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RESEARCH ARTICLE

Sustainable management of the Tiga dam and Kadawa irrigation area: addressing socio-economic and environmental challenges in Kano state, Nigeria

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Abstract

The Tiga Dam and Kadawa Irrigation Area, located in Kano State, Nigeria, are pivotal infrastructures that support agricultural productivity, water supply, and socio-economic development. The Tiga Dam, a key component of the Kano River Irrigation Scheme (KRIS), has transformed the region into a hub of agricultural activity, ensuring food security, creating employment opportunities, and fostering economic growth. However, these infrastructures face significant challenges, including inefficient water management, environmental degradation, siltation, and the impacts of climate change. Additionally, reduced water flow has adversely affected downstream ecosystems, such as the Hadejia-Nguru Wetlands, disrupting biodiversity and local livelihoods. This report highlights the pressing need for sustainable management practices to address these challenges. Recommendations include modernizing water distribution systems, promoting climate-smart agriculture, enhancing infrastructure maintenance, resolving resource conflicts, and integrating technology for real-time monitoring. Emphasizing environmental conservation, equitable water allocation, and institutional collaboration, this report outlines actionable strategies to ensure the long-term sustainability and functionality of the Tiga Dam and Kadawa Irrigation Area. By adopting these measures, these infrastructures can continue to play a critical role in supporting agriculture, livelihoods, and environmental balance in Kano State and beyond.

Citation

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1.0 Introduction

Tiga Dam is a significant reservoir located in the southern part of Kano State, Nigeria. Constructed between 1971 and 1974 during the administration of Governor Audu Bako, the dam was primarily built to address food security challenges through irrigation projects, particularly in response to recurrent droughts in the region [1]. It is situated on the Kano River,

a major tributary of the Hadejia River, and serves as the cornerstone of the Kano River Irrigation Scheme (KRIS), which supports agricultural activities across thousands of hectares. The dam covers an area of approximately 178 square kilometers and has a maximum storage capacity of nearly 2 billion cubic meters. It supplies water to both the Kano River Irrigation Project and Kano City, contributing significantly to agricultural development and water availability in the region. Additionally, it supports renewable energy generation, with a 10MW hydroelectric power plant recently completed to provide power for water treatment plants and street lighting in Kano State. Beyond its utility, Tiga Dam is also a tourist attraction, offering scenic views, fishing, boating, and birdwatching opportunities. However, it has faced criticism for its downstream impacts. The dam has reduced water flow into the Hadejia-Nguru wetlands, affecting wet-season rice farming, fishing, and grazing activities that sustain about one million people. Studies show that the dam has caused significant evaporation losses and disruptions to the livelihoods of downstream communities, contributing to environmental and economic challenges. In recent years, the dam has been part of rehabilitation projects such as the World Bank-funded Transforming Irrigation Management in Nigeria (TRIMING) initiative, which aims to improve irrigation and water management systems [1]. It has also been inspected and monitored to ensure safety, particularly during flood seasons, as water levels can reach critical capacities, posing risks to nearby communities.

Source: Field Trip, 2025

1.1 Activities of Tiga Dam

Tiga Dam supports a range of activities that contribute to its utility, economic significance, and recreational value. Below are the key activities associated with Tiga Dam

1. **Irrigation and Agriculture**

Tiga Dam is the primary water source for the Kano River Irrigation Scheme (KRIS), which irrigates thousands of hectares of farmland in Kano State. Crops such as rice, wheat, maize, and vegetables are cultivated under this scheme, contributing to food security in the region Farmers in the area rely on the dam for year-round farming, particularly during the dry season.

2. **Water Supply**

It provides water for domestic and industrial use in Kano City and surrounding towns. The dam is a critical source for the Kano State Water Board, ensuring a steady supply of treated water for urban areas.

3. **Hydroelectric Power Generation**

A 10 MW hydroelectric power plant was recently installed at the dam to generate renewable energy. This power is used for water treatment plants, street lighting, and other public utilities in Kano State.

4. **Fishing**

The dam supports a thriving fishing industry, providing livelihoods for local fishermen. It is home to various fish species that are essential for both subsistence and commercial purposes.

