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Climate change impact on the architecture and built environment dwellers' well-being in Niger Delta Region: a systematic review

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Climate change resulting from weather conditions has recently attracted global attention and concern; such variations have impacted architecture and the built environment, especially on the urban dweller's well-being and other associated urban problems. This systematic review investigates the effects of climate change on the environment and architecture in the Niger Delta Area of Nigeria and the potential consequences for inhabitants well-being through a systematic review of scholarly literature from Google Scholar, ResearchGate, Science Direct and Scopus covering the period from 2019 to 2024. The study synthesizes current literature, using rigorous inclusion criteria to find relevant studies conducted globally. It involves an assessment procedure that resulted in 25 articles for analysis. The core of the problem lies in the gaps in that climate change has negatively impacted the environment, architecture and building construction mechanism in the Niger Delta Region. This review systematically observes the methodologies in the selected studies to create a standardized framework for future research using a hybrid review approach. Results reveal that the ongoing incidences of perennial flooding in the region are attributable to climate change across different geographic locations and seasons. The authors proffered some recommendations to mitigate these impacts for future research. However, this systematic review of climate change's impact on the architecture and dwellers' well-being in the built environment in the Niger Delta presents valued insights for policymakers and urban health practitioners, enhances the urban built environment health systems resilience, and well organize communities for the climate change challenges.

KEYWORDS

climate change, built environment, architecture, flooding, dwellers well-being, urban challenges

1 Introduction

Mitigating the impact of climate change is among the Sustainable Development Goals (SDGs) listed in the 2030 Agenda for Sustainable Development Goals (SDGs) and adopted by the United Nations in 2015. It is in recognition of its fundamental importance and encompassing nature in the universal call to action to protect the planet and ensure that by 2030, all people will enjoy a peaceful and eco-friendly environment (Hariram et al., 2023). Specifically, Goal 13 of the SDGs focuses on climate change action and advocates for the need to take urgent actions to combat climate change and its impacts. The effects of climate change directly threaten citizens' well-being, particularly children, as many diseases are attributable

to climate change (Sharifi et al., 2021; Watts et al., 2021; Fox, 2024). Other Sustainable Development Goals (SDGs) that are closely related to climate change include Goal I0, which addresses the need to make cities and human settlements safe, sustainable, resilient and inclusive; Goal 14 advocates for the need to protect, promote and restore sustainable use of terrestrial ecosystem, sustainably manage forests; combat desertification; halt and reverse land degradation; and halt biodiversity loss (Sijakovic and Peric, 2021; El Harrouni et al., 2024).

Climate change refers to long-term shifts in heat and weather patterns (Amaglo et al., 2022). It also can be described as a change in a region's average conditions, such as temperature and rainfall, over a long period (Tabari, 2020; Dong et al., 2024). These shifts may be due to natural causes. Climate change is an upsurge in global temperatures (Tunji-Olayeni et al., 2021). However, since the advent of the 19th century, scientists have attributed human activities to be the main drivers of climate change. Human activities are primarily due to energy utilization in the form of burning fossil fuels and gas flaring, which produce heat-trapping gases; manufacturing, which causes urban industrial pollution; cutting down of forests and trees, giving rise to urban heat islands; and powering buildings. These actions negatively influence climate change, global warming, health, and the environment (Zandalinas et al., 2021; Houghton, 2023).

Climate change is at the forefront of significant world discussions (Dabaieh et al., 2021). Concerns are mounting about the degeneration of the entire universe due to the impact of global climate changes (Van der Heijden, 2019; Mani and Goniewicz, 2023). International efforts on climate change issues agreed on the vital need to reduce greenhouse gas emissions, a primary causal agent of climate change and global warming (Ajayi et al., 2022; Andrić et al., 2021). Some concerns border on the environmental consequences, such as increased temperature, resource depletion, water shortages and contamination, desertification, and loss of biodiversity (Mosca et al., 2023; Nguyen et al., 2023): In sub-Saharan Africa, climate change is with intensified temperature extremes, precipitation anomalies, and natural disasters that typically leave millions in peril, famed, homeless or food insecure, and cause severe and costly economic damages. The Report of the Intergovernmental Panel on Climate Change-IPCC (Affoh et al., 2022; Ackerl et al., 2023) stated that: *"rising temperature in Africa affects people's health and livelihoods through extremes and less predictable rainfall and wildfires, heat waves, tropical cyclones, floods, and deforestation*."

The above scenarios vividly illustrate the situation in Nigeria, inclusive of the Niger Delta Area. Odigwe et al. (2020) investigated the climate of the Niger Delta, Nigeria, to determine the variations in rainfall and temperature in the region, revealing an increase of 746.7 mm and a rise of 1.5°C temperature between 1977 to 2017, respectively. Similarly, findings of the research by Balogun and Onokerhoraye (2022), which assessed climate change in Benin City, located in the Niger Delta, Nigeria, also revealed that average temperature, rainfall, and humidity recorded a significant increase for the period of thirty-five (35) years (from 1981 through 2015). The Niger Delta Region is also the most polluted environment in Nigeria because of many years of oil production (Obiam et al., 2022). Pollution relates to the region's low life expectancy under 41 years (Ebhota et al., 2023).

The rationale for the study is due to the significant positive relationship between climate, environment and architecture. The environmental, socio-economic and climatic factors significantly influence the forms of the architecture of buildings' environmental management strategies differently from one geographic region to another. According to Fallmann and Emeis (2020) and Paleri (2022), the environment refers to the aggregate of all external conditions influencing and affecting the life of organisms. Similarly, Architecture is the art and science of the design of buildings and structures for convenient human habitation and utilization (Eltanboly and Ibrahim, 2022; Roos et al., 2022). Its ability to provide a habitable environment has remained the primary function of serving humanity. Therefore, climate and environment all have a strong positive relationship with architecture. The environment is an indispensable asset for architecture. Aghaloo et al. (2024) asserted that the environment is the most valuable asset humans own, share and use with others for communal benefits and improved welfare.

