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A GEOSPATIAL ANALYSIS OF MAJOR DAM INFRASTRUCTURES AND MANAGEMENT MODELS IN NORTH-CENTRAL NIGERIA

AYEDU WASAH[1]; A. T. OGAH[2]; & I. K. SAMAILA[3]

[1]Global Projects Consortium, Abuja Nigeria. [2,3]Faculty of Environmental Science, Nasarawa State University, Keffi.

Corresponding Author: wasayedu@gmail.com

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Abstract

This study presents a geospatial assessment of major dam infrastructure projects in North-Central Nigeria, focusing on both government and private sector involvement. Findings indicate that government-constructed dams, including Itobe Dam (Kogi), Shiroro Dam (Niger), Makurdi Dam (Benue), Oyun Dam (Kwara), Usuma Dam (FCT Abuja), and Doma Dam (Nasarawa), dominate the region. These dams serve multiple purposes, such as irrigation, water supply, power generation, and flood control, reflecting the government's strategic use of water resources for economic and environmental benefits. Private-sector participation, though limited, significantly contributes through operation and maintenance under concession models. Notable examples include Kainji and Jebba dams, managed by Mainstream Energy Solutions Ltd., and the under-construction Zungeru Dam. This shift towards public-private partnerships enhances operational efficiency, technological adoption, and accountability in dam management. The study provides a comprehensive mapping of dam infrastructure, offering critical insights for policymakers and stakeholders in water resource management, energy production, and regional development, highlighting the need for integrated approaches to maximize socio-economic

Keywords: Geospatial Assessment, Dam Infrastructure, North-Central Nigeria, Government Dams, Private Sector Dams, Water Resource Management, Hydropower, Flood Control, Irrigation, Public-Private Partnerships

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and environmental benefits in North-Central Nigeria.

Introduction

In recent decades, dam infrastructure has occupied a central role in global water management, energy generation, flood mitigation, and irrigation systems. Large dams and their associated reservoirs have enabled countries to harness water resources for socio-economic development while simultaneously introducing new environmental and risk management challenges (Grigg, 2019). At a global scale, the majority of the approximately 58,700 large dams were built between 1930 and 1970, many of which are entering or exceeding their design lifespan—raising concerns about ageing infrastructure, sedimentation, and declining performance (United Nations University Institute for Water, Environment and Health [UNU-INWEH], n.d.). This necessitates geospatial assessments that map, monitor and evaluate dam infrastructure in order to inform sustainable management, resilience planning and resource governance.

On the African continent, the rapid expansion of hydropower, irrigation and multipurpose water-storage projects has intensified the deployment of dams, often under challenging environmental, financial and institutional conditions. While dams promise increased energy access and improved water security, they also face unique constraints: sedimentation in tropical rivers, funding shortfalls, governance gaps and climate variability that affect dam operations (Ayeni & Ojifo, 2018). Geospatial techniques and remote sensing are increasingly used in Africa to assess dam-site suitability, reservoir management and sediment dynamics, making mapping and spatial analysis tools more prominent in infrastructure research and practice on the continent.

Turning to Nigeria, the development of dams has long been an integral part of national water-resource, irrigation and electricity strategies. However, empirical studies indicate that many dams suffer from design flaws, under-utilisation, maintenance deficits and sustainability issues. For example, Youdeowei, Nwankwoala & Desai (2019) found that Nigerian dams vary widely in type and purpose but are often constrained by hydrologic change, altered design criteria and unaddressed natural hazards. In addition, a study on the socio-economic dynamics of the Oyan Dam revealed significant community impacts, as well as limitations in harnessing the full potential of the dam due to institutional and infrastructural deficiencies (Ayeni & Ojifo, 2018). Such findings underscore the need for comprehensive spatial mapping and analysis of dam infrastructure within Nigeria, particularly in under-explored regions.

Focusing on the North-Central region of Nigeria, this study aims to conduct a geospatial assessment of major dam infrastructure projects, encompassing government and private-sector-managed developments. The North-Central zone including states such as

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Kogi, Benue, Nasarawa, Niger, Kwara and the Federal Capital Territory hosts significant dams that serve multiple purposes: irrigation, water supply, power generation and flood control. Mapping these dams and analysing their spatial distribution, capacity, management models and operational roles within this sub-national region will contribute to understanding how local dam infrastructure aligns with national and continental trends. More so, it will highlight whether spatial patterns and management models in this region reflect broader issues of sustainability, technological adoption and resource governance.

