NIPES
Journal of Energy Technology and Environment
Journal homepage: www.nipesjournals.org.ng

Nigerian Coastal Region's Vulnerability to Climate Change

Agbonaye, A.I*. and Izinyon, O.C
Department of Civil Engineering, University of Benin, Benin Edo State, Nigeria
*Corresponding Author Email: **augustine.agbonaye@uniben.edu,** **(+2348033781630)**

Article information

Article History
Received: 16 February 2024
Revised: 25 February 2024
Accepted: 27 February 2024
Available online: 15 March. 2024

Keywords:
Climate change, Sea-level rise, Saltwater intrusion, Coastal vulnerability, Habitat loss

OpenAIRE
https://doi.org/10.5281/zenodo.10823101

https://nipesjournals.org.ng

Abstract

Nigeria's coastal region is considered to be highly vulnerable to climate change and climate variability due to its proximity to the sea. With increasing temperature and decreasing rainfall, fewer resources to adapt: socially, technologically, and financially, it isbeing challenged and threatened by a multitude of environmentalproblems such as sea-level rise, Saltwater intrusion in the aquifer,inundation of low-lying areas, flooding, soil and coastline erosion, pollution, habitat loss, loss of biodiversity, etc. A substantial amount of work has already been done by many researchers on assessing the impacts and vulnerabilities of climate change, as well as considering possible adaptation options. However, they have been focusing on individual components of complex systemsand have not been able to fully address issues or inform interventions such as those that aim at empowering communities from a gender perspective in the study areas in a holistic manner.This paper which seeks to address this gap presents a review of several past research studies by carrying out an in-depth study ofmethods adopted, findings, and recommendations. The study identified risks, classified vulnerabilities, and assessed results, revealing that climate variability and change interventions face challenges or are only partially effective.. Reducing the vulnerability of coastal communities to the impact of climatechange requires a holistic approach. To assist adaptation planning and the implementation of strategies, barriers and enablers which are critical have been identified. Our findings willcontribute to the field of climate change impacts in understandingthe complexities of rural development.
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1. Introduction

Vulnerability is one of the main issues that is frequently related to climate change. Vulnerabilityhas a complex relationship with this occurring climate variability, such that it encompasses an extensive range of areas and involves a number of factors.[1] .
According to [2] , in Nigeria, floods are a common natural hazard that have increased in frequency during the past few decades. Trade, infrastructure, agriculture, health, and the economy are all severely

impacted. Severe floods have a negative impact on economic growth in commerce and agriculture, as seen in 2012. Sea level rise-related increased flooding has detrimental effects on human settlements, coastal ecosystems, infrastructure, agriculture, and the economy. Nigeria'sshoreline has been experiencing rising sea levels, which has resulted in coastal erosion and the disappearance of several villages (such as Erstwhile Village in Delta State). According to their estimates, 75% of the Niger Delta's land could disappear if sea levels rose by just one metre.

Literature on vulnerability as it relates to climate change is vast [3] and there is a growing interest in assessing vulnerability for environmental and socio-economic disciplines[4],[5][6],[7][8].[9],[10][13], &[14]. [15] investigated the vulnerabilities of the three major ecological zones in Delta State of the Niger Delta Region to climate change. Indicators of exposure, sensitivity, and adaptive capacity were examined using Principal Component Analysis (PCA).. The results showed that Warri North Local Government Area and Warri Southwest Local Government Area were the most vulnerable in terms of temperature. [16] assessed the vulnerability of West African countries to climate change using selected indicators for adaptive capacity, exposure and sensitivity to generate a vulnerability index for West African countries The vulnerability index was calculated as the net effect of adaptive capacity, sensitivity, and exposure to climate change. ArcGIS 10.2, a GIS software program, was used to create vulnerability maps. The result showed the following: adaptive capacity (61-80), sensitivity (41.00-60.00), exposure (0-20), and vulnerability index (21-40) for Nigeria's coastal Region

In their mix scale application of GIS and descriptive statistics, [17] concentrated on the problems, patterns, and influences related to a regional evaluation of climate change in Southern Nigeria. The region is dealing with changes in climate parameters (land use, greenhouse gas (GHG) emissions, precipitation patterns, sea level rise, flooding, and rising temperature) as a result of pressures from socioeconomic and physical factors, according to results obtained from a combination of scale impacts and efforts. [18] considered the risks from and vulnerabilities to flooding in four urban poor communities close to the coast in Lagos, Nigeria, and the factors that have contributed to increasing flood risks in Lagos, He concluded that the vulnerability of the poor urban population ishighly linked to poor urban management and the government's inability to deal adequately with theissues.

These researchers among others have focused on vulnerability assessment due to climate change in some states and components of complex systems. In addition to the limitation of their research to a few states. They did not completely address problems or provide well-informed solutions, such as those that seek to empower communities in the research regions holistically from a gender viewpoint.
This paper which seeks to address this gap present in several past research studies by carrying out an in-depth study of methods adopted, findings, and recommendations.

2. Materials and Methods

2.1 The Area of Study

Nigeria's coastline region is the study area. Geographically, the region lies between latitudes 4 and 8 degrees North and longitudes 3 and 9 degrees East (Figure.1). Nigeria's coastline stretches 853 kilometers across nine states. namely Cross River, Akwa-Ibom, Rivers, Bayelsa, Delta, Edo, Ondo, Ogun, and Lagos states. Nine stations, each from these states, were selected for representative coverage. The Region is divided into two separate seasons: the wet season (April to November) and the aridity season (December to March). High humidity and temperatures, together with distinctrainy and dry seasons, characterize Nigeria's climate

