International Journal of Research Publication and Reviews, Vol 6, Issue 3, pp 8897-8904 March 2025

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Causes of Climate Change Indicators in the South-South and How it Affects Architecture

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DOI : https://doi.org/10.55248/gengpi.6.0325.12182

Introduction

The past 10,000 years have seen a relatively stable and mild climate, which has been highly beneficial for human development. This period facilitated the rise of agriculture, stable settlements, and complex societies. While there have been minor local weather variations, these changes generally occurred gradually, allowing ample time for adaptation or migration.

However, since the onset of the Industrial Revolution, the rate of climatic variations has accelerated dramatically due to human activities, particularly the combustion of fossil fuels. This has altered the chemical composition of the atmosphere, leading to significant global climatic shifts. The threat of global warming, driven by the accumulation of heat-trapping gases, is now widely recognized.

It is only recently that we have begun to understand the extent to which our actions since the Industrial Revolution, and possibly earlier, have potentially disrupted the fundamental conditions that allowed life to flourish on Earth. Buildings play a significant role in this context due to their substantial energy consumption and associated CO2 emissions.

To address these threats and achieve sustainable development, a new approach to building design and construction is imperative. This approach must consider the complex demands of the environment and the needs of contemporary societies and economies. New concepts in integrated design, incorporating sustainable methods of energy generation and utilization, are essential. This involves combining environmental responsibility (mitigating human impacts) with climate responsiveness (adapting to climate change).

An important lesson can be learned from adaptive natural systems. In nature, living organisms evolve mechanisms to withstand changing conditions without depleting resources or disrupting ecosystem equilibrium. Given the current global climate changes and their rapid pace, adopting an 'adaptive' mindset in building design can provide a foundation for future sustainable construction.

For humans to thrive, it will be necessary to emulate nature's adaptive metabolic systems, integrating ancient knowledge with current and emerging technologies. This can lead to more sustainable design (Altomonte, 2008).

The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate change as a discernible alteration in the state of the climate, identified through statistical tests by changes in the mean and/or variability of its properties, which persists for decades or longer. Ayoade (2003) emphasized that secular variations in climate over 100 to 150 years may not qualify as climate change unless they produce clear, lasting impacts on the ecosystem.

Climate change is distinct from climatic fluctuations or variability, which refer to the inherent dynamic nature of climate on various temporal scales, including monthly, seasonal, annual, decadal, periodic, quasi-periodic, or non-periodic variations. (Akpodiogaga-a & Odjugo, 2010)

Climate is the cumulative result of day-to-day weather patterns. Despite significant attention from scholars and political figures regarding climate change, the issue persists. The environment encompasses the totality of conditions in which an organism lives, including all external factors influencing the development of any living organism (Aloni & Alexander, 2020)

Buildings, monuments, and other man-made structures are integral components of the human environment. The Earth's physical environment is bifurcated into biotic and abiotic elements. It serves as the framework within which humanity organizes society and conducts activities, forming the skeleton upon which humans and other organisms manifest their existence and achievements. This environment also includes elements that enhance the lives of living organisms and humans on Earth. (Budnukaeku & Francis, 2022)

Dearden and Mitchell (2009) described the concept of an ecosystem as a community of organisms cohabiting or occupying a specific region within a biome. In an ecosystem or environment, interactions between organisms and their surroundings, as well as among the organisms themselves, are inevitable.

Effects of Climate Change in the Built Environment

i. Higher Temperatures

The urban heat island effect, where urban areas experience significantly higher temperatures than their rural surroundings, is expected to intensify, particularly during summer nights. This phenomenon results from human activities and the extensive use of materials that absorb and retain heat, such as concrete and asphalt. Consequently, there will be a substantial increase in the demand for cooling systems, leading to higher electricity consumption during the summer months. This increased energy demand can strain the electrical grid and contribute to higher greenhouse gas emissions. Conversely, the demand for space heating during winter will decrease, potentially offsetting some of the increased summer energy use but also impacting energy providers and infrastructure designed for colder conditions.