5. Tourism and Recreation

Tiga Dam is a popular tourist destination in Kano State, attracting visitors for its scenic views and leisure activities. Recreational activities include boating, birdwatching, and picnicking. It is also a spot for local festivals and events.

6. Environmental and Ecological Activities

The dam contributes to wildlife conservation, as it creates habitats for aquatic life and supports nearby ecosystems. It indirectly impacts downstream wetlands, such as the Hadejia-Nguru Wetlands, which are important for biodiversity and migratory birds.

7. Flood Control

Tiga Dam plays a role in flood management, regulating water flow during heavy rains to protect downstream areas from flooding. However, concerns over water levels during flood seasons have led to periodic inspections and safety measures.

8. Research and Development

The dam is a site for academic research and studies on water resource management, agriculture, climate change, and environmental impacts. It is also part of the World Bank-funded RIMING project, which focuses on improving irrigation efficiency and water management in Nigeria.

Source: Field Trip, 2025

1.2 Tributary canals

also known as secondary or feeder canals, are water channels designed to distribute water from a primary source (such as a dam, river, or main canal) to different areas for agricultural, industrial, or domestic use. They are critical components of irrigation systems. Below are the types of tributary canals, classified based on their purpose, flow structure, and design:

Source: Field Trip, 2025

1. Based on Purpose

i. Irrigation Canals

These canals supply water to agricultural fields for crop cultivation. Example: Tributary canals from the Tiga Dam feeding the Kano River Irrigation Scheme (KRIS).

ii. Drainage Canals

Used to carry excess water or wastewater from fields back to rivers or reservoirs to prevent waterlogging.

iii. Navigation Canals

Designed to allow boats or small vessels to transport goods or people. Tributary canals may connect smaller areas to larger navigable waterways.

iv. Water Supply Canals

These canals provide water for domestic or industrial use in urban and rural areas.

2. Based on Flow Structure

i. Perennial Canals

Supply water throughout the year, sourced from reservoirs or perennial rivers. Example: Tributary canals from dams like Tiga Dam that regulate water flow year-round.

ii. Seasonal Canals

Operate only during specific seasons, such as the rainy season, when water is abundant in the main source.

3. Based on Design

i. Lined Canals

These canals are lined with concrete, stones, or other materials to prevent seepage and ensure efficient water delivery. Example: Many modern irrigation projects use lined tributary canals to reduce water loss.