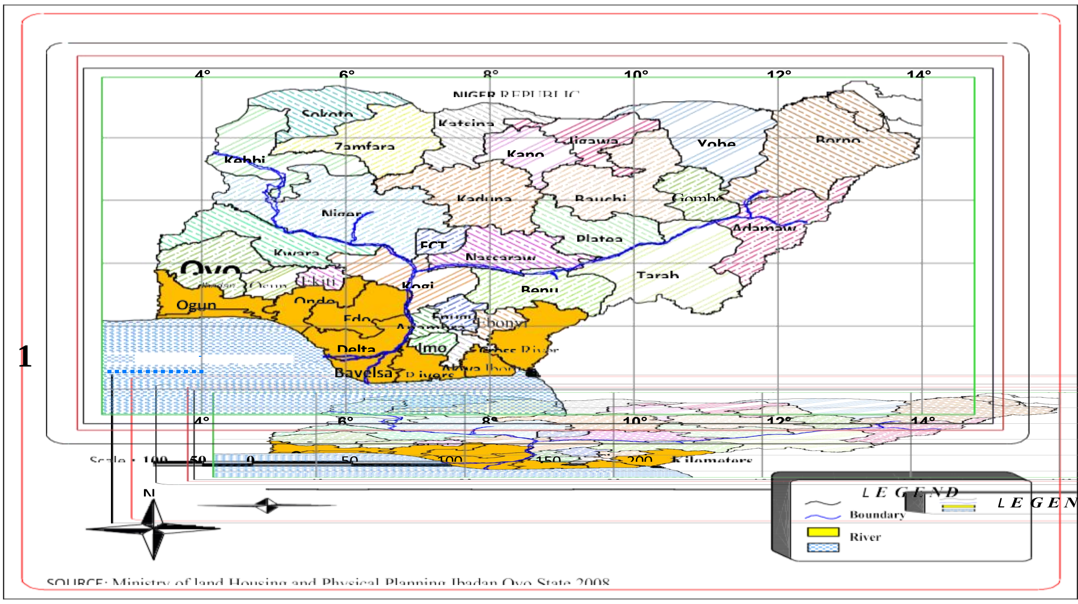

Figure. 1: Nigeria Coastal States

The State's Population and their areas are depicted in Table 1

Table 1: The State's Population and their Sizes (Source: [19] Nigerian Bureau of Statistics, 2006)

State	Population (2006)	Area (Km^2)	State	Population (2006)	Area (Km^2)
Akwa Ibom	5,450,758	7,081	Lagos	17,552,940	3,577
Bayelsa	1,704,515	10,773	Ogun	3,751,140	16,980
Cross River	3,737,517	20,156	Ondo	3,460,877	15,500
Delta	4,112,445	17,698	Rivers	5,198,716	11,077
Edo	3,233,366	17,802	Total	55,919,679	119,500

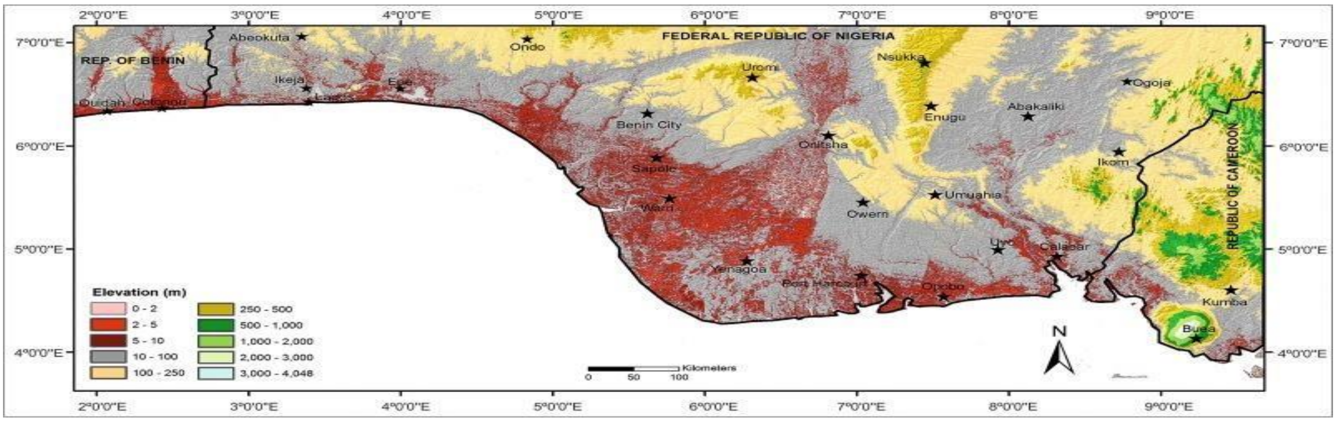

Figure2: Elevation of some major towns and cities in the study area (Source: [20]]

2.2 The Flowchart for the adopted methodology

The adopted methodology is illustrated by the Flowchart in Figure 3:

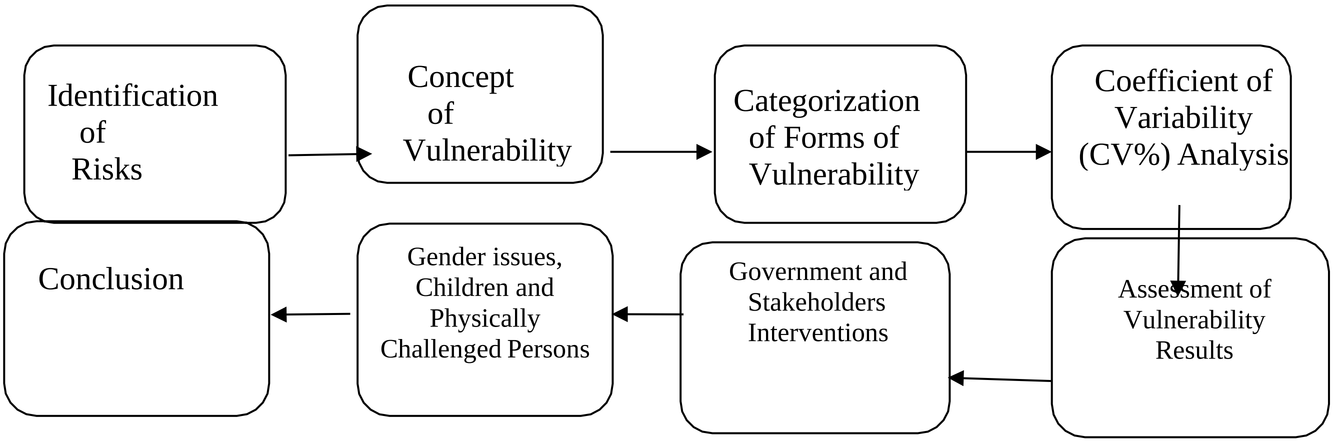

Figure 3: The Flowchart for the Adopted Methodology

2.3 Identification of Risk

In a study carried out by **[**21**]** to identify the risks and effects related to climate change. They came to the conclusion that these risks have a negative impact on people either directly or indirectly, and that they have the potential to significantly increase chronic poverty, hunger, disease, mortality, displacement, and violent conflict in many developing countries when temperature and rainfall patterns change and extreme weather events occur. Furthermore, ecosystems, social and cultural structures, and economic systems are all at risk from climatic fluctuation and change. They believed that the only way to lessen these hazards would be to take adaptive measures. Income, biodiversity, health, mortality, and infrastructure hazards are the different categories of risks. Nonetheless, the following are the primary dangers linked to climatic unpredictability in coastal regions:

A) Risks to agriculture and food security

Living in rural areas, the majority of the impoverished in the region rely either directly or indirectly on agriculture. Climate change has a negative influence on food security and agricultural productivity in the region. The people who practice low-intensity, low-input rainfed farming, are cut off from markets, having little possibilities to accumulate assets and escape poverty. They are mostexposed to the effects of climate change, especially with regard to variations in temperature and rainfall variability. In the entire region, soil erosion and land degradation are already serious issues.The variety of land management techniques that are grouped together under the heading of "climate smart agriculture" have the potential to control rainfall unpredictability and deal with ongoing watershortages in rainfed systems.

B) Risks to water resources and water-dependent services.

The water cycle plays a major role in the effects of climate change, but forecasting these effects is still difficult due to the intricate causal relationship that exists between temperature and rainfall, water supplies, and services that depend on water. Overall, the region's water availability is better than in other areas, although measures hide issues with both temporal and spatial variability. Although "hot spots" of excessive consumption and exploitation are beginning to emerge along the urban-rural interface and in basins where irrigation and hydropower development coexist, mobilizing water for lives and livelihoods remains a major concern. In order to protect against the unpredictability of rainfall and to replenish groundwater, more intense rainfall events may be beneficial. The overall effects on the supply of water will probably be less than those caused by demand-side factors, especially population expansion. The impacts of climate change on water quality is broadly negative and transmitted through rising temperatures and high flow/flood-related sediment and pollution loads [22] **.** Water availability may not be as dangerous to household users as deteriorating water quality, which could have negative effects on health and (mal)nutrition. Although the amount of water taken out of the country for household consumption makes up a minor portion, having access to clean drinking water is essential for both human health and climate resilience. Greater, longer-term hydropower expenditures to fill energy shortfalls run the danger of locking in unsuitable design because of past climate conditions.

C) Risks to health:

It is anticipated that non-communicable (not transmissible) diseases will surpass maternal, newborn, and communicable (transmittable diseases) as the primary causes of death. Though the rate of urbanization and the expansion of informal urban settlements may modify the health landscape, exposing millions to many "urban" dangers associated with substandard housing, unsanitary environments, and basic services, food insecurity, malnutrition, and poverty still primarily affect rural populations. Risks will increase due to rising temperatures and the effects of heavy rains on water supplies and hygienic conditions. This is especially true given the number of people who still lack access to clean water and proper sanitation. Heat stress will also be brought on by rising temperatures and temperature extremes, especially in cities, even though temperatures in lowland rural areas are already above what is livable for humans**..**

D) Risks to urban environments and infrastructure.

Filling in the gaps in the region's power, irrigation, water supply, sanitation, transportation, communications, electrical, and flood protection infrastructure will be extremely difficult. The risk of climate change locking in delayed onset trends like warming, changes in multi-annual variability, fluctuations in mean precipitation conditions, and changes in the frequency and intensity of extremes like droughts and floods must be unlocked with new investments in order to unlock growth and poverty reduction. The most evident threats to the current infrastructure are seen not just in the increasing number of smaller towns and cities where planned infrastructure provision is falling behind urban expansion, but also in established metropolis. The loss of a single road link or bridge can cut off vast areas and a significant population from access to markets in rural areas with low traffic densities.

E) Flood-risk management:

In both rural and urban contexts, as well as at the interface between them, nature-based solutions to reduce flood risk and provide a range of co-benefits are frequently promoted. However, unless they are paired with "hard" infrastructure, they may not be able to effectively address the issue of flooding during heavy rainfall events.

F) Risks to coastal areas and fisheries :

The Nigerian coastline is home to some of the busiest ports, population centers, and tourist destinations in the area. Rising sea levels, increasing temperatures, and more frequent and powerful storm surges pose a threat to local businesses and way of life, with possible regional repercussions. Coastal fisheries, coral reefs, and marine ecosystems are threatened by both rising sea temperatures and marine heat waves, which include biodiversity and climate-sensitive ecosystems. Coastal agriculture and drinking water supplies are also threatened by salt intrusion into coastal aquifers and flood damage. The health of ecosystems and fish stocks are already at risk due to eutrophication and rising temperatures, but overfishing and the release of contaminants into river and lake systems are also contributing factors to these changes. Frequent floods in the vicinity of shorelines and back-ups into tributary rivers already pose issues, forcing people to relocate and interfering with power, transportation, sanitation, and drinking water systems

G) : inter-relationship between risk, vulnerability, exposure, hazard:

The inter-relationship between risk, vulnerability, exposure, hazard is depicted in figure 4.