The climate dictates the physical environment concerning temperature, sunshine, rainfall, radiation, and humidity for the benefit of architecture (Bekele and Atakara, 2023; Hindle, 2024). For this reason, the study of climatology and environmental sciences is imperative in architecture. The knowledge of climatology and the environment is a critical study related to the built environment because buildings are not isolated but designed and built for a specific region. Another important reason is the five factors (climate, materials, technology, culture, and technology) that influence the architecture of a place; only the climate used to be constant (Dai et al., 2022). However, the situation has recently changed due to climate variations (Faranda et al., 2022). As a scientific discipline, architecture strives to harmonize the surrounding geographic and environmental factors to achieve harmony and unity in architecture. Despite this knowledge by building professionals, some buildings are designed and constructed in Niger Delta without due consideration for the climate and environmental factors (Zhang et al., 2022; Huang et al., 2023). These are in buildings with parapet walls, flat roofs of less than 10 degrees slopes, the poor orientation of buildings relative to the site, lack of shading devices, etc. Adapting measures to checkmate these phenomena has become urgent to protect people, homes, businesses, livelihoods, infrastructures, and ecosystems under climate change (Orie, 2021).

The significance of this research is that it highlights the relationships between climate change and architecture and the environment. It further assesses the impacts and implications of climate changes in the study area's architecture and the built environment. Past studies have dealt majorly with environmental degradation, pollution, and exploitation. Therefore, this study, which focuses on the impact of climate change on architecture and the environment, is significant and justified. Thus, this study aims to attempt a theoretical discourse on the effects of climate change on the environment, architecture, and the built environment in general. It is to assess the impact of climate change on buildings *viz*-a-*viz*: Examine the impact of climate change on the architectural environment and evaluate the effects of climate change and its associated urban environmental problems.

2 Materials and methods

The study followed the updated Preferred Reporting Items for Systematic Reviews and Metal Analyses (PRISMA) extension for guidelines, a 27-item checklist to advance transparency in systematic

reviews. These items cover all parts of the manuscript, including the title, abstract, introduction, methods, results, discussion, and funding (Page et al., 2021). PRISMA is an evidence-based minimum set for reporting in systematic reviews and meta-analyses. The review includes the work from 2019 to 2024 (Table 1). The flow diagram represents the information flow through the diverse phases of a systematic review. It maps out the number of records identified, included and excluded and the reasons for exclusions. Systematic literature review articles can be domain-based, theory-based, and method-based. Besides these categories of systematic literature reviews, meta-analytical reviews are widespread in many subject areas (Paul and Barari, 2022). Many domain-based reviews are available in almost all subject areas. This systematic review article is domain-based and engaged the hybrid review category for this study. The hybrid reviews approach integrates a framework to provide directions for future research in a more narrative-oriented literature review. Or through incorporating the tenets of both bibliometric and structured reviews (Paul and Criado, 2020).

2.1 Searches and source documentation

The searches were conducted from 2019 to 2024 using Google Scholar, Researchgate, Science Direct, and Scopus databases.

2.2 Search strategy

The author conducted searches using Google Scholar, Researchgate, Science Direct, and Scopus databases, as shown in Table 2, engaging the keywords stated and grouping them. Other websites, perhaps the World Health Organisation library databases, were employed to search for data. The search process involved several steps:

- We are identifying significant terms related to the research question (based on PRISMA).
- We are listing keywords from existing articles relevant to our study.
- We are searching for synonyms and alternative terms.
- We use Boolean operators (OR and AND) to connect significant terms.
- We are employing an asterisk (“) as a wildcard operator.

The keywords employed were on the vocabulary generally engaged in this topic, including:

“Climate Change” AND “Built Environment” AND “Health” OR “Well-being” And “Architecture.” To select suitable studies, the reviewers searched articles and vetted them based on titles, abstracts, and full text.

2.3 Study objective

This study aims to investigate the effects of climate change on the dweller’s well-being and the architecture of the urban built environment in the Niger Delta, Nigeria, a potential implications for urban health concerns.

2.4 Study characteristics

The researchers reviewed Twenty (25) articles (7 from Google Scholar, 5 from Researchgate, 8 from Science Direct and 5 from Scopus) for qualitative synthesis. The authors summarized the characteristics of each article: authors, article title, source title, cite by (number of citations), document type, country and publication date in Table 1. The literature review revealed that most research findings were in the Global North. However, only a few were in Africa, and the analysis was in coastal communities; some studies indicated a specific community, such as Niger Delta neighborhoods in Nigeria.

2.5 Systematic review

The author used inclusion and exclusion criteria to select the studies for a systematic review.

2.5.1 Inclusion criteria

Refers to studies that measure the impact of climate change on the dweller’s well-being and architecture of the urban built environment in this study. Articles were restricted to publications in English and conducted in communities and climatic zones. The studies offer lucid information on the impact of climate change, engaging inclusion in the systematic review. Literature that reported data on the following metrics includes (1) effects of climate change on the dweller’s well-being in the Niger Delta urban built environment, Nigeria and (2) effects of climate change on the architecture of urban built environment in the Niger Delta, Nigeria.

2.5.2 Exclusion criteria

Summarized publications, abstracts, and subscription-based articles studies on the impact of climate change in urban built environments. The authors excluded access to newspaper reports and studies other than the above subject from this review.

2.6 Data extraction and synthesis

The authors extracted data from Google Scholar, ResearchGate, Science Direct and Scopus databases by reviewing titles and abstracts for inclusion and exclusion criteria. Upon engaging in a systematic review and meta-analysis, we did not assess statistical heterogeneity and publication bias while performing meta-analyses.

2.7 Quality assessment

The reviewer measured the included articles for methodologies bias, engaging the earlier described tool (Kelly et al., 2024). Items on the tool are clarity of approach, constant use of the appropriate procedure, extraction and detection method, quantification process, lucidity on sites and transparency in presenting the outcomes. Figure 1 provides a synopsis of the systematic process employed and statistics on the papers collected, screened and reviewed at each stage. The authors independently analyzed

TABLE 1 Present the authors in research related to climate change, built environment and architecture in the Niger Delta Area from 2019 to 2024 (Google Scholar, Researchgate, Science Direct, and Scopus).