ii. Flooding

The frequency and intensity of winter rainfalls are anticipated to increase, leading to more frequent riverine flooding and overwhelming urban drainage systems that are not designed to handle such volumes of water. Additionally, rising sea levels, increased storminess, and more frequent tidal surges will necessitate more closures of the Thames Barrier, a critical defense mechanism for London against flooding. These changes will require significant investment in flood defense and water management infrastructure to protect urban areas and mitigate the impacts on communities and businesses.

iii. Water Resources

Hot, dry summers will lead to heightened water demand as people and agriculture require more water for cooling and irrigation. Simultaneously, there will be reduced soil moisture and groundwater replenishment, exacerbating water scarcity issues. River flows are expected to be higher in winter due to increased precipitation and lower in summer due to higher evaporation rates and reduced rainfall. Water quality problems are likely to arise in the summer, associated with increased water temperatures and discharges from stormwater outflows, which can carry pollutants into water bodies. These challenges will necessitate improved water management practices and infrastructure to ensure sustainable water supply and quality.

iv. Health

Poorer air quality will become a more significant issue, particularly affecting individuals with respiratory conditions such as asthma. Increased air pollution can also cause damage to plants and buildings, contributing to broader environmental and public health problems. Higher mortality rates are expected during the summer due to heat stress, particularly affecting vulnerable populations such as the elderly and those with pre-existing health conditions. Conversely, lower mortality rates in winter are anticipated due to a reduction in cold spells, which typically contribute to higher rates of illness and death. Public health strategies will need to adapt to these changing patterns to protect communities and reduce health risks.

v. Biodiversity

The competition from exotic species, alongside the spread of diseases and pests, will significantly affect both fauna and flora. These changes can disrupt local ecosystems, leading to the loss of native species and the alteration of habitats. Rare saltmarsh habitats, which are particularly vulnerable to sea level rise, will be threatened, potentially leading to the loss of these critical ecosystems. Increased summer droughts will stress wetlands and beech woodlands, which rely on consistent moisture levels. Additionally, earlier springs and a longer frost-free season will affect the timing of biological events such as bird egg-laying, leaf emergence, and plant flowering, disrupting the synchronization of ecological processes and potentially leading to mismatches in food availability and habitat conditions.

vi. Built Environment

The increased likelihood of building subsidence on clay soils, which expand and contract with moisture changes, will pose significant risks to infrastructure stability. Increased ground movement during winter will affect underground pipes and cables, leading to higher maintenance and repair costs. Additionally, the reduced comfort and productivity of workers due to extreme weather conditions will impact businesses and economic output. Building design and construction practices will need to adapt to these new conditions, incorporating resilient materials and techniques to mitigate the impacts of climate change on the built environment.

vii. Transport

Extreme weather events will cause increased disruption to transport systems, affecting the reliability and efficiency of public and private transportation. Higher temperatures will reduce passenger comfort on the London Underground, where temperatures can already become uncomfortably high during the summer. Infrastructure damage, such as buckled rails and rutted roads, will become more prevalent, leading to higher maintenance costs and safety risks. However, there will be a reduction in cold weather-related disruptions, which currently pose challenges during winter. Transport planning and infrastructure will need to adapt to ensure resilience against a wider range of climatic conditions.

viii. Business and Finance

The insurance industry will face increased exposure to extreme weather claims, driving up costs and premiums. Households and businesses will find it increasingly costly and difficult to obtain flood insurance cover, particularly in high-risk areas. However, the need for improved risk management and adaptation strategies will provide significant business opportunities for companies specializing in resilience planning and climate adaptation services.