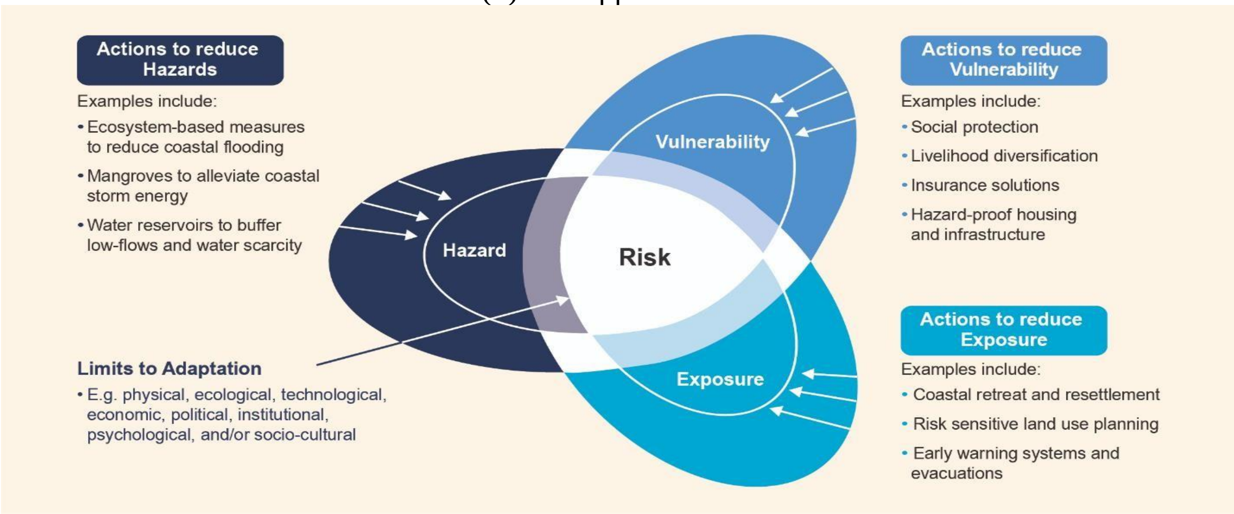

Figure 4: inter-relationship between risk, vulnerability, exposure, hazard, and actions to reduce them [23]

There is a direct link between vulnerability and risk **(**where: Risk = f (Hazard, Exposure, Vulnerability). Eutrophication and rising temperatures are already putting ecosystems and fish stocks in jeopardy,but overfishing and the discharge of pollutants into river and lake systems are also major contributors to these changes. Regular flooding near shorelines and backups into tributary rivers already cause problems, displacing residents and disrupting systems for power, transportation, sanitation, and drinking water.

2.4 Concept of Climate Vulnerability

Numerous research have attempted to examine the meaning and idea of vulnerability. [24] , [25]. A common theme appears in most definitions of vulnerability. They all agree that vulnerability shows the degree of susceptibility of society to a hazard, which could vary either as a result of variable exposure to the hazard or because of coping abilities
The intergovernmental panel for climate change [26] defined vulnerability as “the degree to which a system (natural or social) is susceptible or unable to cope with the adverse effect of climate change and its extremes”. It defined vulnerability as a function of exposure (the frequency of events), sensitivity (a system's ability to be impacted), and adaptive capacity (a system's ability to deal with or adapt to the changing situation). Countries and regions may be exposed to similar extremes of climate change, but they differ in their ability to adapt to these shocks.

Vulnerability = function [exposure (+); sensitivity (+); adaptive capacity (-). It is also expressed as:
Vulnerability = potential impact (sensitivity x exposure) – adaptive capacity

[27] similarly defined vulnerability to climate change as “the degree to which geophysical, biological and socio-economic systems are susceptible to and unable to cope with, adverse impacts of climate change”. It is considered that vulnerability is a result of "exposure."”, “sensitivity” and “adaptive capacity” [28]. Exposure is seen as the extent to which a system experiences internal and external system perturbation, pressures, or changes[29] .Sensitivity is defined as the degree to which a system is affected or will respond to system perturbations or changes (such as a change in climate) either positively or negatively[30] .Such changes could be either long-term changes in climate conditions, or changes in climate variability, which includes the magnitude and frequency of occurrence of extreme climatic events[31] **.** Adaptive capacity is defined as the ability of a system to adjust its behavior and characteristics to enhance its ability to cope with external stress[32]. It is

considered "a function of wealth, technology, education, information, skills infrastructure, access to resources, and stability and management capabilities" [30].

Vulnerability maps are powerful visual tools that can be used to point out areas more susceptible to harm compared to other areas [1] . It is used by researchers in analyzing aggregates of indicators that determine varying spatial levels of vulnerability across various geographical zones on the bases of ecological or socio-economical differences [33] . Spatial differences in climate change vulnerabilities are depicted in vulnerability maps, which provide researchers and policymakers with information identifying areas that are more prone to climate change impacts and require intervention measures, as well as what type of intervention measures, are appropriate, to forestall the advent of associated disasters[34] .Inter-relationship between climate variability, sensibility, exposure, potential impact, adaptive capacity, and vulnerability. is presented in Figure 5
.