Authors	Title	Source title	Cited by	Document type	Country	Publication date
Abbass et al. (2022)	A review of the global climate change impacts, adaptation, and sustainable mitigation measures	Environmental Science and Pollution Research	798	Review	Belgium	2022
Affoh et al. (2022)	The impact of climate variability and change on food security in sub-Saharan Africa: Perspective from panel data analysis	Sustainability	78	Article	Switzerland	2022
Balogun and Onokerhoraye (2022)	Climate change vulnerability mapping across ecological zones in Delta State, Niger Delta Region of Nigeria	Climate Services	11	Article	Netherlands	2022
Bhaga et al. (2020)	Impacts of climate variability and drought on surface water resources in Sub-Saharan Africa using remote sensing	Remote Sensing	113	Review	Switzerland	2020
Daoudi et al. (2019)	Vernacular architecture in arid climates: Adaptation to climate change	Bioclimatic Architecture in Warm Climates	15	Article	Switzerland	2019
Eccles et al. (2019)	A review of the effects of climate change on riverine flooding in subtropical and tropical regions	Journal of Water and Climate Change	84	Review	United Kingdom	2019
Graça et al. (2022)	Designing urban green spaces for climate adaptation: A critical review of research outputs	Urban Climate	45	Review	Netherlands	2022
Hassan et al. (2020)	Potential impacts of climate change on extreme weather events in the Niger Delta part of Nigeria	Hydrology	21	Article	Switzerland	2020
Hindle (2024)	Y02 as Climate Praxis	Technology| Architecture+ Design	0	Article	United Kingdom	2024
Houghton (2023)	The gap in capacity building on climate, health, and equity in built environment postsecondary education	Frontiers in Public Health	2	Article	Switzerland	2023
Jones (2022)	The health impacts of climate change: Why climate action is essential to protect health	Orthopedics and Trauma,	16	Article	Netherlands	2022
Khatibi et al. (2021)	Can public awareness, knowledge and engagement improve climate change adaptation policies?	Discover Sustainability	79	Article	Switzerland	2021
Klinsky and Mavrogianni (2020)	Climate justice and the built environment.	Buildings and Cities	50	Article	United Kingdom	2020
Kwok and Ng (2021)	Trends, topics, and lessons learnt from real case studies using mesoscale atmospheric models for urban climate applications in 2000–2019	Urban climate	27	Article	Netherlands	2021
Laino and Iglesias (2023)	Scientometric review of climate-change extreme impacts on coastal cities	Ocean & Coastal Management	6	Review	United Kingdom	2023
Morufu et al. (2021)	Creating the Healthiest Nation: Climate Change and Environmental Health Impacts in Nigeria	Scholink Sustainability in Environment	82	Review	United States	2021
Mosca et al. (2023)	Strategies for adaptation to and mitigation of climate change: Key performance indicators to assess nature-based solutions performances	Urban Climate	8	Article	Netherlands	2023
Ofoezie et al. (2022)	Climate, urbanisation and environmental pollution in West Africa	Sustainability	6	Article	Switzerland	2022

(Continued)

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TABLE 1 (Continued)

Authors	Title	Source title	Cited by	Document type	Country	Publication date
Qian et al. (2022)	Urbanisation impact on regional climate and extreme weather: Current understanding, uncertainties, and future research directions	Advances in Atmospheric Sciences	135	Article	China	2022
Salim et al. (2024)	A comprehensive review of navigating urbanisation-induced climate change complexities for sustainable groundwater resource management in the Indian subcontinent	Groundwater for Sustainable Development	0	Review	Netherlands	2024
Sharifi (2021)	Co-benefits and synergies between urban climate change mitigation and adaptation measures	Science of the total environment	306	Review	Netherlands	2021
Sharifi et al. (2021)	A systematic review of the health co-benefits of urban climate change adaptation	Sustainable Cities and Society	86	Review	Netherlands	2021
Sijakovic and Peric (2021)	Sustainable architectural design: toward climate change mitigation	Archnet-IJAR	18	Article	United Kingdom	2021
Tabari (2020)	Climate change impact on flood and extreme precipitation increases with water availability	Scientific reports	948	Article	United Kingdom	2020
Watts et al. (2021)	The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises	The Lancet Public Health	145	Article	United Kingdom	2021

primary studies based on titles, abstracts, and keywords in the initial search phase. When discrepancies arose in the extracted data, we resolved these disagreements through reviewing sessions to achieve a consensus. We moved to the second screening stage, a designed form that facilitated data extraction. This form collected evidence related to the research question and assessed the full paper quality from pre-selected articles. The checklist evaluated relevance, clarity, and data quality using a ratio scale: Yes as 1, No as 0 and partially as 0.5. Each study's total quality score ranged from 0 (very poor) to 2 (very good). The authors independently reviewed and applied the checklist to the pre-selected studies. They followed a similar process during the appraisal stage, but the checklist adjustment emphasized scope, analysis, and significance. Currently, emerging themes are in the discussion section in the context of selected articles. Therefore, in the synthesis stage, the authors thoroughly reviewed the documents against these themes until we reached a complete agreement in a review meeting.

2.8 Validation for database and keyword choices

The authors chose Google Scholar and ResearchGate for their extensive coverage. At the same time, Scopus and Science Direct for their inclusive bibliographic database, advanced search options and citation analysis. Merging these databases can deliver a comprehensive and exhaustive search for articles applicable to the research topic. Choosing keywords in a search approach is vital for retrieving appropriate and complete data.

3 Results

There are several ways to evaluate the results of systematic literature reviews (Lame, 2019). Still, considering the field and content, the authors decided that the most efficient approach for analyzing the article would be emerging themes due to the main findings (Linnenluecke et al., 2020). In synthesizing these, the authors identified six key groups and four themes. The groups included Climate Changes and Variations in the Niger Delta Region, Climate Change and Architecture, Built Environment and Climate Change and Climate Change and Associated Problems. The themes associated with each group and the articles that addressed them are shown in Supplementary Table S1, with the articles arranged alphabetically by lead author and an "x" representing the directly addressed theme. The rest of the section is organized according to the groups, discussing the themes aligned under each.

3.1 Description of studies

The keyword search established 31,404 possible articles (18,600 from Google Scholar, 3,477 from ResearchGate, 9,308 from Science Direct and 19 from Scopus). Further screening excluded 850 reports. Overall, the reviewers agreed on twenty-five (25) articles (7 from Google Scholar, 5 from ResearchGate, 8 from Science Direct and 5 from Scopus) used for data extraction, as shown in Figure 1.

4 Discussion

The authors selected Twenty-five (25) studies (5 from Scopus, 5 from ResearchGate, 8 from Science Direct and 7 from Google Scholar) in the present review, as shown in Supplementary Table S1. The review offers some understanding of the impact of climate change on architecture and dwellers' well-being in urban built environment matrices, which serve as a healthier insight into the effects of climate change on the Niger Delta environment in Nigeria. It includes investigating the concerns of severe climate change impact and mitigating the after-effects caused by climate change variations by using climate-sensitive planning and design with climatic parameters/factors in building design.

TABLE 2 Table outlining the databases and search terms utilized.