Financial markets and investment strategies will also need to incorporate climate risk assessments to safeguard against potential losses and capitalize on emerging opportunities.

ix. Tourism and Lifestyle

Increased temperatures could attract more visitors to London, boosting the local economy and tourism sector. However, high temperatures may also encourage residents to leave the city for more frequent holidays or breaks to escape the heat, impacting local businesses. Outdoor living, dining, and entertainment may become more favored, with people spending more time in green and open spaces. These areas will be used more intensively, requiring better maintenance and management to ensure they remain attractive and functional. Urban planning and development will need to accommodate these lifestyle changes, creating more sustainable and enjoyable environments for residents and visitors alike. ('A Review of Climate Change Impacts on the Built Environment: Ingenta Connect', 2007)

Study Area

The South-South region of Nigeria, one of the six geopolitical zones in the country, comprises six states: Akwa Ibom, Bayelsa, Cross River, Delta, Edo, and Rivers. This region is characterized by a humid tropical climate, marked by distinct wet and dry seasons. Economically, the South-South region is of paramount importance due to its rich crude oil reserves, which form the backbone of Nigeria's economy. Furthermore, this region accounts for a significant proportion of Nigeria's population (Ukhurebor & Abiodun, 2018).

Figure 1: A Map of the Picture of Geopolitical Zones of Nigeria

Source: (Yakubu, 2021)

Figure 2: The Map of South-South Region of Nigeria

Source: (Tribunal, 2023)

Natural Causes of Climate Change

i. Plate Tectonics

The interactions between tectonics, life, and surface processes on Earth are intricate and not always immediately apparent. The formation of compressional mountain ranges is heavily influenced by orographic precipitation. Furthermore, global tectonic activities have created conditions that trap reduced carbon, thereby enabling the accumulation of atmospheric oxygen, which is vital for sustaining life. Additionally, the deep subduction of water in tectonic zones leads to significant arc volcanism. (Sleep, 1995)

The impact of life on tectonics is harder to demonstrate compared to the influence of climate. It is evident that organisms affect both mechanical and chemical erosion, and they also play a role in determining where different types of sediments are deposited. A more significant interaction is proposed by the Gaia hypothesis, which suggests that life helps maintain surface conditions on Earth that are conducive to its own existence (Lovelock, 1989).

ii. Volcanic Activity

Explosive volcanic eruptions significantly impact the Earth's natural processes and climate by causing temporary disturbances in the planet's energy balance and triggering complex climate feedback mechanisms. These eruptions are known to cool the atmosphere for a few years, but they also influence major climate variability modes and leave detectable signals in the subsurface ocean for decades. Over the past two centuries, volcanic activity has reduced global warming by approximately 30% by offsetting ocean heat uptake. In the future, volcanic eruptions could slightly slow global warming, which must be factored into long-term climate predictions. Renewed interest in the impacts of volcanic eruptions is also due to their potential as natural analogs for climate geoengineering strategies, such as creating an artificial aerosol layer in the lower stratosphere to combat global warming (Stenchikov, 2021)

iii. Variations in the Earth’s orbit

The Earth's climate is characterized by trends, anomalies, and quasi-periodic oscillations over various time scales. Long-term trends are primarily driven by plate tectonics, causing gradual changes over millions of years. Anomalies occur when thresholds are crossed, leading to rapid or extreme climate changes visible in the geological record. Quasi-periodic oscillations are influenced by astronomical cycles—eccentricity, precession, and obliquity—that affect the Earth's orbit and axis orientation, resulting in climatic oscillations over tens to hundreds of thousands of years. Geological records, ice cores, and proxy data provide evidence of these astronomically induced climate oscillations. Understanding orbital forcing is essential for addressing and mitigating both long-term natural and short-term global climate change issues.(Lourens & Tuenter, 2009)

iv. Solar variability

The Sun has an obvious effect on climate since its radiation is the main energy source for the outer envelopes of our planet. Nevertheless, there is a long-standing controversy on whether solar variability can significantly generate climate change, and how this might occur. This is a crucial issue not only in the field of paleoclimatology, but also for predicting the future of the Earth's climate, which will be subject to perturbations by anthropogenic greenhouse gases. Indeed, if climate changes due to the Sun were large and rapid, this would make it more difficult to extract the anthropogenic effects from precise records of instrumental data over the past century. Hence, Sun–climate relationships have never been so controversial as today, forming a debate that often escapes the scientific arena.(Bard & Frank, 2006)