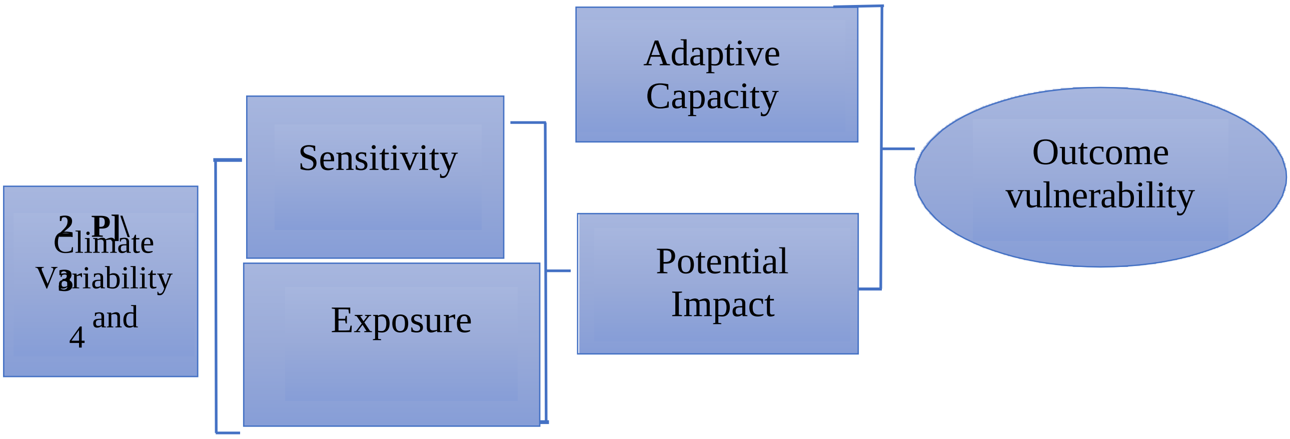

Figure 5: Interdependence Of Climate Variability, Exposure, Sensitivity, Potential Impact, Adaptability, And Vulnerability.

Evaluating the possible effects of climate change entails determining their potential size, which is contingent only upon exposure and sensitivity.

Variables that may affect how sensitive you are to climate change
(1)mental and physical well-being and age (for socio-economic groups);
(2 the degree to which climate stimuli have an impact on goods and services (for industries);
(3)the degree to which climatic factors have an impact on physical structures and the services they provide (for assets and infrastructure);
(4)resilience, connectedness, and state of health of ecosystems (for ecosystems)

Variables that may affect how sensitive you are to climate change:
(1) the capacity to obtain and evaluate information; (2) the funds to devote to adaptation
(3) A system's ability to adapt to changes in the climate (4) Adaptability and openness to adjust (5) Capability of species migration or ecosystem expansion into new zones Sensitivity and adaptive capacity matrix is shown in Table 2

Table 2: Sensitivity and adaptive capacity matrix:.(Source: [35] .

		Sensitivity: Low to High				
Adaptive Capacity: Low to High		S0	S1	S2	S3	S4
	AC0	V2	V3	V4	V5	V5
	AC1	V1	V1	V2	V3	V4
	AC2	V0	V0	V0	V1	V2

ACI, AC2, AC3, AC4, AC5, and AC5 are Adaptive while S1, S2 S3, S4. and S5 are Sensitivity.

Vulnerability Results are classified into five levels and assigned values ranging from 1 to 5: V5: High vulnerability (5), V4**:** medium-high vulnerability (4), V3: medium vulnerability (3), V2: medium-low vulnerability (2), and V1: low vulnerability (1)

2.5 Major Classifications of Climate Change Vulnerabilities

Varying rainfall and increasing temperature in the Coastal Region of Nigeria led to these various forms of vulnerabilities

1) Water resources vulnerabilities -declining water availability and water quality, sea level rise causing saltwater intrusions into the shallow aquifer
2) Food vulnerabilities. Climate change is a serious threat to food security due to declining crop yield, fishery, animal production ,and chronic hunger and malnutrition for a large percentage of the population.
3) Energy sector vulnerabilities to climate change- rising temperatures, in particular, would increase energy demand for air conditioning, refrigeration, and other household uses. Hydroelectric power generation is frequently hampered by the low inflow into dams. Impacts on transmission, distribution and transfers.
4) Land degradation and vulnerabilities- coastal flooding. Coastal erosion and land loss
5) Human health vulnerabilities. -frequent widespread and sustained epidemics of infections and waterborne diseases with high human mortality
6) Ecosystem and biodiversity vulnerability-loss of entire ecosystem and extinction of many of the ecosystem species
7) Rural economy vulnerabilities- insecurity, violent conflict over land, migration, infrastructural loss, loss of jobs.

Two approaches are utilized in this study to obtain the coastal vulnerability index (cvi): an analytical hierarchical process (ahp) based approach to coastal vulnerability studies and the cvi formula proposed by[36]. Based on geomorphic units, the Nigerian coast was separated into seventeen (17) parts. The various vulnerability variables were ranked from 1 to 5, where 1 denoted the least vulnerability and 5 the most vulnerability. The socioeconomic characteristics include population, cultural heritage, land use/cover, and road network, whereas the geomorphological and physical parameters include coastal slope, bathymetry, geomorphology, wave height, mean tidal range, coastline change rate, and relative sea-level rise.

[37] quantified and classified the vulnerability of the Nigerian coastline to these threats using the analytical hierarchical approach. In order to determine the coastal vulnerability index (cvi), socioeconomic and physical characteristics that indicated the vulnerability of the coastline were used for the whole coastal region.
Vulnerability index computed using this approach ranged from 3.29 to 4.70. The results obtained from both approaches showed that 59–65% of the entire Nigerian coastline is under moderate to high vulnerability to sea-level rise coastal vulnerability maps, highlighting the physical–geomorphological and socioeconomic vulnerability status of the Nigerian coastline were also generated.

2.6 Nigeria's Coastal Region Vulnerability Due to Climate Variability

Climate variability will increase vulnerability if prudential policies for adapting to its effects are not established at a convenient time [38] . Hence climate variability study is crucial in understanding climate vulnerability and any development strategy should consider climate variability as a persistent vulnerability to poverty.
The degree of variability in long-term mean distributions of climatic variables is indicated by the variation's coefficient. It is employed to evaluate the dispersion of the data points around the mean. The coefficient of variation is a commonly used metric for assessing data dispersion between several data series. Unlike the standard deviation, which is always taken into consideration when determining the mean of the data, the coefficient of variation provides a quick and easy method for comparing various data sets. The coefficient of variation (CV) eliminates the unit of measurement from the standard deviation of a series of data by dividing it by the series' mean [39] .
The equation for the percentage coefficient of variation is;

$$CV = \frac{SD \ x \ 100}{\bar{X}} \quad (1)$$

Where SD is the Standard Deviation and X is the mean of the data set

3. Results and Discussions

3.1 Descriptive Statistics of Spatial Rainfall and Temperature for the First and Second Climatic Periods Compared

The Descriptive statistics of mean annual rainfall for the first and second climatic periods (1956-1986 and 1987-2016) respectively, in the coastal region of Nigeria are presented in Table 3.