Database	No. of papers
Google Scholar	18, 600
ResearchGate	3, 477
Science Direct	9,308
Scopus	19

This study analyzed the existing literature on the impact of climate change, architecture, and built environment matrices, aiming to understand the possible implications for urban dwellers' well-being comprehensively. The investigation included varied ecological locations, methodologies, and study phases to ensure a vigorous synthesis of obtainable evidence. The review presents a changing occurrence of climate change across diverse built environment matrices (Sharifi, 2021). The persistence of climate change impacts suggests the possibility of constant threat in communities. Perhaps the causes of variations in climate are a blend of either natural (bio-geographical) or human activities (anthropogenic) processes (Kemela and Phoebe, 2021). Human factors are accountable for the

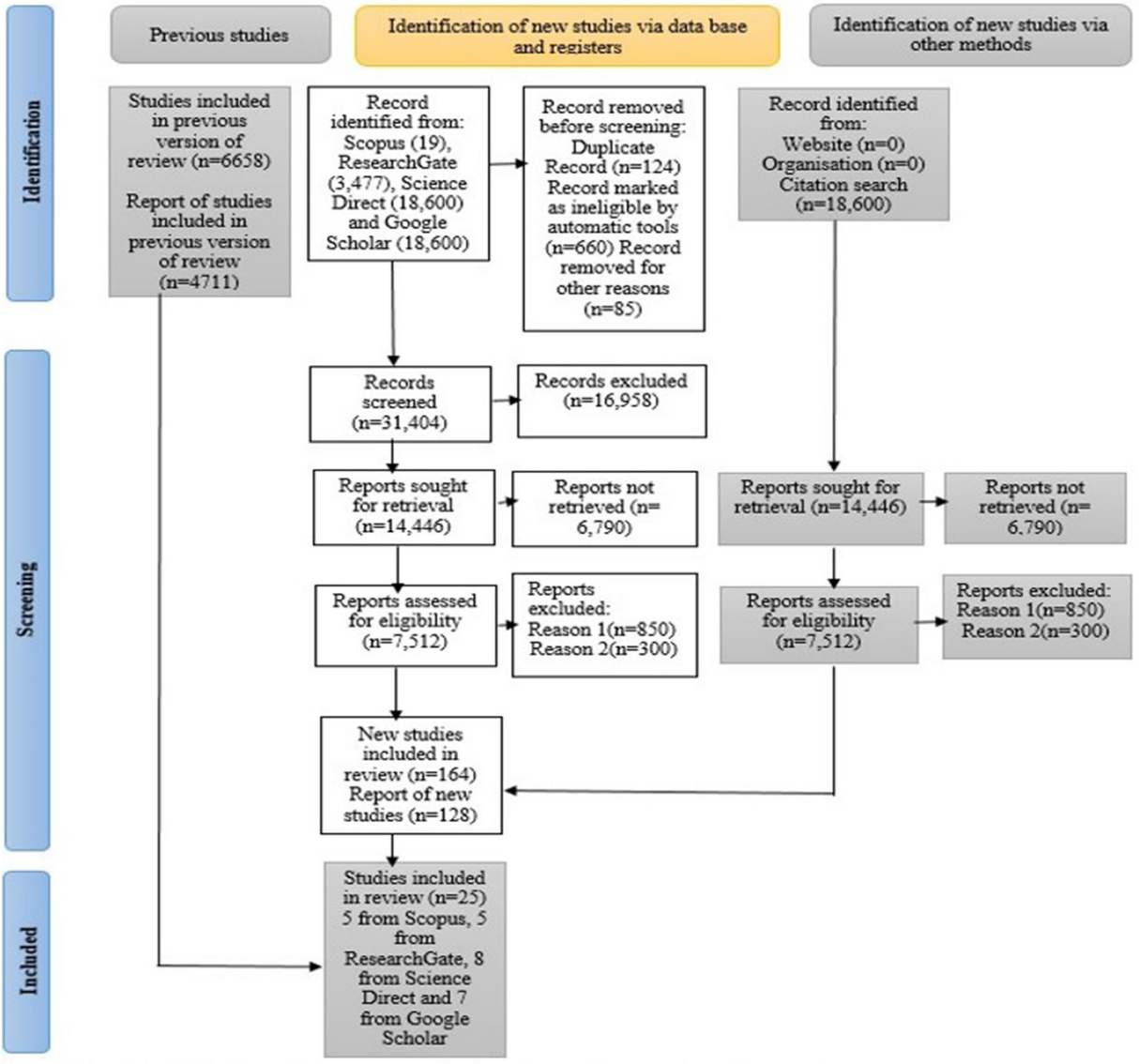

FIGURE 1
PRISMA flow diagram of article selected for systematic reviews.

undeniable climate change and global warming (Demuzere et al., 2022; Senande-Rivera et al., 2022). Variations in climate in the Niger Delta Region have been credited more to anthropogenic factors (gas flaring and socio-economic activities of urbanization) resulting in loss of biodiversity which have left the vegetation cover bare, resulting in carbon in the atmosphere (Laino and Iglesias, 2023). This biodiversity loss has resulted in overheating the atmosphere and a temperature rise. The consequential effects have been excessive evaporation of the sea and nearby water bodies. It leads to high rainfall variability, which results in environmental problems (Salim et al., 2024).

Hassan et al. (2020) and Odigwe et al. (2020) investigated the climate of the Niger Delta, Nigeria, to determine the variations in rainfall and temperature in the region, as shown in Figure 2. The study made use of the ex-post facto research design. It utilized the annual rainfall and temperature time series data from 1925–2018. Climate Research Unit (CRU) Ts 4.03 archive generated primary data using Google Earth. The study revealed that the highest and lowest temperatures (27.4°C and 25.9°C) were in 2017, 1976, and 1977, indicating a rise of 1.5°C. The highest and lowest rainfall (2,600.7 mm and 1,854 mm) was in 1955 and 1984, marking an increase of 746.7 mm. The study further discovered that there are statistically significant variations in rainfall and temperature, respectively the Niger Delta Region.

The systematic review has underscored the climate change impacts on the architecture and dweller well-being of the Niger Delta built environment matrices, highlighting the valuable tool for impact mitigating monitoring. Policymakers must consider incorporating mitigation and control tools into implementation strategies to enhance quick response competencies.

