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The impact of climate change on the sustainability of water resources in Nigeria: An analytical study of the challenges and possible solutions

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RESEARCH ARTICLE

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ABSTRACT

This study concludes that Nigeria faces a dual and complex water crisis due to climate change. Warming and erratic rainfall have caused a sharp decline in water levels in the north (Lake Chad has shrunk by 90%) and a drop in groundwater levels in states such as Kano and Borno. Meanwhile, rising sea levels and extreme flooding in the south threaten to salinize and pollute aquifers. This hydrological imbalance has led to a 20% decrease in the flow of the Niger and Benue rivers, causing economic crises related to food security and energy production, as well as social conflicts over water resources. The study recommends adopting water harvesting technologies and digital basin management to ensure the sustainability of water resources in an unstable climate.

KEYWORD: sustainability; geographical location; Water; River Discharge; Niger

1. INTRODUCTION

Climate change is the most significant challenge facing the planet in the 21st century, with its effects transcending geographical boundaries and casting a shadow over vital ecosystems, particularly water resources. Nigeria stands out as a prime example of a developing country experiencing significant climate vulnerability, given its geographical location stretching from the humid Atlantic coast in the south to the arid edges of the Sahara Desert in the north. The sustainability of water resources in Nigeria is no longer merely an environmental issue; it has become a matter of national security, intersecting with rapid population growth and increasing demand for food and energy[1,2].

Nigeria is experiencing severe climate shifts characterized by fluctuating rainfall and rising temperatures, leading to disruptions in the hydrological cycle of major river basins such as the Niger and Benue rivers. In the north, desertification is rapidly encroaching, causing a historic shrinkage of Lake Chad, upon which millions of families depend, resulting in the depletion of groundwater and the degradation of agricultural land. Conversely, the South faces the risks of rising sea levels, which threaten to salinize coastal aquifers, as well as catastrophic flooding that destroys water infrastructure and contaminates available sources[3-5].

This disruption to water resources has complex socio-economic repercussions, intensifying conflicts between pastoralists and farmers over water and grazing land, and impacting the country's ability to generate hydroelectric power from major dams such as the Kainji Dam. Therefore, this study urgently needs to analyze the gap between current water policies and the reality of accelerating climate change [6,7]. This research seeks to explore possible adaptation strategies, such as rainwater harvesting, desalination, and the development of sustainable irrigation systems, aiming to establish a

framework that guarantees future generations' right to access safe and sufficient water in a climate that is no longer as stable as it once was[8-10] .

2. RESEARCH PROBLEM

The main problem lies in the fact that Nigeria faces a "water-climate paradox." While the north suffers from severe drought and desertification, leading to the depletion of surface water resources (such as the Lake Chad Basin), the south experiences devastating floods resulting from erratic rainfall and rising sea levels. This climatic imbalance has led to:

- Water deficit: A decline in per capita freshwater availability due to rapid surface water evaporation and reduced groundwater recharge levels.
- Deterioration of water quality: Pollution of water sources in the south due to flooding, and salinization in coastal areas.
- Failure of traditional management: Current water policies in Nigeria are unable to keep pace with the rapid changes in climate, threatening food and energy security (electricity generation) and social stability.

3. RESEARCH QUESTIONS

This research seeks to answer the following fundamental questions:

- What is the nature of the climate changes (temperature and rainfall) that have occurred in Nigeria during the period (e.g., from 1990 to 2025)?
- To what extent has climate change affected the water balance in major river basins (such as the Niger River and the Benue River)?
- What are the environmental and economic consequences of decreasing water resources in northern Nigeria compared to increasing (flooding) water resources in the south?
- How can modern technologies (such as Geographic Information Systems and remote sensing) contribute to monitoring and predicting future water crises?
- What are the best adaptation strategies that Nigeria can adopt to ensure the sustainability of its water resources?

4. RESEARCH HYPOTHESES

- Hypothesis 1: There is a statistically significant relationship between rising temperatures and declining water levels in Lake Chad and northern rivers.
- Hypothesis 2: Increased frequency of flash floods in the south leads to a deterioration in groundwater quality due to pollution from flooding.
- Hypothesis 3: Adopting rainwater harvesting strategies and trans boundary basin management will significantly contribute to mitigating the effects of drought in affected areas.

5. RESEARCH METHODOLOGY

5.1. Climate Analysis Phase: Rainfall Variability Index (RVI)

The Rainfall Variability Index is the most important statistical tool for understanding rainfall anomalies in Nigeria. It is calculated by subtracting the average annual rainfall from the actual rainfall and dividing by the standard deviation[11]., like that in table 1.

Table 1. Classification of Rainfall Variability Years in Nigeria (An Analytical Study)[12]:

Year	Primary Region	RVI Value	Climate Condition	Impact on Water Resources
2012	Southern Nigeria	+2.5	Extremely Wet	Massive flooding in the Niger-Benue trough.
2015	Northern Nigeria	−1.8	Severe Drought	Depletion of shallow wells and surface reservoirs.
2019	Central Belt	−1.2	Mild Drought	Reduced river discharge and agricultural water stress.
2022	National Scale	+2.1	Extremely Wet	Groundwater contamination and infrastructure damage.
2024 (Est.)	Northern Nigeria	−1.5	Persistent Dryness	Further shrinkage of Lake Chad and loss of wetlands.

5.2. Study of River Discharge at Measuring Stations

Hydrological data at the Lokoja and Onitsha stations show a decrease in the flows of the Niger and Benue rivers during dry seasons, and a sudden and dangerous increase during extreme rain seasons. Table 2 shows this [13,14].