Table 3, Descriptive statistics of mean annual rainfall (1956- 1986 And 1987-2016),

Climatic Station	Climatic period	Mean mm	SD mm	Min mm	Max mm	Range mm	Sum mm	%CV	Skewness	Kurtosis
Akwa Ibom	First	256.432	141.655	31,419	446.198	406.778	2820.75	55.241	-0.150	-1.428
	Second	253.454	145.712	40.227	470.165	429.938	2787.99	57.490	-0.124	-1.376
Bayelsa	First	274.493	149.599	55.805	475.693	419.889	3019.42	54.500	-0.015	-1.334
	Second	*276.182*	158.524	52.279	485.564	433.285	3038.00	57.398	-0.087	-1.472
	First	236.034	135.542	31.429	405.662	374.233	2596.00	57.425	-0.144	-1.512

Cross River	Second	263.23	157.897	36.292	490.555	454.264	2884.53	59.984	-0.114	-1.469
Delta	First	223.572	134.8	27.564	412.789	385.226	2459.29	60.294	-0.079	-1.344
	Second	221.053	141.228	22.596	414.844	392.248	2431.58	63.889	-0.139	-1.586
Edo	First	182.991	108.158	20.274	334.582	314.309	2012.91	59.106	-0.217	-1.255
	Second	185.668	116.391	15.556	337.091	321.535	2042.35	62.688	-0.295	-1.524
Lagos	First	147.865	93.264	16.924	327.6	310.677	1626.52	63.414	-0.455	-0.246
	Second	146.072	101.573	13.805	334.537	320.732	1606.79	69.536	0.407	-0.792
Ogun	First	149.942	86.752	15.808	274.283	258.475	1649.37	57.857	-0.138	-1.146
	Second	152.723	100.209	11.945	286.989	275.043	1679.95	65.615	0.018	-1.640
Ondo	First	177.673	101.729	22.792	324.987	302.194	1954.41	57.256	-0.172	-1.174
	Second	184.326	121.432	14.254	363.276	349..022	2027.58	65.880	0.004	-1.361
Rivers	First	271.801	146.829	51.256	465.637	414.382	2989.82	54.021	-0.056	-1.409
	Second	258.555	148.322	46.251	468.963	422.712	2844.11	57.366	-0.113	-1.481

Table 3 shows that the average yearly rainfall in Lagos (second climatic period) is 1606.79 mm, while it is 3038.00 mm in Bayelsa (second climatic period). Kurtosis and skewness varied from -1.640 to -0.246 and 0. 407 to -0.015, respectively. Additionally, Table 4 provides descriptive statistics of the mean annual temperature during the first and second climatic eras (1956–1986 and 1987–2016, respectively) in Nigeria's coastal region.

Table 4 Descriptive data on annual temperature for various climate periods.

Climatic Station	Climatic Periods	Mean	SD	Min	Max	Range	Sum	%CV	Skewness	Kurtosis
Akwa Ibom	First	30.276	1.336	28.220	32.126	3.906	333.035	4.213	-0.064	-1.222
	Second	30.760	1.143	28.399	32.538	4.138	338.361	3.716	-0.319	-1.200
Bayelsa	First	30.081	1.324	31.817	30.081	3’645	330.89	4.401	-0.171	-1.150
	Second	30.583	1.422	28.362	32.274	3.913	336.413	4.650	-0.392	-1.502
Cross River	First	30.363	1.469	28.021	32.382	4.361	333.991	4.838	-0.119	-1.121
	Second	30.674	1.520	28.107	32.598	4.491	337.418	4.955	-0.126	-1.069
Delta	First	30.271	1.565	27.999	32.269	4.270	332.978	5.170	-0.244	-1.554
	Second	30.759	1.680	28.155	32.733	4.578	338.345	54.618	-0.396	-1.522
Edo	First	30.129	1.848	27.441	32.292	5.053	331.428	6.134	-0.206	-1.571
	Second	30.614	1.970	27.573	32.965	5.393	336.755	6.435	-0.323	-1.535
Lagos	First	30.284	1.639	27.955	32.338	4.383	333.128	5.412	-0.189	-1.623
	Second	30.685	1.683	28.138	32.643	4.504	337.538	5.485	-0.329	-1.574
Ogun	First	30.491	1.875	27.755	32.882	5.127	335.401	6.149	-0.152	-1.619
	Second	30.911	1.938	27.398	33.244	5.346	340.022	6.270	-0.278	-1.562
Ondo	First	30.348	1.848	27.663	32.748	5.085	333.826	6.089	-0.155	-1.594

	Second	30.817	1.938	27.829	33.150	5.321	338.989	6.289	-0.291	-1.568
Rivers	First	30.195	1.288	28.298	31.937	3.639	332.140	4.266	-0.035	-1.326
	Second	30.686	1.393	28.438	32.377	3.939	337.550	4.539*	-0.314	-1.306

From Table 4,Ogun (second climatic period) and Bayelsa (first climatic period) had different average annual temperatures of 30.911 ^oC and 30.081 ^oC, respectively. Standard deviation changed from 1.970 to 1.143 degrees Celsius, and skewness and kurtosis changed from -0.623 to -1.069 and -0.396 to -0.035, respectively.3.2 assessing the quality of spatial data for climate variability analysis

The validity analysis performed by [40] revealed that the CRU data are validated. Moreover, the outcomes demonstrated that the CRU climate data series had a normal distribution, allowing parametric approaches to be applied to their analysis. It was discovered that the rainfall data for the following states was uniform: Bayelsa, Delta, Edo, Lagos, Ogun, and Ondo. Their high level of reliability made them appropriate for use in additional analysis and study. Additionally, the results showed that the cru climate data series had a normal distribution and that the data could be further analyzed using parametric techniques. For the states of Bayelsa, Delta, Edo, Lagos, Ogun, and Ondo, there was rainfall data homogeneity; for the states of akwa ibom, cross rivers, and rivers, there was inhomogeneity. Every state under investigation had temperature data that was found to be non-homogeneous.