Man-made Causes of Climate Change

Climate change is widely believed to be driven by human activities. This perspective aligns with the views of scholars such as (Karl & Trenberth, 2003), who argue that climate change is anthropogenic in nature. Supporting this stance, researchers have identified several human-induced factors contributing to climate change, including urbanization, transportation, land use changes, deforestation, the exponential growth of the global population, industrialization, and the increased release of greenhouse gases, predominantly from buildings. Research indicates that these factors contribute to the depletion of the ozone layer, leading to global climate change. Specific examples of anthropogenic emissions include carbon dioxide (CO_2), greenhouse gases (GHGs), nitrous oxide (N_2O), methane (CH_4), ozone (O_3), and chlorofluorocarbons (CFCs), which have significantly caused global warming and, consequently, the climate change we observe today (Welch et al., 2010)

Causes of climate change in the South-South Region of Nigeria

A primary contributor to climate change in the South-South region of Nigeria is the extensive exploration and exploitation of crude oil, driven by the region's rich deposits of this valuable mineral resource. The activities associated with oil extraction and processing, including drilling, flaring, and transportation, release significant amounts of greenhouse gases and pollutants into the atmosphere. These emissions contribute to global warming and environmental degradation, altering local climatic conditions and impacting the health and livelihoods of the communities in this region. Furthermore, oil spills and other environmental hazards associated with crude oil exploitation have severe ecological consequences, disrupting local ecosystems and reducing biodiversity. The cumulative effect of these activities underscores the critical need for sustainable practices and stringent regulatory measures to mitigate their impact on climate change.

The activities associated with oil exploration and exploitation result in significant environmental alterations, many of which have negative effects. However, some of these adverse effects can be mitigated or prevented through proactive measures. Effective monitoring is crucial, but it is notably insufficient in the Niger Delta region. Challenges such as the remote locations of oil companies, difficult terrain, accessibility issues, revenue constraints, lack of manpower, and the absence of qualified personnel hamper the government's ability to monitor and regulate these activities effectively (Kadafa, 2012).

Additionally, there are lesser but significant contributors to climate change in the South-South region. These include urbanization, transportation, changes in land use, deforestation, the rapid growth of the global population, industrialization, and the increased emission of greenhouse gases, mainly from buildings.

Climate Change Indicators Present in Nigeria

Nigeria's climate has been changing, evident in: increases in temperature; variable rainfall; rise in sea level and flooding; drought and desertification; land degradation; more frequent extreme weather events; affected fresh water resources and loss of biodiversity. The durations and intensities of rainfall have increased, producing large runoffs and flooding in many places in Nigeria.

Rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands. Droughts have also become a constant in Nigeria, and are expected to continue in Northern Nigeria, arising from a decline in precipitation and rise in temperature. Lake Chad and other lakes in the country are drying up and at risk of disappearing.('Climate Change in Nigeria', 2019)

Flooding is the most frequent and recurring natural disaster in Nigeria. While the damage and losses from the 2012 flood disaster were substantial, the 2022 floods, which occurred on a multidimensional scale, had even more devastating effects. This report presents an impact assessment of the 2022 floods in Nigeria, highlighting key findings regarding their impact, recovery, and coping mechanisms employed by affected households. It also provides an evidence-based strategy for future flood risk mitigation and adaptation. The assessment focused on six states—Anambra, Bayelsa, Delta, Jigawa, Kogi, and Nasarawa—which represent a significant portion of the population affected by the 2022 floods. The survey was conducted in collaboration with NBS, NEMA, and UNDP.('Nigeria Flood Impact, Recovery and Mitigation Assessment Report 2022-2023 | United Nations Development Programme', 2023)

Climate change effect on Architecture

"Architecture is the art and science of making sure that our cities and buildings actually fit with the way we want to live our lives: the process of manifesting our society into our physical world". - Bjarke Ingels in AD Interviews('121 Definitions of Architecture | ArchDaily', 2019)

The role of architecture in regulating the indoor environment is well established. Some authors refer to architecture as the "third skin" of humans, serving as an intermediary between the user's body and their surroundings. Therefore, design solutions and building materials should be tailored to outdoor climatic conditions to enhance indoor comfort through natural and passive methods. Conversely, if architectural solutions are not well-suited to climatic needs, energy consumption for artificial air conditioning increases.(González Couret, Rodríguez Díaz, & Abreu de la Rosa, 2013)

The indoor environment of buildings serves as a protective barrier against the changing and potentially hazardous conditions of the outdoor environment. Buildings provide occupants with protection, space for economic activities such as manufacturing and food production, and opportunities to promote human health and well-being, including education. (Gupta, Vahanvati, Häggstrom, & Halcomb, 2020).