The rationale for this research draws on the intersection of geospatial technologies, infrastructure resilience, sustainable development and regional water-resource management. Globally, the ageing of water infrastructure demands new approaches to monitoring and evaluation. In Africa, and particularly in Nigeria, the effectiveness and sustainability of dam systems remain uncertain and inadequately documented. Conducting a geospatial assessment in North-Central Nigeria will provide valuable empirical evidence to inform planners, policymakers and stakeholders about the spatial character, functional status and developmental impacts of dams in the region. Ultimately, this study seeks to enhance understanding of how dam infrastructure contributes to socio-economic development, water security and environmental sustainability in the North-Central Nigerian.

MATERIALS AND METHODS

North-Central Nigeria is strategically situated in the heart of the country, serving as a bridge between Nigeria's northern and southern regions. Its central location connects it to the North West, North East, South West, and South-South geopolitical zones, making it a key crossroads for transportation, commerce, and socio-cultural exchange. This unique positioning enables North-Central Nigeria to function as an important link, allowing for smooth movement of goods, services, and people across the country. Its accessibility and connectivity have helped it develop as a focal point in Nigeria’s economic and cultural landscape.

The geographical expanse of North-Central Nigeria is significant, as it covers a broad swath of the country. The region comprises six states, Benue, Kogi, Kwara, Nasarawa, Niger, and Plateau, along with the Federal Capital Territory (FCT), Abuja. Together, these states form a sizable and varied region with differing landscapes, from the river valleys of Niger and Benue to the highlands of Plateau State. This varied terrain supports diverse agricultural and mineral resources, further enhancing the region's economic value. North-Central Nigeria’s considerable size makes it one of the larger regions in the country, with a prominent role in both natural resource production and agricultural output.

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Abuja, Nigeria's capital city, is located in the Federal Capital Territory at the center of North-Central Nigeria, and this position adds political and administrative significance to the region. Established as the capital in 1991 due to its central location, Abuja serves as the seat of government and hosts all major federal institutions, embassies, and foreign missions. This choice was intended to promote unity and accessibility, as Abuja's central placement allows it to be equally reachable from all parts of the country. The presence of Abuja within North-Central Nigeria not only increases the region's visibility but also contributes to its economic and infrastructural development, as the area benefits from federal investment and development projects.

The vast land area of North-Central Nigeria is home to a variety of landscapes and ecosystems, from fertile plains and river basins to rolling hills and highlands. This ecological diversity supports a wide range of agricultural activities, with the region producing crops such as yams, rice, maize, and millet, as well as livestock farming. The Niger and Benue rivers, two of Nigeria's largest rivers, traverse parts of this region, providing water resources that are essential for both irrigation and hydropower. These natural features make North-Central Nigeria a resource-rich area, contributing substantially to the nation's food supply and economic stability.