3.3 Coefficient of Variability (Cv%) Analysis

Using equation (1), the coefficient of Variability of Spatial of Mean Annual Rainfall and Temperature Data were computed and the results are shown in Table 5.

Table 5- Variability of Spatial Average yearly Rainfall and Temperature Data

S/N	Location	Rainfall			Temperature		
		MEAN(Rm)	SD	CV (%)	MEAN(Tm)	SD	CV (%)
1	Akwa Ibom	236.54	150.75	63.73	30.569	1.328	4.344
2	Bayelsa	256.17	160.73	62.74	30.393	1.324	4.356
3	Cross River	230.25	153.82	66.81	30.561	1.431	4.682
4	Delta	206.05	142.87	69.34	30.579	1.562	5.108
5	Edo	170.35	117.34	68.88	30.447	1.838	6.037
6	Lagos	136.28	99.56	73.06	30.597	1.629	5.324
7	Ogun	140.02	96.94	69.23	30.811	1.856	6.024
8	Ondo	167.34	116.23	69.46	30.665	1.826	5.955
9	Rivers	246.76	154.04	62.43	30.112	1.299	4.314

According to [41] CV is used to classify the extent of variability of rainfall and temperature events as low (CV < 20), moderate (20 < CV < 30), high (CV >30), very high CV>40% and extremely high CV>70% inter-yearly rainfall variability. With the exception of Lagos, all of the states exhibited coefficients of variation (CV) ranging from 62.43% to 69.56% when the observed data was taken into consideration. This suggested that the region's precipitation varied greatly. With a coefficient of variation (CV) of 74.06%, Lagos State has exceptionally high inter-annual rainfall variability.

An indicator of climate risk, the annual rainfall coefficient (CV) shows the probability of variations in agricultural productivity or reservoir storage from year to year. In terms of agriculture, marginal areas might have a higher significance for this statistic than wet areas or extremely dry areas where farming operations have adapted to variable and considerably lesser inter-annual variability is typically predicted.

In every state in the study area, the spatial mean annual temperature data's coefficient of variation (CV) ranged from 4.314% to 6.037%. suggesting a minimal degree of temperature change across years. Standard Deviation (SD) is equal to Coefficient of Variability (CV) x Mean /100

3.4 Vulnerability categorization of states in the coastal region of Nigeria

Socio-economic and biophysical indicators of vulnerability were obtained and weighted by [42] using Principal Component Analysis and analyzed using integrated vulnerability assessment approach. assessment approach. The vulnerability pattern in Nigeria is shown in Figure 5 obtained from his article. Also,Table 6 was adapted from the same article.

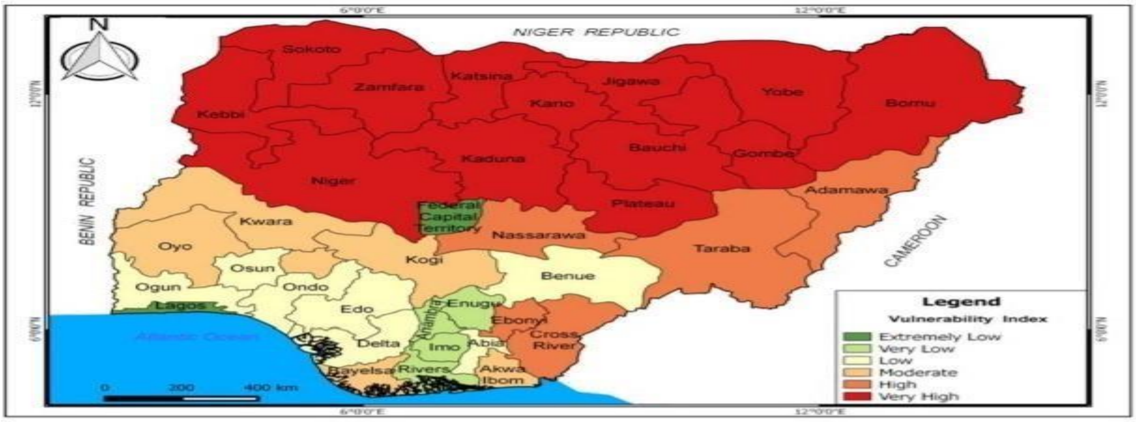

Figure 6: The pattern of Vulnerability in Nigeria

Figure 6 depicts the vulnerability pattern in Nigeria. The explanation of the legend in Figure 5 is presented in Table 6

Table 6: Vulnerability categorization of states in the coastal region of Nigeria

S/N	State	Geopolitical zone	Rainfall Variability CV (%)	Variability Categorization	Vulnerability index	Vulnerability Categorization
1	Akwa Ibom	south-south	63.73	Very high	7.16	Moderate
2	Bayelsa	south-south	62.74	Very high	7.79	Moderate
3	Cross River	south-south	66.81	Very high	5.54	High
4	Delta	south-south	69.34	Very high	8.21	Low
5	Edo	south-south	68.88	Very high	8.65	Low
6	Lagos	South-west	73.06	Extremely high	24.78	Extremely low
7	Ondo	South-west	69.46	Very high	9.71	Low
8	Ogun	South-west	69.23	Very high	9.68	Low
9	Rivers	south-south	62.43	Very high	11.64	Very low

NB: The lower value indicates more vulnerability

Declining rainfall, rising sea levels, coastal erosion, and flooding have made the coastal region of Nigeria vulnerable, resulting in the displacement of several coastal communities.