Conversely building design significantly impacts the urban environment and can potentially double certain risks. For instance, increased building density can exacerbate urban heat island effects and urban flooding. However, strategies such as greening buildings can help mitigate these issues. Capturing and filtering water from buildings can also reduce excessive runoff during flash floods. The integration and collaboration among built environment professionals are fundamental to applying holistic urban design principles. This approach will be crucial for maintaining the habitability and asset value of both existing and new buildings in the face of increasingly unpredictable and extreme climate change threats.(Ezeabasili & Okonkwo, 2013)

The Current State of Architecture

The architecture industry stands at a pivotal juncture. While it is one of the largest contributors to climate change, architects possess the unique potential to design buildings that are more sustainable and resilient to climate change impacts.

The industry is in the nascent stages of transitioning toward a more sustainable future, yet there is a growing push to adopt greener practices, including the use of recyclable materials and renewable energy sources. As this movement gains traction, architects will play an increasingly vital role in combating climate change.

Given that buildings are crucial to our transition to a low-carbon future, retrofitting existing structures is essential. For instance, in 2020, over 220 million buildings in Europe were energy-inefficient and reliant on fossil fuels for heating and cooling. This presents a significant opportunity to reduce CO2 emissions through smarter, more efficient designs(Sadler, 2023).

Roles of Architects in Response to Climate Change

As climate change increasingly affects the world, architects are playing a crucial role in addressing this global issue. Utilizing their expertise in designing the built environment, architects have the capacity to substantially reduce greenhouse gas emissions and advance sustainable building practices.

One of the primary ways that architects are addressing climate change is by designing buildings that are energy efficient and use renewable energy sources. High-performance building materials, optimized building orientation, and passive design strategies such as natural ventilation and daylighting can all help to reduce energy consumption and promote sustainability. Architects are also incorporating renewable energy sources, such as solar panels and geothermal heating and cooling systems, to reduce dependence on fossil fuels and decrease greenhouse gas emissions. Additionally, smart building technologies, such as automated lighting and HVAC systems, can further reduce energy consumption and promote sustainability.

Another key aspect of architecture's response to climate change is the use of sustainable materials and construction practices. Sustainable materials, such as bamboo, reclaimed wood, and recycled steel, can help reduce the carbon footprint of building materials and decrease waste. Additionally, architects are exploring new construction techniques, such as prefabrication and modular construction, which can reduce construction waste and lower energy consumption during the construction process.

In addition to promoting energy efficiency, architects are also designing buildings and communities that are resilient to the impacts of climate change. This can include designing buildings that can withstand extreme weather events such as floods, hurricanes, and wildfires. Architects are also designing buildings that are adaptable and can respond to changing climate conditions, such as incorporating green roofs and rainwater harvesting systems to help mitigate the impacts of urban heat islands and storm water runoff. Additionally, architects are exploring the potential for designing entire sustainable communities that prioritize green spaces, walkability, and access to public transportation. By taking a holistic approach to sustainable design, architects are helping to create more resilient and equitable communities that can better withstand the impacts of climate change.

Sustainable land use and transportation are also key areas where architects can contribute to reducing greenhouse gas emissions. By designing compact, walkable communities that encourage the use of public transportation, architects can help reduce the amount of carbon emissions associated with transportation. Architects are also advocating for climate action policies and encouraging their clients to prioritize sustainability in their building projects. This can include advocating for policies that incentivize sustainable design and green building practices, such as tax credits and building codes that promote energy efficiency and renewable energy. Additionally, architects are working with their clients to promote sustainable design and prioritize energy efficiency in their building projects. By encouraging clients to prioritize sustainability and advocating for policy change, architects are helping to create a more sustainable built environment that can help address the challenges of climate change ('(17) Building a Sustainable Future: How Architecture Is Responding to Climate Change | LinkedIn', 2023).