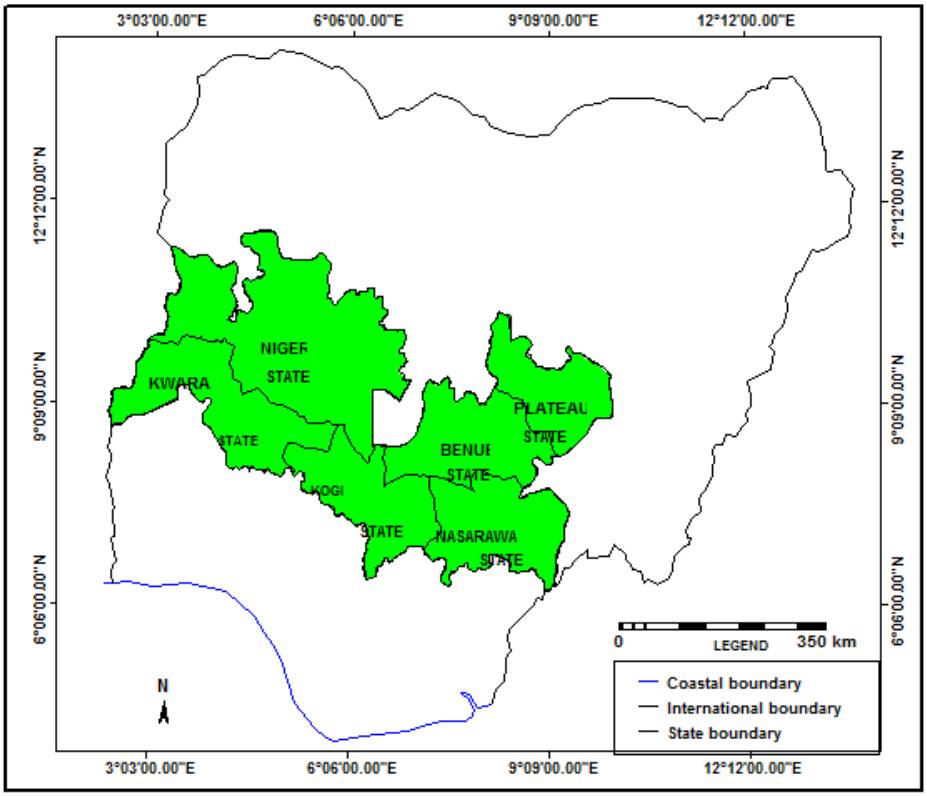

Figure 1: North-Central States

Source: Author 2024

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The study employed a descriptive research design aimed at identifying, mapping, and assessing major dam infrastructure projects in North-Central Nigeria, integrating both qualitative and quantitative approaches. Primary data were collected through field surveys, structured interviews, and observation of selected dams, including government-constructed facilities such as Itobe, Shiroro, Makurdi, Oyun, Usuma, and Doma dams, as well as privately managed dams like Kainji, Jebba, and the under-construction Zungeru Dam. GPS devices were used to capture accurate coordinates of each dam, while high-resolution satellite imagery from Landsat 8 and Sentinel-2 provided supplementary data for spatial analysis. Secondary data were obtained from government reports, published literature, and online databases including the Global Dam Tracker (GDAT), FAO Aquastat, and UNESCO water resources datasets. Geospatial analyses were conducted using ArcGIS 10.8 and QGIS 3.28 to map dam locations, analyze reservoir capacities, evaluate spatial distribution patterns, and assess the relationship between dam placement, hydrological features, and socio-economic activities in the region. Digital Elevation Models (SRTM-DEM) were utilized to examine topography, watershed boundaries, and potential flood zones. The collected data were processed, cleaned, and integrated into a GIS database, while descriptive statistics, tables, and thematic maps were generated to summarize dam characteristics, capacities, purposes, and management structures. The methodology ensured a comprehensive and multi-dimensional assessment, combining field verification, stakeholder insights, and advanced geospatial techniques to provide a robust understanding of the status, distribution, and impacts of major dam infrastructure in North-Central Nigeria.

RESULTS

Major Dam Infrastructure Projects in North-Central Nigeria

The result reveals that government-constructed dams dominate the landscape, with notable projects such as Itobe Dam in Kogi State, constructed in 2015 with a capacity of 5,000 million cubic meters, serving purposes like irrigation and power generation. Similarly, Shiroro Dam in Niger State, built in 1990, has a capacity of 9,200 million cubic meters and is essential for power generation and flood control. The Makurdi Dam in Benue, Oyun Dam in Kwara, Usuma Dam in the FCT and the Doma Dam in Nasarawa complement this list by focusing on irrigation, water supply, and other multi-purpose roles, as summarized in Table 4.1. These projects highlight the government's commitment to leveraging water resources for economic and environmental benefits.

Private-sector-managed dams, though fewer, play a significant role in the region's hydropower and water management sectors. Examples include the Kainji and Jebba dams in Niger State, initially government-built but now operated under concession agreements

by private entities like Mainstream Energy Solutions Ltd. Such management models have demonstrated enhanced efficiency and sustainability, particularly for power generation. Additionally, the Zungeru Dam, currently under construction, is a testament to the growing involvement of private and hybrid funding models in dam infrastructure development. Table 4.2 summarizes the major Private Sector dam projects, emphasizing their substantial contributions to hydropower and flood control.

The involvement of private concessions in operating and maintaining government-constructed dams illustrates a pivotal shift towards public-private partnerships in managing critical infrastructure. This trend has implications for sustainability, as private management often introduces improved operational practices, technological advancements, and accountability.