According to Ighedosa (2020), planning and designing with climate-sensitive parameters in the Niger Delta built environment can be a timely warning sign for possible community threats. Applying policies that allow swift response and mediation based on climate change impact data can prevent and minimize the impact on architecture and public health (Jones, 2022). The findings suggest variations in climate change differ across diverse environmental areas. Therefore, policymakers must assign resources based on the acknowledged high-risk zones, directing mediations and resources where necessary. This targeted approach can optimize resource utilization and improve the efficiency of climate change impact measures. Practical Communication approaches are vital for implementing climate change impact policies (Khatibi et al., 2021).

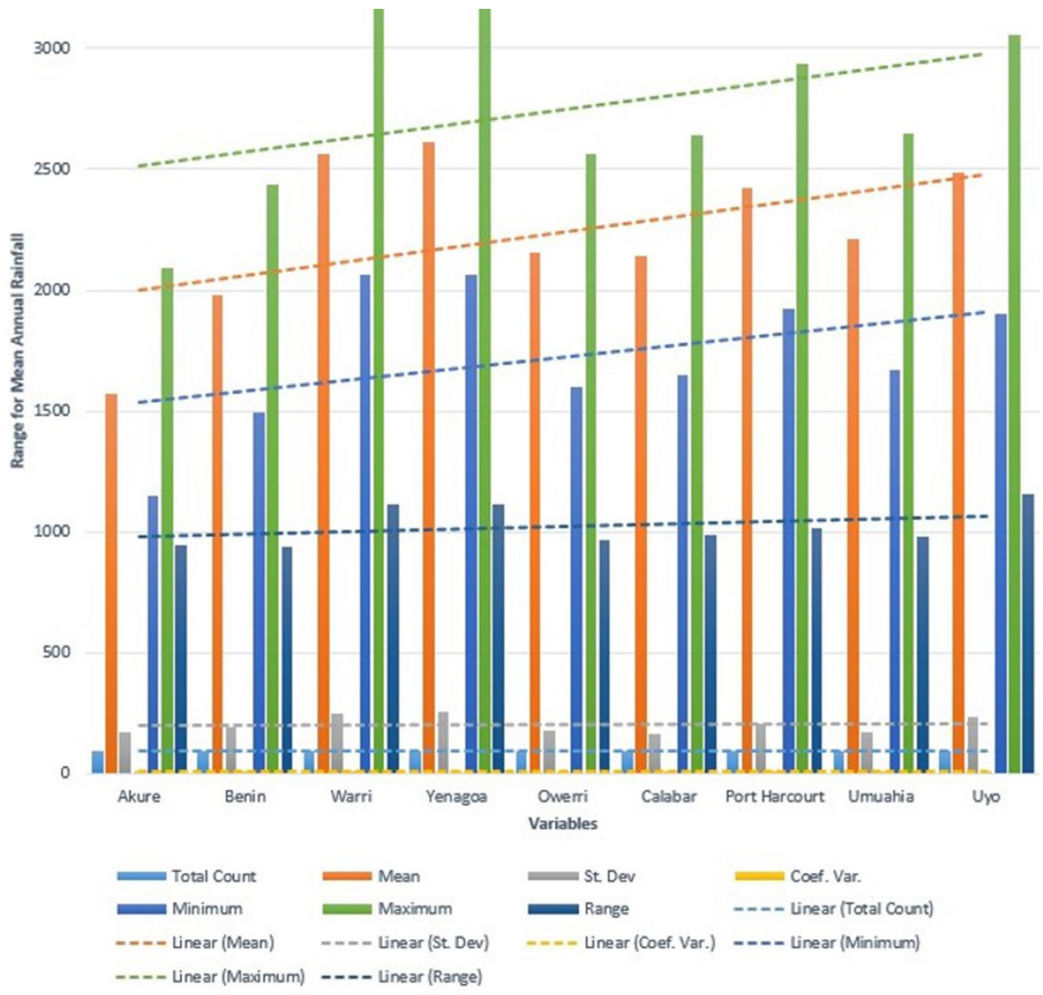

FIGURE 2
Mean annual rainfall in the Niger Delta Region. Source: Adopted from Odigwe et al. (2020).

Policies must embrace transparent and timely communication with the community concerning the findings of the repercussions of climate change impacts. Engaging the public in appreciating the significance of these processes can nurture support and compliance with suggested interventions.

The paucity of studies conducted in Africa on the impact of climate change in Niger Delta built environment matrices is due to several issues, such as inadequate infrastructure, data collection concerns, restricted research partnership, minimum awareness and the severity of climate change (Balogun and Onokerhoraye, 2022; Agboola et al., 2023). For example, inadequate infrastructure: Many African countries face concerns regarding infrastructure and funds for scientific research. No monetary assistance, laboratory services, and trained personnel can deter the skill to conduct such research—data collection concerns: collecting and analyzing climate change variations and impacts requires specialized apparatus and proficiency. In several African countries, these competencies might be missing or untapped (Bhaga et al., 2020). Low awareness: climate change or global warming and its impact is at the front burner of research. Built environment professionals (BEPs), health and medical professionals (HMPs), policymakers, and researchers in Africa may lack awareness of its potential benefits. Seasonal nature: climate change impacts tend to be adverse in some seasons in several areas, including Africa, making it further challenging to conduct perennial reconnaissance and limiting the apparent urgency of such research (Awolala et al., 2022).

Consequently, to address the lack of research in Africa, it is vital to prioritize capacity building, support global collaboration, heighten the significance of climate change awareness, and assign resources precisely for this purpose. Investing in research infrastructure and training for local researchers and institutions can bridge the gap and contribute to a more inclusive knowledge of climate change's impact on the region. Moreover, increasing awareness about the possible benefits of climate change mitigation and control can encourage more extraordinary research efforts in this area.

4.1 Climate changes and variations in the Niger Delta Region

Mangodo et al. (2020) observed climatic trends in the Niger Delta, Nigeria, employing 1951–2012 climatic data for five synoptic stations in the region. The study used rainfall, rain days and mean temperature as variables. The correlation coefficient was engaged to determine the statistical import of the trend, and the result indicated that yearly mean temperature exposed an upward trend from 1951 up to 2012 in the region; the practical upward trend is statistically vital at a 99% level of confidence ($\alpha = 0.01$) while rainfall and rain days are not statistically vital. The result of the standardized anomalies of annual mean rainfall in the Niger Delta depicts a fluctuating rainfall pattern (Qian et al., 2022). In contrast, the standardized mean temperature anomalies indicated warming in the region, indicating more positive deviation from the mean. It suggests that are pieces of evidence of climate change in the Niger Delta Region.

