within the Central ecological zones sustain a fairly high negative or positive mean difference that is statistically insignificant differences in the series. The further probes on the results in context of Western littoral ecological zone of Niger Delta clearly reveal that differences existed, but each remains statistically insignificance across distinct climatic period designated in the sequence.

The high mean distribution patterns are strong affirmation of the maxims of annual rainfall congruities in the Tropics. However, the direct influence of local geography especially, land breeze and Ocean current, thermal heating and cooling, vegetation and land use, as well as other intervening variables that are peculiar to the littoral ecological zones of Niger Delta.

Implication of Findings on the Sustainability of Hunting and Allied Livelihoods

The assessments of rainfall dynamics in the littoral ecological zones of zones of Niger Delta region depicted the level of disparities on the month and annual distributions with attendance adverse implications on hunting and allied livelihood activities. It is evidence that rainfall distribution remained a highly dynamics in the littoral ecological zones of Niger Delta over time sequence, with the corresponding differences in impacts on farmers' crop productivities in particular and the regional ecosystem in general. The volatile nature of the study area driven by varying types of water induced erosion (e.g. splash, sheet, rill, and gully) on marginal land, rivers, and Ocean, as well as floods (e.g. coastal, marine, river, urban, flashflood) had and will continue to affect hunting livelihood, agricultural output and food security in one dimension, thereby calling for proactive actions.

Similarly, the regression and time series model of space time trends and oscillation in rainfall indicates that the Eastern LEZ and Central LEZ sustain homogeneity with rather diverging negative trending patterns and the corresponding downward trend of the average lines, but with comparatively higher predictive power in the Eastern. For hunting livelihoods, this has several vital implications. The drying and downward rainfall trends mean wildlife will become scarcer, harder to find, and more unpredictable. This directly threatens the viability of hunting as a livelihood in both Eastern and Central LEZ, but especially in the Eastern where the trend is stronger and more sustained. Another implication is that the two ecological zones within Niger Delta are most likely to experienced increase in agricultural production and better quality of life. Efforts should be directed to avert or mitigate drought through river irrigation system, enlightenment and people-oriented emancipation programmes in the area.

On the contrary, the Western LEZ remains positive in it high predictive power leading to upward trending pattern of the regression line in the series. For hunting livelihoods in general, this trend carries several important implications including improved habitat conditions and wildlife abundance, more stable and predictable hunting seasons, return or influx of migratory species and reduced pressure and conflict over resources among others. The upward and positive rainfall trend in the Western LEZ promotes vegetation growth, increases wildlife availability, and stabilizes hunting seasons. These may likely make hunting a more viable and productive livelihood compared to the drying Eastern and Central LEZ.

Another likely implication is that the excess rainfall scenarios will continue to exceed the land (soil) carrying capacity leading to flood, erosion, excess moisture contents, sporadic loss of major nutrients and the devastating effect of low agricultural productivities and increase food insecurity. However, the structural engineering works on drainages, dredging of water bodies and land/crop conservation practices remains inevitable in this context to serve agriculture and ecosystem from such anomalies and stressors.

CONCLUSION AND RECOMMENDATIONS

The preceding discourses on patterns, trends, and dynamics of rainfall in littoral ecological zones in Niger Delta reveal spatial and temporal variations. In context of space, the Eastern LEZ maintains protracted and persistent high annual and interval rainfall characteristics over other literal zones. Such patterns are majorly attributed to its proximity to and influence of ocean, rivers, and wetland vegetation which collectively accelerate cloud formation and convectional rainfall. On the contrary, the Central LEZ depicts consistent and comparatively low variations in the distributive patterns of rainfall in the Niger Delta due to the effect of local geography with obvious negative implications on hunting activities and allied livelihoods.

Competing Interest

The authors declare that no conflicting interest exist in this manuscript.

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REFERENCES

Baiyegunhi, L. and Fraser, G. (2014). Poverty incidence among smallholder farmers in the amathole district municipality, Eastern Cape Province, South Africa. *Journal of Human Ecology*, 46(3), 261 – 73. https://doi.org/10.1080/09709274.2014.11906725.

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.