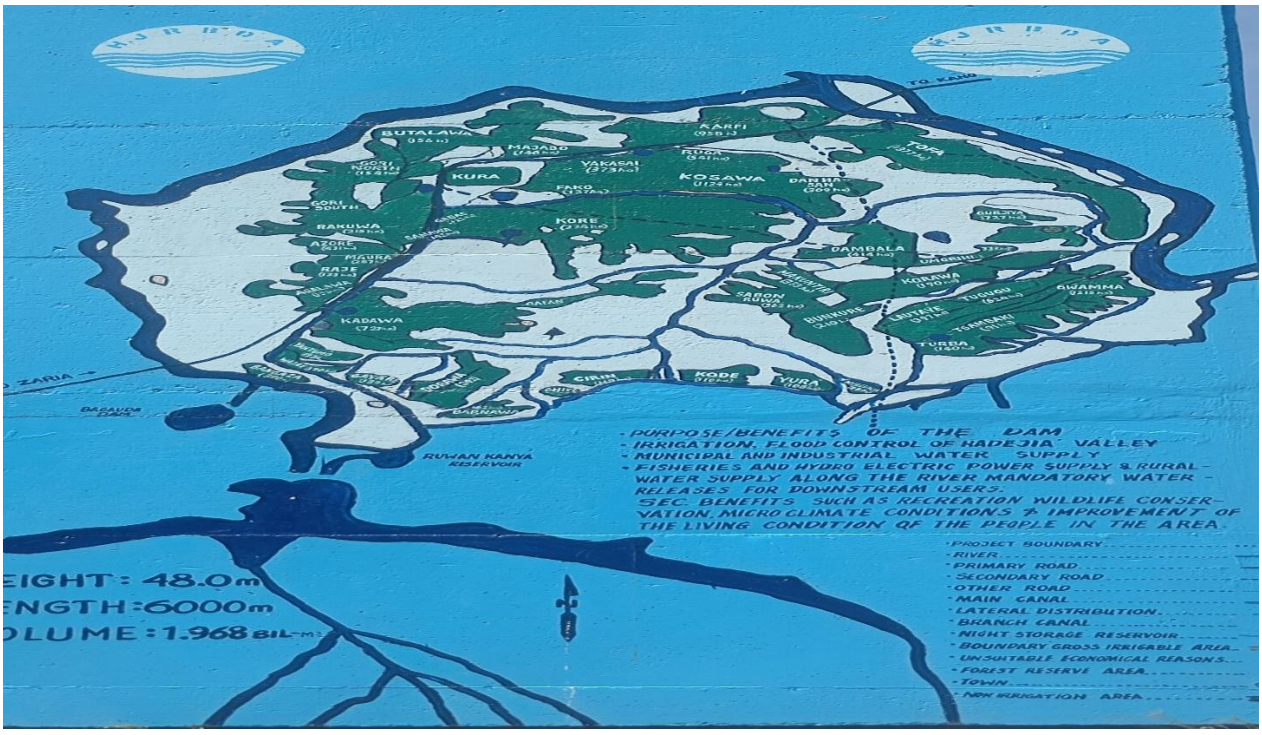
Unlined Canals

These are earth canals without any lining, which are more prone to seepage and erosion. They are cheaper to construct but less efficient.

4. Based on Water Distribution Method
i. Gravity Canals
Use the natural slope of the land to distribute water through gravity flow. These are cost-effective and commonly used.
ii. Pumped Canals
Use pumps to lift water to higher elevations or areas where gravity flow is not possible.
5. Based on Function within the Irrigation Network
i. Secondary Canals
Branch out from the main canal and distribute water to smaller regions or sub-areas.

Tertiary Canals

Smaller canals branching out from secondary canals, delivering water to individual farms or plots.
ii. Field Canals
The smallest canals in the system, delivering water directly to crops in the fields. Example from Tiga Dam: In the case of the Kano River Irrigation Scheme (KRIS) fed by the Tiga Dam, tributary canals include secondary canals that branch off from the main canal and tertiary canals that deliver water directly to individual farms.



Source: Field Trip, 2025

1.2.0 Control room

is a centralized space where operations, monitoring, and management of critical systems or processes are carried out. It serves as the operational hub for overseeing activities in facilities such as dams, power plants, industrial complexes, or other infrastructure systems. In the context of a dam like Tiga Dam, the control room is crucial for managing water flow, power generation, and overall safety.

1.2.1 Key Features of a Control Room

1. Monitoring Systems

Equipped with screens, sensors, and control panels to monitor real-time data such as water levels, flow rates, and pressure. Supervises the operation of gates, turbines (if hydroelectric power is present), and irrigation systems.

Automation and Control

Automated systems allow operators to open and close spillway gates, regulate water flow, and manage dam operations efficiently. Computerized systems ensure precision and quick response to changes in conditions.

Safety and Emergency Management

The control room is responsible for monitoring flood risks, issuing alerts, and managing emergency protocols during extreme weather or dam failures.

Alarm systems notify operators of critical issues such as rising water levels or equipment malfunctions.

2. Hydroelectric Power Management (if applicable)

In cases where the dam generates electricity (e.g., Tiga Dam's 10 MW hydroelectric power plant), the control room manages the turbines and power output.

3. Communication Hub

Acts as the central point for communication between engineers, field operators, and external stakeholders (e.g., water management authorities or government agencies). Can coordinate with downstream communities for water release schedules or flood warnings.

1.2.2.1 Control Room at Tiga Dam

The control room at Tiga Dam likely includes: Systems for monitoring water levels in the reservoir to regulate irrigation and urban water supply. Equipment for managing the hydroelectric power plant installed at the dam, ensuring efficient energy generation. Flood monitoring and management tools to prevent overflow and ensure safety downstream. Communication systems to coordinate with agencies like the Hadejia-Jama'are River Basin Development Authority (HJRBDA).

1,2.2 Importance of a Dam Control Room

- Efficient Operations: Ensures the smooth functioning of irrigation, power generation, and water supply systems.
- Safety Assurance: Prevents disasters by monitoring critical parameters like water pressure, structural integrity, and weather conditions.

➢ Resource Optimization: Helps manage water release schedules to balance irrigation, urban use, and environmental needs.