Similarly, Ofoezie et al. (2022) assessed that the urban climate of Benin City in the region showed that the city had experienced climatic changes due to rapid urbanisation. The study attributed this to deforestation, vegetation modification and loss of fauna, which invariably modifies atmospheric thermal and hydrological characteristics that affect climate change. Climate change is a grave global challenge facing the universe in the 21st century. Climate change affects the architecture, environment, and people in urban centers. Its impact has affected peoples' health, housing, safety, work, and ability to grow food (Atubi and Osoyibo, 2020). Therefore, the critical issues for discussion in this paper are (i) Climate change and Architecture, (ii) Climate change and the environment, and (iii) Climate change and Associated Urban problems.

4.2 Climate change and architecture

According to Andrić et al. (2021), Climate change impacts the architecture of buildings in various ways. It is due to its effects on temperature, precipitation, wind, and sunlight, which are all critical factors in defining climate and influencing the architecture of buildings. The extreme high temperature from climate change gives rise to high radiation, which affects some building materials; much precipitation also negatively impacts building materials, such as moods and problems associated with humidity. In Benin City, research uses data collected from the Nigerian Meteorological Agency (NIMET) to assess climatic changes in Benin City within Thirty-five (35) years from 1981 to 2015. The study revealed that the average temperature increased significantly from 27.17 degrees Celsius to 28.12 degrees Celsius as the average Annual Rainfall rose from 153.66 mm between 1981 and 1990 and 211.57 mm from 2011 to 2015. Similarly, humidity between 1981 and 2015 increased from 81.51 per cent to 22.73 per cent, as shown in Tables 1, 2, Supplementary Table S1, respectively. These findings are significant and critical in assessing architecture, environment, and climate change in Benin City.

Another critical problem of the urbanisation process related to architecture or building design is the issue of poor indoor air quality, outdoor pollution and atmospheric pollution, all closely related to climate conditions. Given these, human health could be in danger if climatic conditions do not favor good indoor and outdoor qualities. Hence, the architecture of the building should seriously consider these factors. Architecture enhances human activity by providing suitable dwelling units to satisfy its occupants (Dimuna and Olotuah, 2019). It can be primarily through the designed arrangement and proper harmonization of other design elements and factors that enhance thermal comfort, acoustic controls, adequate ventilation, and daylighting (Graça et al., 2022). Altomonte et al. (2024) opined that good architecture must and should satisfy some basic requirements for users or occupants of a designed environment. Among these requirements are physical needs in terms of (satisfactory body reaction to feelings); emotional needs in terms of (esthetics and psychological enhancements); and intellectual needs (logic, orderliness, and flawlessness) (Zallio and Clarkson, 2021). Therefore, housing or buildings that are adequate, decent, and of good quality must have good architecture.

Such architecture must be responsive to the climate and other socio-economic factors that tend to influence forms of architecture, building designs, and environmental management strategies in general or in different ways (Fallmann and Emeis, 2020). Architects, therefore, should pay more attention to the area's climatic conditions because of the need to find a possible metrological solution to the

growing quantity of suspended particulate matter, especially in urban centers, due to the impact of climate change.

4.3 Built environment and climate change

The built environment is a sum of all living and non-living and their effects influencing human life. The built environment is our immediate surroundings, including living and non-living things. According to Lee and Kim (2021), the built environment is the aggregate of all external conditions influencing and affecting the organism's life. The totality of the built environment is three significant areas: natural, built, and human-based organization environment (social environment). The natural environment, called the biophysical environment, comprises biotic and abiotic subcomponents and conditions of living and non-living things (Fan et al., 2023). The built environment includes the entire environment devoid of the natural environment and, in more specific terms, involves the environment removing the natural ecosystem and replacement with several forms of physical development established in multiple dimensions.

The built environment refers to the buildings, infrastructures, and space around them. These are numerous in the urban centers in different forms, shapes, sizes, spatial extent, and skyscrapers, among others, where architect display their talents. On the other hand, human-based organizations (social environments) are part of the resources in an urban environment. It is extrinsic (Klinsky and Mavrogianni, 2020). These extrinsic resources, when exploited, can produce positive or negative impacts.

Man's insatiable quest to exploit natural resources has led to deforestation, the non-availability of timber in the forest, and, consequently, the high prices of timber derivates for building construction (Cole, 2020). Environmental degradation has become commonplace in Nigeria, as evidenced by deforestation, water and air pollution, floods, particularly in southern Nigeria's rainforest humid region, and droughts and desertification in far northern Nigeria. Morufu et al. (2021), Adi (2023), and Akanwa et al. (2024) opined that environmental degradation has severely affected human well-being. In the same vein, Heinzlef et al. (2022). argued that ecological degradation and the decline of the environment could lead to the depletion of resources such as soil, water and air, the demolition of the ecosystem habitat, loss of wildlife and pollution. The environment degrades when climate change destroys natural habitats or depletes natural resources. Environmental degradation, therefore, arises from the interplay of socio-economic, institutional, and technological activities (Balogun et al., 2021). To some extent, the quality of the environment affects the quality of health of citizens. Man's anthropogenic activities, mining and farming, and other pollution-related activities damage the environment and biodiversity (Santamouris, 2020).

The environmental crisis of the twenty-first century resulting from climate change and consequent effects on ecological degradation, environment deterioration, etc., (Dong et al., 2024), have been described as injustice to developing countries such as Asia, Latin America, and sub-Saharan Africa. It is so because these nations have not contributed significantly to climate change but are directly affected by the impending disasters resulting from climate change (Abbass et al., 2022). On the other hand, developed countries continue to exploit the environment with a lifestyle based on heavy industrialization, depleting resources and producing a quality of waste that the environment cannot absorb. Concerns about the degeneration of the entire universe and global climate change are mounting. Climate change, resource depletion, water shortages, contamination and biodiversity loss are some environmental consequences that today's generation is concerned about (Gaisie and Cobbinah, 2023). In recent times, the global environment has witnessed various forms of environmental degradation, with unprecedented disasters rampaging different continents. It affects sub-Saharan countries, including Nigeria. The environment is also an indispensable asset for architecture.