Recommendations

Mitigating the issues caused by oil exploration and exploitation in the South-South region of Nigeria requires a multi-faceted approach that integrates policy reforms, community engagement, technological innovation, economic diversification, corporate responsibility, education, and international collaboration. By adopting these strategies, the region can work towards a more sustainable and prosperous future.

Architects today are confronted with significant challenges in designing sustainable buildings that can endure extreme weather events intensified by climate change. To ensure resilience, buildings must be designed to withstand severe hurricanes, intense storms, and increased flooding. This necessitates employing resilient design strategies such as reinforced structures, elevated foundations, and advanced stormwater drainage systems. Architect Kunlé Adeyemi highlights the issue, noting that despite many major cities being located by coastlines, effective adaptations to

Reducing the carbon footprint of construction is a key concern for architects, though it presents its own set of challenges. Currently, there is insufficient regulation and public awareness regarding sustainable design practices. The lack of mandatory regulations often means that sustainable design is not prioritized due to cost or time constraints. While there are voluntary green building programs, their limited reach means that sustainable practices are not universally adopted.

Despite growing environmental awareness among consumers, public knowledge about the benefits of sustainable construction remains low. This lack of awareness can hinder architects' efforts to educate clients about the value of sustainable designs. Additionally, sustainable materials and technologies are often more expensive, which can deter clients from opting for green solutions.

Architects must also address the challenges of heatwaves and water scarcity. Rising temperatures, even in traditionally temperate regions, are intensifying these issues. Designing for thermal comfort requires considerations such as reflective roofing and walls, effective ventilation strategies, and materials that maintain cool indoor temperatures. Architects must also consider the social and economic impacts of their designs on occupant health and environmental resources.

Water scarcity is another critical issue, with rising temperatures and altered water cycles reducing water availability. Building designs need to incorporate features like low-flow plumbing and rainwater collection systems to optimize water use. Limited water availability may also affect construction methods, necessitating practices that conserve water.

Overall, the performance and design standards of buildings must evolve to embrace energy efficiency, material reuse, and climate adaptability. This includes designing buildings that maximize natural shade, employ effective ventilation, and incorporate drought-resistant landscaping. The architecture industry faces numerous challenges but also holds the potential to address these issues through innovation and public initiatives aimed at creating smarter, more eco-friendly buildings.

Conclusion

There is unequivocal evidence that the populations, infrastructure, and ecosystems of urban areas are vulnerable to the impacts of climate change. Nevertheless, various tools are emerging to address some of the most severe effects. These include appropriate building design and climate-sensitive planning, the avoidance of high-risk areas through stricter development control, the incorporation of climate change allowances in engineering standards applied to flood defenses and water supply systems, and shoreline protection works.

A fundamental function of any building is to mitigate at least some of the adverse effects of the climate in which it is located. Buildings, regardless of the climatic zones in which they are found, should be capable of filtering, absorbing, or repelling climatic elements based on their adverse or beneficial contributions to the thermal comfort of their occupants. Therefore, in designing for thermal comfort, it is crucial to determine the relationship between climate and architecture and to formulate guidelines for architects in various climatic zones.

In conclusion, as articulated by (Fuentes, Roaf, & Thomas, 2007), all architectural designs should adhere to the following principles:

i. Design for climate.

ii. Design for the environment.

iii. Design for time, whether it be day or night, a season, or the lifetime of a building.

iv. Design for adaptability over time.

Adhering strictly to these design guidelines can significantly reduce the cost of maintaining a comfortable interior environment through mechanical means such as air-conditioning, extractor fans, and heaters in Nigeria. Ultimately, this will lead to the development of healthier buildings by new-generation architects for all climatic zones in Nigeria.

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