Source: Field Trip, 2025

1.2.3 Kano power plan for Tiga Dam

revolves around the 10 MW Tiga Hydro Independent Power Plant, which aims to address critical energy and infrastructure needs in Kano State. This project, spearheaded by the Kano Hydro and Energy Development Company (KHEDCO), is designed to generate clean, renewable energy for key facilities and improve living conditions in the state.

Source: Field Trip, 2025

1.2.3.1 Key Features of the Tiga Dam Power Plan

1. **Power Generation Capacity**

The power plant operates with two generators: an 8 MW vertical generator and a 2 MW horizontal generator, producing a total of 10 MW. This electricity is generated at 33 kV and transmitted to key locations.

2. **Primary Uses of Generated Power***

a. Tamburawa Water Treatment Plant: A significant portion of the generated electricity is directed to the Tamburawa Water Treatment Plant, which ensures clean drinking water for Kano's population and helps combat waterborne diseases

b. Street Lighting: The power plant supplies electricity to Kano's metropolitan streetlights, addressing long-standing issues of poor lighting, which have contributed to security concerns such as robbery and carjacking,

3. **Economic and Social Impact**

a. The project is expected to reduce reliance on diesel-powered generators, saving costs for the state government and minimizing environmental pollution.

b. By improving water supply and lighting, it directly enhances public services, boosts industrial activity, and creates job opportunities for Kano residents.

4. **Infrastructure and Certification**

a. Evacuation lines from Tiga to Tamburawa Water Treatment Plant have been fully completed, with a step-down transformer (33-11 kV) installed to ensure efficient power supply.

b. Pre-commissioning tests and certification by the Nigerian Electricity Management Services Agency (NEMSA) were critical steps before the plant's operation. Automation processes, such as linking the power generation to the SCADA system, were also finalized to ensure smooth operation.

Challenges and Delays

Initially conceived in 2002 during Governor Rabiu Musa Kwankwaso's tenure, the project faced significant delays, with completion initially planned for 2018 but only achieved in 2023. Factors such as funding, logistical issues, and project reviews contributed to these delays.

5. Future Plans and Integration

The Tiga Dam power plant is part of a larger energy strategy that includes the 6 MW Challawa-Gorge Hydropower Plant, which, together with Tiga, aims to strengthen Kano's energy independence. The state also plans to explore additional hydroelectric opportunities by converting other dams into power plants.

1.2.3.2 Impact on Kano State

The Tiga Dam power plan is a game-changer for Kano, addressing key challenges like water shortages, unreliable power supply, and urban insecurity. By providing clean energy to critical facilities and boosting industrial activity, it is poised to transform the state's socio-economic landscape. Additionally, the use of renewable energy aligns with global efforts to combat climate change and reduce carbon footprints.

1.3 Kadawa irrigation area

is a vital agricultural zone located in Kano State, Nigeria. It is one of the key components of the Kano River Irrigation Scheme (KRIS), which is fed by water from the Tiga Dam. The area is known for its large-scale irrigation farming, which supports food production, economic activities, and rural livelihoods in the region.

i.Overview of Kadawa Irrigation Area: Irrigation System

a. The irrigation area relies on canals supplied by water from the Tiga Dam.

b. Water is distributed through a network of primary, secondary, and tertiary canals, which irrigate thousands of hectares of farmland.

Land Use

c. Kadawa is primarily used for intensive agriculture.

d. Farmers cultivate crops such as rice, wheat, maize, tomatoes, onions, and vegetables, contributing significantly to food production in Nigeria.

Farming Practices

e. The area practices dry-season farming, made possible by the availability of irrigation water.

Source: Field Trip, 2025

ii. Geographical Location

Kadawa is situated in the northern part of Nigeria, specifically in Kano State. It is part of the Kano River Irrigation Scheme, which was established to promote agricultural development in the semi-arid region.

Farmers often use modern agricultural techniques, including mechanized farming and the application of fertilizers, to boost productivity.

Management

The Kadawa Irrigation Area is managed by the Hadejia-Jama'are River Basin Development Authority (HJRBDA), which oversees water distribution, canal maintenance, and farmer support services. Economic and Social Importance:

iii. Food Security

Kadawa plays a critical role in ensuring food security in Kano State and beyond by producing staple crops and vegetables.