4.4 Climate change and associated problems

Climate change defines a change in the average conditions, such as temperature, humidity, rainfall, *et cetera*, in a region over an extended period (Abodunrin and Emetere, 2021; Spiridonov and Ćurić, 2021). Climate change is at the forefront of significant world discourse due to the negative impact of global warming caused by gas flaring and other environmental degradation. The effects of climate change, indeed, appear to threaten the future of human life and existence. Climate change can affect public health, capacity to grow food, housing, safety and work (Abi Deivanayagam et al., 2023). The report highlights that people are experiencing climate change in diverse ways: *"Earth's temperature has risen by an average of 0.14° Fahrenheit (0.08°C) per decade since 1880 or about 2°F (16.67°C) in total. Nigeria's mean annual temperature is 26.9°C, with an average monthly temperature between 24°C (December, January) and 30° C in April. The mean annual precipitation is (1,650 mm). It has been predicted by (2030) that about 3 billion to 3.6 billion people will live in a highly vulnerable context to climate change. An estimated 700 million people will be at risk of displacement by drought alone."*

Heat and humidity are also problems in urban areas. Urban Heat Island (UHI) and associated problems are due to climate change or variations. Weather sensitivity in man is an issue that needs addressing. Man's physiological and psychological responses to weather changes, known as meteor-tropism, are widespread and generally result in some bodily impairment in man. Climate changes and variations have impacted man by causing reactions such as scars and corns. Its attribution is to changes in atmospheric moisture, which causes differential hygroscopic expansion and contraction between healthy and abnormal skin, leading to pain. Patients with rheumatoid arthritis, commonly known as rheumatism, are widely affected by weather changes; both pain and swellings of affected joints have been with increased atmospheric humidity (Azzouzi and Ichchou, 2020). Sudden cooling can also trigger such symptoms. High value can cause prickly heat and itchy rash attributable to partial blocking of sweat glands. Weather is also a significant factor in asthma attacks.

4.4.1 Loss of biodiversity

Biodiversity refers to the variety of plants and animals' lives in the world or a particular habitat, a high level of which is usually considered essential and desirable (Dorst et al., 2019). Biodiversity has three levels or types: genetic diversity, species diversity, and ecosystem diversity. Each works together in the ecosystem to maintain and support life on Earth and exist in a delicate balance (Pender, 2023). Another term closely associated with biodiversity is the ecosystem. The natural environment contains the flora (plants) and fauna (animals) that live and relate to the setting. This natural harmony affects climate change

in various ways (Zandalinas et al., 2021). One noticeable aspect is deforestation, which has become a critical phenomenon in Nigeria, especially in the rainforest belt of southern Nigeria. It covers the Niger Delta States. Tropical forests are disappearing at a very high rate. If the current trends continue, most tropical forests will soon be severely damaged or destroyed. Fuel wood demand, harmful logging practices and population growth have all contributed to deforestation.

4.4.2 Urban flooding

Flooding is an overflowing or eruption of a significant body of water over land not typically submerged (Mfon et al., 2022). Flooding comes with climate change. Climate change with more intense rainfalls increases the chances of flooding. Floods are weather-related hazards that are most widespread around the world. It occurs both in developed and developing economies. Typically, flooding is traced to a water body that moves faster than usual due to the large body of water and the speed of an increased amount of water upstream, leading to an increase in the pressure gradient that drives the flow. In most cases, the fast-moving flood carries debris of different natures and sizes, such as trees, vehicles, boulders, damaged structures, etc. It, in turn, can sweep away any movable obstacles on its path and with resultant damages and destruction.

Natural and human activities cause flooding; the natural causes are excessive rainfall, soil weathering, and terrain denudation. The primary and significant causes of flooding in Nigeria's major cities and towns as a result of human activities, according to Mfon et al. (2022), include the growth of illicit structures on/across drainage, land recovery or infringement, deprived physical planning, inadequate drainage channels, obstruction of canals and drains, shrunken dams and nature of terrain and bad solid waste management (Aghaloo et al., 2024). Other causes include poor environmental planning and monitoring, housing development in flood-prone areas, deforestation, and haphazard development resulting in blockages in the drains, inadequate waste disposal and management, and negligence by government workers and agencies (Mensah and Ahadzie, 2020). Various scholars identified rapid growth urbanisation, poor urban planning and climate change significantly increased frequency and intensity of rainfall as part of the cause of flooding in Nigeria (Echendu, 2023). Eccles et al. (2019) traced flooding to the relative contribution of climate elements and environmental variables. Udokpoh and Garba (2023) show climate change is responsible for the recent severe flooding in Uyo, Akwa Ibo State. Another cause of perennial flooding in Nigeria is the river and ocean surges. Scholars have identified two major types of floods – flash floods and river floods (Mujumdar et al., 2020).

Flooding has resulted in the destruction of wildlife habitats and that of humans. Flooding in Nigeria is associated with heavy loss of lives and properties, hardship, misery, diseases, and famine due to farmland damage. Flooding can destroy homes, roads, and rail lines and disrupt drainage and sewage systems; silt and sediment from flood water can ruin farm crops. Leveque et al. (2021) stated that floods can compromise the drinking water supply, and contaminated flood water can pollute rivers and habitats. Javadinejad (2022) concluded that flooding leads to water pollution, property damage, and loss of lives. Floods affect the economic life of people, animals, and the environment. Week and Wizor (2020) identified connections between the magnitude of flooding to determine the vulnerability of some neighborhoods, especially those in the coastal areas.

In recent times, Nigeria has recorded and witnessed severe flooding. The remarkable ones include those of July 2012 and November 2012. Reports from Nigeria's National Emergency Management Agency (2012), as cited by Alimi et al. (2023), revealed that thirty (30) of Nigeria's thirty-six (36) states were affected by the flood. It resulted in the displacement of over seven million people, 363 deaths and affected over seven million people. NEMA estimated that the floods caused damages and losses of #2.6 trillion naira. The flood overran many of Nigeria's coast and inland towns and cities. The major cities were Niger State, Kogi State, Delta State, Edo State, Anambra State, Imo, River and Bayelsa, as shown in Figures 3A–F. Others include Lagos, Oyo State, especially the Niger Delta Geopolitical Zones of the South–South Nigeria.

4.5 Climate change and mitigation strategies

4.5.1 Climate-sensitive planning

Climate-conscious planning requires analyzing and understanding urban climatological problems (Kwok and Ng, 2021). It will involve appreciation and documentation of the nature of surface texture, extent, human activities, and metropolitan population distribution. Achieving a better urban climate requires understanding, first and foremost, the urbanisation features responsible for changes in the atmospheric environment (Bekele and Atakara, 2023). These essential features are air pollution, anthropogenic heat, surface geometry and building conditions. There is a need to pay attention to land-use patterns in the form of zoning. By this, industrial, residential, commercial, recreational, and educational zones will be classified and adhered to reduce why the weather is generally becoming hotter in Sub-Sahara Africa and significantly colder elsewhere. What impact do these conditions have on architecture and the built environment? There seem to be some irregularities in the timing and intensity of climatic conditions. Therefore, there is a need to address these challenges. Along this line of reasoning, this paper attempts to draw some challenges that the climate change crisis poses to architecture and the built environment.