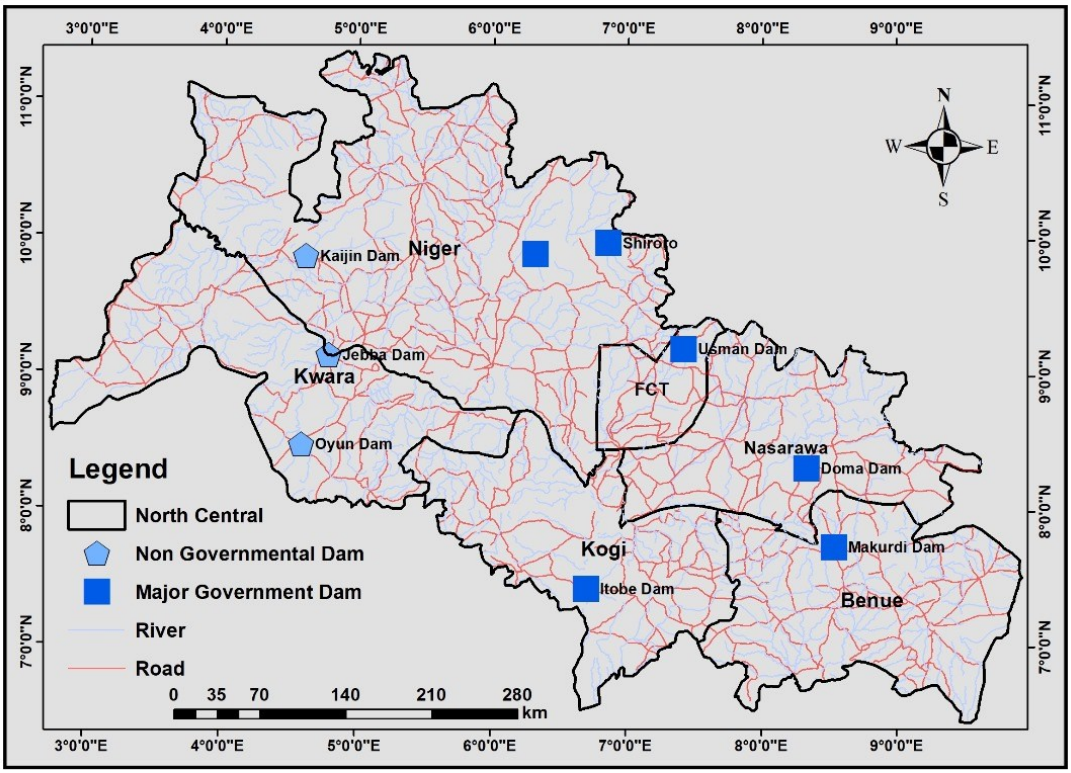

Figure 2: Map of Major Dam Infrastructure (Government and Private Sector Constructed) Development Projects in North-Central Nigeria

Source: Authors Field Work 2024

Table 1: List of Major Government Dam Infrastructures Projects in North-Central Nigeria

State	Project Name	Year of Construction	Capacity (Million Cubic Meters)	Purpose
Kogi	Itobe Dam	2015	5,000	Irrigation, power generation
Kwara	Oyun Dam	2012	1,000	Irrigation, water supply
Niger	Shiroro Dam	1990	9,200	Power generation, flood control
Benue	Makurdi Dam	2000	1,500	Water supply, irrigation
FCT Abuja	Usuma Dam	1980	100	Water Supply, Aquaculture
Nasarawa	Doma Dam	1988	37.5	Irrigation, Water Supply

Source: Authors Field Work 2024

Private Sector Constructed Dams in North Central Nigeria

Private Sector constructed dams in North-Central Nigeria are relatively few compared to government-initiated projects. Among these, a common approach has been private concessions for operation and maintenance rather than entirely privately-funded constructions.

Kainji and Jebba dams, although initially built by the Nigerian government, are now operated by Mainstream Energy Solutions Ltd. under concession, illustrating a trend where Private Sector entities manage major dams, enhancing efficiency and maintenance while supporting energy demands and water resource management in North-Central Nigeria.

Table 2: List of Major Private Sector Dam Infrastructures Projects in North-Central Nigeria

State	Project Name	Year of Construction	Capacity (Million Cubic Meters)	Purpose
Niger	Kainji Dam	1968	15,000	Power generation
Niger	Jebba Dam	1985	3,500	Hydropower, irrigation
Niger	Zungeru Dam	Under construction	11,000	Hydropower, flood control

Source: Authors Field Work 2024

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CONCLUSION

The study revealed that North-Central Nigeria is endowed with significant dam infrastructure, predominantly government-constructed, serving multi-purpose roles including irrigation, water supply, flood control, and power generation. Private-sector participation, though limited, has enhanced operational efficiency and sustainability through concession-based management models, as seen in Kainji and Jebba dams. The geospatial assessment highlighted the spatial distribution, capacities, and functional roles of these dams, emphasizing their socio-economic and environmental importance to the region. Overall, the findings underscore the critical need for integrated planning, monitoring, and management of dam infrastructure to maximize their contribution to regional development, water security, and energy provision.

Recommendations

It is recommended that government and private stakeholders adopt integrated water-resource management practices and enhance public-private partnerships to ensure the optimal operation and maintenance of existing dams. Regular geospatial monitoring should be institutionalized to track reservoir capacities, sedimentation, and flood risk zones. Additionally, investment in modern technology, capacity building for dam management personnel, and community engagement programs will improve operational efficiency, sustainability, and socio-economic benefits derived from dam infrastructure across North-Central Nigeria.

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