Table 2. effect of rivers by rain

Year	Event Type	Peak Discharge (m3/s) at Lokoja	Peak Discharge (m3/s) at Onitsha	Impact & Observations
1983	Severe Drought	9،5	11،2	Historical low; caused major power outages and crop failure.
2012	Extreme Flood	31،6	35	Highest recorded levels in 50 years; 2.1 million displaced.
2015	Hydrological Drought	12	14،5	Significant drop in the Niger River's dry-season flow.
2022	Mega Flood	33،5	38	Catastrophic flooding; contaminated 70% of local water wells.
2024 (Est.)	High Variability	28	32	Erratic patterns; unexpected flash floods after a dry spell.

5.3. Analysis of Groundwater Decline in Northern Nigeria (Kano, Sokoto, Borno)

The northern states of Nigeria are experiencing a sharp decline in water stability. Global warming and increased over-pumping have led to a drop in groundwater levels of 0.5 to 1.5 meters annually in the Sokoto and Chad basins. Data analysis in Kano and Borno indicates that shallow aquifers are no longer being adequately replenished due to evaporation of rainfall before it reaches the soil. This threatens to deplete the wells upon which 80% of rural communities depend for drinking water and small-scale irrigation [15,16].

5.4. Socio-economic Impact Analysis Phase [17]

- Water resource disruption leads to disastrous consequences that extend beyond the environment to the economy and society:
- Spatial conflicts: Drought in the north has caused pastoralists to migrate south (to the Middle Belt), leading to bloody conflicts over water resources.
- Food security: Production of strategic crops (such as maize and millet) has declined by more than 30% in drought-affected areas.
- Energy: Reduced output from hydroelectric power plants (such as the Kainji Dam) due to decreased river flow has impacted national industry.

6. INDICATORS AND STATISTICAL DATA

First: Climate Variability Indicators (Statistical Data)

The following table shows the variation in rainfall and temperature rates in Nigeria (table 3), which explains the pressure on water resources:

Table 3. Change in climate indicators in Nigeria (1991 - 2024)[18,19]

Climate Indicator	Average Value (1990s)	Estimated Value (2024)	Impact on Water Resources
Mean Annual Temperature	26.5◦C	27.8◦C	Increased evaporation rates from dams and surface reservoirs.
Annual Rainfall (Northern Region)	600mm	450mm	Accelerated shrinkage of Lake Chad and aquifer depletion.
Annual Rainfall (Southern Region)	2500mm	3200mm	Severe flash flooding and contamination of drinking water.
Sea Level Rise (Coastal Zones)	Baseline (0)	+20cm	Saltwater intrusion into coastal freshwater aquifers (e.g., Lagos).
River Niger Annual Discharge	100% (Reference)	80%	Reduction in hydropower generation and irrigation capacity.

Second: The State of Water Resources (Descriptive Chart) The data shows that surface water resources in Nigeria are suffering from severe degradation: Lake Chad: Its area has shrunk from 25,000 km² in 1963 to less than 2,000 km² currently. The Niger River: A decrease in annual flow of up to 20% in the last three decades due to drought in upstream countries and a change in rainfall patterns.

Third: Distribution of Water Stress[20]

- Northern regions (red zone): Suffer from "severe water stress" where groundwater extraction rates exceed natural recharge rates.
- Delta regions (blue zone): Suffer from "polluted water abundance" due to annual floods that mix sewage with drinking water show that in table 4.

Table 4. Water flow rate

Hydrological Station	Mean Dry Season Flow (April)	Mean Peak Flood Flow (October)	Climate Variability Impact
Lokoja Station (Confluence)	≈1,500m3/s	≈25,000m3/s	Widening gap between extremes; severe low flows and catastrophic peaks.
Onitsha Station (Lower Niger)	≈2,000m3/s	≈31,000m3/s	Increased flood magnitude due to extreme rainfall and sea-level backwater effects.
Kainji Dam Area (Upstream)	≈500m3/s	≈4,500m3/s	Reduced reliability for hydropower generation during prolonged dry spells.

7. CONCLUSION

The study concludes that Nigeria faces a dual crisis: a quantitative decline in the north and a qualitative decline in the south. This imbalance has led to severe economic and social crises. The study recommends adopting water harvesting technologies and digital basin management to ensure sustainability.

8. RECOMMENDATIONS

- Adopting Water Harvesting Strategies: Expanding the construction of small dams and rainwater harvesting reservoirs in northern states (such as Kano and Borno) to utilize flash floods and compensate for groundwater depletion.
- Developing Sustainable Irrigation Systems: Transitioning from flood irrigation to drip and sprinkler irrigation to reduce water loss in the agricultural sector, which consumes the largest share of Nigeria's water resources.
- Activating Water Diplomacy: Strengthening cooperation with Lake Chad Basin and Niger River Basin countries to ensure equitable water distribution and joint dam management to mitigate the effects of transboundary droughts.
- Investing in Geographic Information Systems (GIS) and Remote Sensing: Establishing a national hydrological monitoring network based on GIS and remote sensing to predict floods and effectively manage water crises.
- Protecting Coastlines from Salinization: Constructing technical barriers and developing desalination systems in coastal cities like Lagos to counter the encroachment of seawater into freshwater aquifers.
- Community awareness: Launching national programs to educate farmers and herders on the importance of water conservation and the need to adapt to drought-resistant crops.
- Updating legislative policies: Updating the National Water Resources Law to include strict provisions related to the over-pumping of groundwater and the protection of waterways from industrial and flood pollution.

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