Easterling, D.R., Meehl, G.A., Parmesan, C., Changnon, S.A., Karl, T.R., & Mearns, L.O. (2000). Climate extremes: Observations, modeling, and impacts. *Science*, 289, 2068 – 2074. https://doi.org/10.1126/science.289.5487.2068

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

Fink, A.H., Brücher, T., Krüger, A., Leckebusch, G.C., Pinto, J., Ulbrich, U. (2004). The 2003 European summer heatwaves and drought –synoptic diagnosis and impacts. *Weather*, 59, 209 – 216. Retrieved from https://doi.org/10.1256/wea.73.04

Food and Agriculture Organization (FAO, 2015). *Climate change and food security: Risks and responses*. The United Nations.

Garai, J. (2014). The impacts of climate change on the livelihoods of coastal people in Bangladesh: a sociological study. In: Leal FW, Alves F, Caeiro S, Azeiteiro U, editors. International Perspectives on Climate Change. *Climate Change Management. Cham: Springer*, 151 – 163. https://doi.org/10.1007/978-3- 319-04489-7_11.

Hänsel, S., Schucknecht, A., and Matschullat, J. (2015). The modified Rainfall Anomaly Index (mRAI)—Is this an alternative to the Standardized Precipitation Index (SPI) in evaluating future extreme precipitation characteristics? *Theoretical and Applied Climatology*. Retrieved on 22/2/2023 from https://doi.org/10.1007/s00704-015-1389-

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*, https://doi.org/10.1038/s41597-020-0453.3

Islam, M.M., Sallu, S., Hubacek, K., and Paavola, J. (2014). Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh. *Regional Environmental Change*, 14(1), 281 – 94. https://doi.org/10.1007/s10113-013- 0487-6

Khan, A., Hasan, K. and Kabir, K.H. (2022). Determinants of households' livelihood vulnerability due to climate induced disaster in southwest coastal region of Bangladesh. *Progress in Disaster Science*, 15 100243 https://doi.org/10.1016/j.pdisas.2022.100243

Kabir, KH, Khan MA, Hasan K, and Aftab S. (2022). Driving forces of adaptation decision and strategies to climate-related events: case on farming households in South–West Coastal Bangladesh. *Journal of Environmental Assessment and Policy Management,* 2250019. https://doi.org/10.1142/S1464333222500193

Kundzewicz, Z.W., Radziejewski, M., & Pińskwar, I. (2006). Precipitation extremes in the changing climate of Europe. *Climatological Research*, 31, 51 – 58.

Lehner B, Döll P, Alcamo J, Henrichs T, Kaspar F (2006). Estimating the impact of global change on flood and drought risks in Europe: A continental, integrated analysis. *Climate Change*, 75, 273 – 299. https://doi.org/10.1007/s10584-006-6338-4

Lobell, D.B., Schlenker, W. & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616 – 620.

Lobell, D., Baldos U. C. and Hertel, T.W. (2013). Climate adaptation as mitigation: the case of agricultural investments. *Environmental Research Letters,* 8, 1 – 12.

Lloyd-Hughes, B. and Saunders, M.A. (2002). A drought climatology for Europe. *Inter. Journal of Climatology*, 22, 1571 – 1592. https://doi.org/10.1002/joc.846

Okoro, U.K., Chen, W., Chineke, C., and Nwofor, O. (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

Omofonwan S.I. (2013). The challenges of infrastructural development in Niger Delta trigon of Nigeria. *Benin Journal of Social Sciences,* 21(1), 24 – 31.

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*. PhD Thesis, University of Benin.

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B. & Travasso, M.I. (2014). Food security and food production systems. *In* C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea & L.L. White, eds. *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects*, pp. 485–533. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, and New York, USA, Cambridge University Press.

Rebetez M, Mayer H, Dupont O, Schindler D, Gartner K, Kropp JP, Menzel A (2006). Heat and drought 2003 in Europe: A climate synthesis. *Anal for Sciences*, 63, 569 – 577. https://doi.org/10.1051/forest:2006043

Sujakhu, N.M., Ranjitkar S., Niraula, R.R., Salim, M.A., Nizami, A., Schmidt-Vogt, D., et al. (2018). Determinants of livelihood vulnerability in farming communities in two sites in the Asian Highlands. *Water International*, 43(2), 165 – 82. https://doi.org/10.1080/02508060.2017.1416445

Umo, I.S. and Ike, M.C. (2020). *A dimension of geographic regions and landforms*. Chapters 14 – 15, Owerri, Brilliant Print.

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, 229 pages..

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/3.4.2021.27 [Goggle Scholar]

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. https://doi.org/10.11648/j.wros.20211003.13 [Goggle Scholar]