Employment

The irrigation area provides employment opportunities for thousands of farmers, laborers, and traders involved in agricultural activities.

iv. Rural Development

The irrigation scheme has improved livelihoods in the region by increasing agricultural productivity and generating income for local communities.

v.Export Contribution

Crops grown in Kadawa are also supplied to other parts of Nigeria and neighboring countries, contributing to regional trade.

1.3.1 Challenges Facing Kadawa Irrigation Area

1. Water Management Issues

Inefficient water distribution and canal maintenance can lead to water shortages or wastage. Farmers sometimes face challenges accessing adequate water during peak farming periods.

2. Siltation of Canals: Sediment buildup in irrigation canals reduces water flow efficiency,

requiring regular maintenance.

Climate Change

Variability in rainfall and temperature affects water availability and crop yields.

Land Degradation

Overuse of farmland and improper farming practices may lead to soil degradation and reduced productivity.

Funding and Policy Gaps

Limited government support and inconsistent funding for irrigation projects hinder improvements in infrastructure and farmer support.

1.3.2 Efforts to Improve Kadawa Irrigation

i. TRIMING Project
Transforming Irrigation Management in Nigeria (TRIMING) initiative, funded by the World Bank, has been working to rehabilitate and modernize the Kano River Irrigation Scheme, including Kadawa. This involves improving water delivery, canal systems, and farmer training.

ii. Farmer Training and Support

Local authorities and NGOs provide training on best farming practices, modern irrigation techniques, and efficient use of resources.

iii. Use of Technology

Efforts are being made to introduce technologies such as drip irrigation and water-efficient systems to optimize resource use.

1.4 Impact to the Neibouring communities

The Kadawa Irrigation Area and its activities have significant impacts both positive and negative on neighboring communities in Kano State and beyond. These impacts are primarily linked to agriculture, water management, and socio-economic activities associated with the *Kano River Irrigation Scheme (KRIS).

1.4.1 Positive Impacts on Neighboring Communities

1. Improved Food Security

The Kadawa Irrigation Area contributes to increased agricultural productivity, ensuring the availability of staple crops such as rice, wheat, maize, and vegetables. Neighboring communities' benefit from the surplus food produced, reducing reliance on imported food and enhancing local food self-sufficiency.

2. Employment Opportunities

The irrigation scheme provides direct and indirect employment for thousands of people, including farmers, laborers, traders, and transporters. Neighboring communities' benefit from economic activities related to farming, such as crop processing, storage, and transportation.

3. Economic Growth

The irrigation area stimulates local economies by fostering trade and commerce. Farmers sell their produce in local markets, and neighboring communities' benefit from the influx of goods and services. It also supports regional trade by supplying agricultural produce to other states and neighboring countries.

4. Access to Water

Communities near the irrigation canals benefit from improved access to water for domestic use, livestock, and small-scale farming. The availability of water has reduced the burden of fetching water from distant sources, especially for women and children.

5. Infrastructure Development

The establishment of the irrigation scheme has led to the construction of roads, bridges, and other infrastructure, improving connectivity for neighboring communities. Access to irrigation canals has encouraged the development of small-scale irrigation systems for private farms in nearby areas.

6. Knowledge Transfer and Agricultural Innovation

Neighboring communities have benefited from exposure to modern farming techniques, fertilizers, and irrigation technologies introduced through the Kadawa Irrigation Area. - Training programs and partnerships with agricultural extension services have improved farming practices in the region.

7. Social Development

The economic benefits of the irrigation area have improved living standards in nearby communities, with better access to education, healthcare, and other social amenities.

1.4.3 Negative Impacts on Neighboring Communities

1. Water Scarcity and Competition

The diversion of water from the Kano River for irrigation purposes can lead to reduced water availability for downstream communities, especially during the dry season. Overuse of water resources in the irrigation area sometimes creates tension between farmers and other water users, such as fishermen and herders.

2. Environmental Degradation

Poor water management and over-irrigation in Kadawa can lead to waterlogging and soil salinization, reducing the fertility of farmland in neighboring areas. Siltation and sedimentation in canals and rivers have affected water flow and aquatic ecosystems, impacting fishing communities downstream.