The physical vulnerability of the coastal region of Nigeria is exacerbated by its economic vulnerability. Despite recent tremendous progress on both the social and economic fronts, Human Capital Development remains weak and underdeveloped due to underinvestment. The nation's Human Capital Index rating remains low. Despite ongoing efforts to diversify the economy, its reliance on crude oil poses significant development and infrastructure challenges. Climate change has had the most significant impact on Nigeria's coastal regions, desertification-prone areas, and wetlands. Farmers, fishermen, the elderly, women, children, and poor urban dwellers are the most vulnerable to climate change.

Numerous factors, including socioeconomic and environmental ones, influence how vulnerable these communities are to the effects of climate change. Using the Anloga village as a case study, this study attempted to evaluate how vulnerable coastal communities in Nigeria are due to the effects ofclimate change. In order to do this, a case study design was chosen, and the study used multi-stage sampling with basic random procedures and purposive sampling. Using information gathered from primary and secondary sources, an integrated vulnerability assessment approach was employed to investigate vulnerability indicators of exposure, sensitivity, and adaptive capability. The study's findings showed that the community's geographic location makes it extremely vulnerable to the effects of climate change. In addition to a dearth of job opportunities,

3.5 Total Land Loss (km^2) From Coastal Erosion and Floods Estimated from Different Scenarios of Sea Level Rise in the NigerDelta Region.

Land loss due to sea level rise is in Table7

Table 7 Total Land Loss (km^2) From Coastal Erosion and Floods Estimated from Different Scenarios of Sea Level Rise in the Niger Delta Region

S/N	SLR (m)	Low Estimates (km^2)	High Estimate (km2)
1	0.2	2,846	2,865
2	0.5	7,453	7,500
3	1.0	15, 125	15,332
4	2.0	18, 398	18,803

Source: [43]

This research highlights the most vulnerable states in terms of the current climate risk and the primary drivers of vulnerability based on an evaluation. A standard approach and a set of common indicators form the basis of the assessment. States also conducted individual district-level vulnerability assessments.

1) State-level vulnerability indices vary over a range:1 to5. This means all states must deal with concerns related to vulnerability.
2)The state with a relatively high vulnerability like Cross River State, requiring prioritization of adaptation interventions.
3) State-level vulnerability indices range from extremely low to high
4) Vulnerability indices are relative measures. This means, that all states in the region are vulnerable, but some are relatively more vulnerable than others, requiring prioritized adaptation interventions

3.6 Governments and Stakeholders Intervention Measures in adaptation and mitigation of climate Change Vulnerability in the Coastal region of Nigeria

Nigeria's Federal Government has participated in climate change measures through various agencies. These include the Nigerian Meteorological Agency (NIMET), the National Emergency Management Agency (NEMA), the Nigeria Hydrological Services Agency (NIHSA), and the National Environmental Standards and Regulations Enforcement Agency (NESREA) [44], [45]. Nevertheless, a number of federal, state, and local governments have made major investments in institutional frameworks to lessen the effects of climate change. There are indications that the policies put in place need to be revised.

There is currently an increasing trend of local governments becoming more involved in the governance and formulation of climate change policies. Local governments are in an excellent position to help with the implementation and improvement of climate change adaptation strategies because they are the closest to the people. The vulnerability is high but low adaptation efforts in Nigeria's coastal region. Adaptive efforts are frequently concentrated on responding reactively to the natural disasters that are occurring currently rather than proactively planning for those that may arise in the future. Moreover, adaption planning still takes the form of broad guidelines devoid of specific implementation guidelines. Urban poverty issues and the quickening pace of urbanization reduce people's ability to adapt. The success of measures to mitigate disasters can be positively impacted by the presence of community participation. Additionally, it can lessen the vulnerability of the local community and raise public knowledge as well as local adaptive capability. One factor influencing community involvement in disaster mitigation activities is place attachment.

3.7 Vulnerability of Women, Children, and Physically Challenged Persons Due to Climate Variability.

The degree to which men and women have access to social and economic rights determines how vulnerable they are to climate change. The ability to adapt is negatively impacted by gender discrimination. In line with this, cultural sustainability can be measured through economic, social, and environmental indicators[46] .

Although disaster affects both women and men, the physical burden of coping is dependent on women [34] .Disasters increase women’s domestic burden, create great hardship and undermine women’s well-being because of their dependence on economic activities linked to the home. Moreover, women are more vulnerable because of the effects of climate change when they are highly dependent on local resources for their livelihoods [47] .Poor women suffer from a lack of food, clothing, and shelter, whereas young girls suffer from insecurity. Often, unemployed men stay idle or migrate somewhere else, thus leaving their household members behind. Under these circumstances, women take responsibility for caring for the needs of their children, other members of the family, livestock, and belongings. To ensure the survival of their families, many women remainhungry to support their children and work long hours in their old age [47]).

Mothers take care of their parents, siblings who are disabled, and their children. Women make an elevated bed out of wood and rope for sick or disabled family members who live in flood-prone locations [48] , [49] ,& [50] .Women make an effort to cope with disasters, but for a variety of reasons, they are less adaptive than men. Less power over family assets is given to women. In most households, men are the primary owners of land, animals, and poultry. Women's access to the work market is restricted. Women's mobility, access to education, and training are restricted because men possess physical assets like machinery and equipment[48] .These are a few of the variables influencing women's ability to adapt. Given that both sexes are constituents of society.

4. Conclusions

With a coefficient of variation (CV) of 74.06%, Lagos State has exceptionally high inter-annual rainfall variability. Also, the coefficient of variation (CV) of Cross River state is 66.81% indicating very high inter-annual variability of rainfall. However, the vulnerability of 5.54 was categorized as high. The flooding in Lagos and other cities in the study areas is caused by the effect of climate change and most probably due to the blockage of drains with waste and the building of houses of natural drainage channels

A vulnerability assessment is the first step toward adaptation planning. Gender issues must be incorporated in any adaptation and mitigation plan.
Our findings will contribute to the field of climate change impacts in understanding the complexities of rural development.

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