4.5.2 Design with climatic parameters/factors in building design

Designing buildings with climatic parameters is an essential architectural strategy (Javanroodi et al., 2023). Adopting this strategy helps the building designer or architect to take important climatic factors such as temperature, rainfall, humidity and sunshine into consideration(Eltanboly and Ibrahim, 2022). The professional is to interrogate why the weather is generally becoming hotter in Sub-Saharan Africa and significantly colder elsewhere. What impact do these conditions have on the architecture and the built environment in such a geographical location? Recognizing that there seem to be some irregularities in the timing and intensity of climatic conditions is the first step to providing good architecture. It is a topical issue that housing must be reasonably maintainable, architecturally expressive, and compliant with the environment (Pan et al., 2024). Therefore, the architecture should be responsive to the environment. It should determine building forms, floor plans, roof patterns and esthetic values. Experience has shown that old traditional architecture made space for a courtyard. Design themes, provision of balconies, verandas or patios, wide roof

eaves and window hoods to protect against rain and reduce the effect of sunlight seem better concepts when compared to new elevations that adorn the cities of the Niger Delta.

4.5.3 Mitigate incidences of flooding

Checking the incessant incidences of flooding is vital in managing urban problems. Controlling unwarranted and haphazard urban physical developments could do this. Authorities should not grant building permits in areas along the natural flood drains and terrain. Adequate measures should be taken by the government and citizens to continually ensure that water channels such as gutters and concrete water drains allow for easy flow of water.

4.5.4 Reduce unwarranted cutting of trees

Architects and builders should maximize the benefits of existing vegetation in the design by incorporating such features into the building landscape. Trees planted around buildings provide extensive shade to the surroundings and reduce heat gain to buildings during the day. Trees help to prevent solar radiation and stop structures and surfaces from heating up beyond the ambient temperature (Sankar Cheela et al., 2021). Trees and vegetation help to cool buildings by providing shade from direct sunlight. It is another way of achieving energy efficiency in buildings and reducing energy use, especially in humid tropical climates such as that of the Niger Delta—the trees and vegetation benefit building occupants as they impact the health and psychology of the occupants.

4.5.5 Sustainable conscious architecture

Sustainable architecture seeks to create an environment and buildings that satisfy the physical and psychological needs of the occupants. The physical needs include comfort (adequate space), insufficient lighting and ventilation, and noise. In contrast, the

FIGURE 3
(A–F) Flooding inside Christ Grace Ministry Church Owerri, Imo and Asaba, Delta. Source: Adopted from Authors' Fieldwork.

psychological needs include pleasant surroundings, a serene environment and an environment that educates and motivates the residents. There is a link between architecture, environment, and climate change (Daoudi et al., 2019). In the opinions of several authors (Li et al., 2020), the issues of sustainability and environmental conservation are central to the architecture profession, especially in climate change. Therefore, there is a need to appreciate and incorporate energy efficiency principles in the architecture and planning of houses. It ensures the realization that energy matters and zero-carbon emissions when planning for a green environment.

5 Limitations

This research had some limitations, including the fact that the review was cross-sectional and thus may not deduce causal directions. However, the articles we examined were slightly adequate compared to others. There were correspondingly inadequate studies on Niger-delta climate change, which led to a restricted number of studies exactly addressing the impact of climate change on dwellers well-being and the architecture of Niger-delta built environment, deterring the ability to draw healthy conclusions about the required public health mediations and prefer suitable recommendation to mitigate the global warming effect within communities in the Niger-delta, Nigeria.

5.1 Contributions

The review article contributes by employing building envelope improvements and other system efficiencies to reduce emissions (GHGs), encourage the government to take bold, ambitious climate action now, Use energy efficiently, encourage green commuting, Consume and waste less, Support Indigenous-led climate action, Invest in renewables and divest from fossil fuels, Eat for a climate-stable planet, Better forestry management and sustainable agriculture, Sustainable buildings, Conservation-based solutions, Industrial solutions and emphasizes the use of eco-friendly materials, such as recycled, reclaimed, and rapidly renewable resources.

6 Conclusion

This study systematically reviewed the impact of climate change in the Niger Delta Region. Based on the review of the extant literature, the study concluded that there is a significant change in the climate of the Niger Delta Area. The review also highlighted that these climate variations have impacted architecture, building designs, the environment and the well-being of dwellers in different ways in the region. Climate change and its variations have become a natural phenomenon that is irreversible. However, its impact on architecture, the built environment, and the well-being of the dwellers should undergo mitigation.

6.1 Policy recommendation/implications for urban planning, building regulations, or disaster management

The following recommended policy measures:

i Architectural design must consider using Flood-resistant building designs and materials, Elevated structures and stilts to protect against flooding, Green roofs and walls for insulation and temperature regulation, Rainwater harvesting systems and Climate-resilient building codes.

ii Environmental measures should consider the application of biomimicry principles and strategies as innovative solutions in alleviating the impact of flooding in the Niger-delta region through techniques such as Mangrove restoration and conservation, Wetland protection and restoration, Coastal erosion control measures (e.g., seawalls, breakwaters), Sustainable urban planning and land-use management and Climate-smart agriculture practices.

iii Climate Change Adaptation Measures need implementation by the Metrological Agency and relevant ministries in the form of early warning systems for flood and storm alerts, Climate-resilient infrastructure, Disaster risk reduction and management plans, Community-based adaptation initiatives and Climate change education and awareness programs.

iv Global governments must be proactive and adopt the necessary Policy and Regulatory Frameworks such as National Climate Change Policy and Action Plan, Niger Delta Regional Climate Change Strategy, Environmental Impact Assessment (EIA) regulations, Building codes and zoning regulations and Incentives for climate-resilient development.

v Other measures include Institutional and Community Engagement, such as Establishing climate change departments in government agencies, Community-based climate change adaptation committees, Public-private partnerships for climate resilience, capacity building for climate change mitigation and adaptation and Climate change research and development institutions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

KD: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. EE: Conceptualization, Data curation, Formal analysis, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. ON: Data curation, Investigation, Methodology, Resources, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2024.1498938/full#supplementary-material

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