3. Impact on Hadejia-Nguru Wetlands

The irrigation scheme has reduced the flow of water into the *Hadejia-Nguru Wetlands*, a critical ecosystem for fishing, grazing, and biodiversity. This has disrupted livelihoods for communities that depend on these wetlands.

3. Increased Flood Risk

Poorly managed irrigation canals and water release from Tiga Dam can lead to localized flooding, affecting neighboring communities and their farmland.

4. Social Inequality

Some neighboring communities, particularly those without direct access to the irrigation system, feel excluded from the benefits. This has led to complaints of unequal resource distribution.

5. Health Issues

Stagnant water in irrigation canals can become breeding grounds for mosquitoes, leading to an increase in malaria and other waterborne diseases in nearby communities. Agrochemical runoff from farms in Kadawa can contaminate water sources, posing risks to human health and aquatic life.

6. Land Conflicts
The expansion of irrigation farming has led to disputes over land ownership and usage between farmers, herders, and neighboring communities.

1.5 Strategies to mitigate negative impacts

1. Efficient Water Management

Implementing water-saving technologies such as drip irrigation and ensuring equitable water distribution for all users.

2. Environmental Conservation

Introducing soil conservation practices and monitoring water quality to reduce environmental degradation.

3. Community Engagement

Involving neighboring communities in decision-making processes to ensure inclusive development and resource sharing.

4. Conflict Resolution

Establishing platforms for dialogue between farmers, herders, and other stakeholders to address land and water disputes.

5. Health Interventions

Providing healthcare services, mosquito control programs, and public awareness campaigns on agrochemical uses.

1.6 Challenges and Benefits

Kadawa Irrigation Area, as part of the Kano River Irrigation Scheme (KRIS), has brought numerous benefits to its immediate and neighboring communities. However, it also faces significant challenges that affect its operations, sustainability, and impacts on the environment and local livelihoods. Below is a detailed breakdown of the challenges and benefits associated with the Kadawa Irrigation Area:

1.6.1 Benefits of Kadawa Irrigation Area

1. Increased Agricultural Productivity

The irrigation system allows year-round farming, including dry-season farming, which boosts crop yields and ensures consistent food production. Crops such as rice, wheat, maize, and vegetables thrive in the area, contributing to local and national food security.

2. Economic Growth

The irrigation area generates income for farmers and creates a ripple effect in local economies through trade, transportation, and processing of agricultural goods.

It supports regional and cross-border trade, especially for crops like rice and vegetables.

3. Employment Opportunities

Thousands of jobs are created for farmers, laborers, and traders involved in agriculture and related activities. The irrigation area also supports industries such as fertilizer distribution, crop processing, and equipment sales.

4. Improved Livelihoods

Farmers benefit from better access to water for irrigation, leading to higher crop yields and increased income. The availability of water also supports small-scale businesses and livestock farming in surrounding communities.

5. Infrastructure Development

The establishment of the irrigation scheme has led to the construction of roads, bridges, and other infrastructure, improving connectivity and access to markets.

6. Food Security

By producing staple crops such as rice and wheat, the Kadawa Irrigation Area reduces dependence on food imports and enhances the availability of affordable food for local communities.

7. Knowledge Transfer

Farmers in the area are exposed to modern farming techniques, irrigation technologies, and best practices, improving their skills and productivity.

8. Renewable Energy Contribution

The irrigation area benefits indirectly from the hydroelectric power generated by the Tiga Dam, which supplies energy for water treatment and local infrastructure.

1.6.2 Challenges of Kadawa Irrigation Area

1. Water Management Issues

Inefficient water distribution and canal maintenance lead to water shortages for some farmers while others experience over-irrigation.

2. Water losses due to seepage and evaporation in unlined canals reduce the efficiency of the irrigation system.
3. Environmental Degradation

Over-irrigation has caused waterlogging and soil salinization, which reduce soil fertility and crop productivity.

4. Agrochemical runoff from farms contaminates water sources, affecting aquatic ecosystems and downstream communities.
5. Climate Change Impacts

Irregular rainfall patterns and rising temperatures affect water availability and increase the risk of droughts. Extreme weather events, such as floods, can damage irrigation infrastructure and disrupt farming activities.

6. Siltation of Canals

Sedimentation in the canals reduces water flow efficiency, requiring frequent maintenance and dredging, which are costly and time-consuming.

7. Social and Land Conflicts

Expansion of irrigation farming has led to disputes over land use between farmers, herders, and 8. neighboring communities.

Unequal access to irrigation water has created tensions among farmers, particularly those located farther from the main canals.

Health Risks

Stagnant water in canals serves as breeding grounds for mosquitoes, leading to an increase in malaria and other waterborne diseases. Agrochemical pollution from fertilizers and pesticides poses risks to human health and the environment.

9. Financial Constraints

Maintenance of irrigation infrastructure is expensive, and funding from the government or external sources is often inadequate. Many smallholder farmers struggle to afford modern farming equipment, fertilizers, and seeds.

Dependence on Tiga Dam

The Kadawa Irrigation Area relies heavily on the Tiga Dam for its water supply. Any operational issues or structural problems at the dam can disrupt irrigation activities.

1.6.3 Impact on Downstream Communities

- Water diversion for irrigation reduces flow to downstream areas, such as the Hadejia-Nguru Wetlands, affecting fishing, grazing, and other activities that sustain local livelihoods.
- Balancing Challenges and Benefits

Efforts are being made to maximize the benefits of the Kadawa Irrigation Area while addressing its challenges. Some strategies include:

- Rehabilitation of Infrastructure

Programs like the World Bank-funded TRIMING Project aim to modernize irrigation systems, improve water distribution, and enhance canal maintenance. Sustainable

- Farming Practices

Training farmers on proper irrigation techniques, agrochemical use, and soil conservation helps reduce environmental degradation.

- Conflict Resolution Mechanisms

Local authorities are working to mediate disputes over land and water use among farmers, herders, and other stakeholders.

- Climate Adaptation

Introducing water-efficient irrigation systems (e.g., drip irrigation) and drought-resistant crop varieties can help mitigate the impacts of climate change.

1.7 Research methodology

This study on the Tiga Dam and Kadawa Irrigation Area employs a mixed-methods approach, combining qualitative and quantitative research techniques to provide a comprehensive understanding of the challenges, impacts, and potential solutions related to these critical infrastructures. The methodology is structured as follows:

1. Literature Review

A thorough review of existing literature, including academic journals, government reports, and project documents, was conducted to gather background information on the Tiga Dam and Kadawa Irrigation Area. This review helped identify key issues, historical context, and the socio-economic and environmental impacts of these infrastructures.

2. Data Collection

Primary Data: Field observations, interviews with stakeholders (farmers, local communities, and project managers), and focus group discussions were conducted to gather firsthand insights into the challenges and successes of the dam and irrigation system. Secondary Data: Data on water usage, agricultural productivity, and environmental impacts were sourced from relevant government agencies, research institutions, and project reports.

3. Data Analysis

Quantitative data were analyzed using statistical methods to identify trends and patterns in water management, agricultural productivity, and environmental impacts. Qualitative data from interviews and focus group discussions were analyzed thematically to understand stakeholder perspectives and experiences.

Case Studies

Specific case studies of similar dam and irrigation projects were examined to draw lessons and best practices that could be applied to the Tiga Dam and Kadawa Irrigation Area.

4. Stakeholder Analysis

A stakeholder analysis was conducted to identify and engage key actors, including government agencies, local communities, farmers, and non-governmental organizations, in the research process. This ensured that the study reflected the needs and concerns of all relevant parties.

5. **Recommendations Development**

Based on the findings, a set of recommendations was developed to address the identified challenges and enhance the sustainability and effectiveness of the Tiga Dam and Kadawa Irrigation Area. These recommendations were informed by best practices in water management, environmental conservation, and sustainable agriculture.

Validation The findings and recommendations

were validated through stakeholder consultations and expert reviews to ensure their relevance and feasibility. This methodology provides a robust framework for understanding the complexities of the Tiga Dam and Kadawa Irrigation Area and for developing practical solutions to the challenges they face.

1.8 Conclusion and recommendations

Tiga Dam and Kadawa Irrigation plan are critical infrastructures in Kano State, Nigeria, playing a vital role in supporting agriculture, water supply, and socio-economic development in the region. The Tiga Dam, constructed to regulate water flow and provide irrigation water, has enabled the establishment of the Kano River Irrigation Scheme (KRIS), with the Kadawa Irrigation Area as one of its key beneficiaries. Together, they have transformed Kano State into a hub for agricultural production, ensuring food security, creating employment opportunities, and fostering economic growth. Despite these benefits, the Tiga Dam and Kadawa Irrigation plan face significant challenges, including inefficient water management, environmental degradation, social conflicts, and the impacts of climate change. Downstream ecosystems, such as the Hadejia-Nguru Wetlands, have also been negatively affected by reduced water flow, leading to disruptions in fishing, grazing, and biodiversity. Additionally, maintenance issues, siltation, and unequal access to irrigation water have hindered the full realization of the potential benefits of these infrastructures. To ensure the sustainability of the Tiga Dam and Kadawa Irrigation Area, it is crucial to address these challenges through coordinated efforts, improved management practices, and inclusive policies. By balancing the needs of agriculture, water supply, and environmental conservation, these infrastructures can continue to serve as a foundation for sustainable development in Kano State and beyond.

Recommendations

1. Efficient Water Management
2. Modernize water distribution systems by lining canals to reduce seepage and water losses. Promote the adoption of water-efficient irrigation techniques, such as drip or sprinkler irrigation, to optimize water use. Develop and implement equitable water allocation policies to ensure fair access for all farmers, including those at the tail end of the irrigation network.
3. Environmental Protection
4. Monitor and mitigate environmental degradation, including waterlogging and soil salinization, by training farmers on sustainable irrigation practices. Control agrochemical runoff to protect water quality in the Tiga Dam reservoir, Kadawa irrigation canals, and downstream ecosystems. Ensure that sufficient water is released downstream to sustain the Hadejia-Nguru Wetlands, which are vital for biodiversity and local livelihoods.
5. Infrastructure Maintenance
6. Regularly desilt and dredge the dam reservoir and irrigation canals to improve water flow and prevent blockages. Allocate adequate funding for the maintenance of Tiga Dam and irrigation infrastructure through government budgets, public-private partnerships, or community contributions.
7. Climate Change Adaptation
8. Introduce climate-resilient crops and promote climate-smart agricultural practices to mitigate the impacts of irregular rainfall and rising temperatures. Develop early warning systems for floods, droughts, and other climate-related risks to protect communities and infrastructure.
9. Conflict Resolution

10. Establish platforms for resolving disputes over land and water use between farmers, herders, and other stakeholders. Ensure inclusive decision-making processes that engage all affected communities, including marginalized groups and women.
11. Farmer Training and Capacity Building
12. Provide farmers with access to training programs on modern irrigation technologies, pest control, and soil conservation. Strengthen agricultural extension services to offer technical support and advice to fin the Kadawa Irrigation Area.
13. Downstream Ecosystem Conservation
14. Conduct environmental impact assessments to balance the needs of irrigation with the preservation of downstream ecosystems like the Hadejia-Nguru Wetlands. Engage with conservation organizations to protect biodiversity and sustain livelihoods dependent on these ecosystems.
15. Technology Integration
16. Use Geographic Information Systems (GIS) and remote sensing to monitor water use, crop health, and environmental changes in the Tiga Dam and Kadawa Irrigation Area. Leverage real-time data to improve decision-making in water allocation and infrastructure maintenance.
17. Institutional Collaboration
18. Strengthen coordination between the Hadejia-Jama'are River Basin Development Authority (HJRBDA), local governments, and development partners to streamline the management of Tiga Dam and Kadawa Irrigation Area. Partner with international organizations, such as the World Bank and FAO, to secure funding for sustainable irrigation and water management projects.
19. Community Involvement
20. Empower farmer cooperatives and water user associations to take an active role in managing irrigation systems and maintaining canals. Foster community-based decision-making to ensure that policies and projects address local needs effectively.

Ethical Considerations

This study was conducted in accordance with recognized ethical standards for academic research. The research is based on the analysis of secondary data, policy documents, and publicly available reports, complemented by contextual observations of socio-economic and environmental conditions in Kano State, Nigeria. No human participants were directly involved, and no personal or sensitive data were collected. Consequently, formal ethical approval was not required. Throughout the study, due diligence was exercised to ensure accuracy, objectivity, and respect for affected communities and environmental systems.

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