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Research Article

Climate Change Challenges the Wetland Resource in Nigeria: Significant Impacts on Hydrology and Biogeochemistry of Aquatic Ecosystem

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ABSTRACT

The Hadejia-Nguru Wetlands represent a complex and dynamic landscape where human activities and natural processes intersect. These wetlands' integrity and functionality are heavily dependent on hydrological conditions, particularly the surrounding water table. The present study aim to determine the climate change challenges the wetland resource in Nigeria: significant impacts on hydrology and biogeochemistry of the aquatic ecosystem. Borehole sampling and logging across the wetlands provided data on soil stratigraphy, while water quality was assessed by measuring parameters such as temperature, total dissolved solids, dissolved oxygen, pH, and turbidity. Results indicate that the wetlands maintain a generally alkaline water environment (pH 9.45) with an average temperature of 16.61°C, conducive to the survival of various aquatic species. The dissolved oxygen level averaged 4.97 mg/L, supporting moderate aquatic life, while the turbidity levels showed significant variability, with a mean of 108.67 NTU. The study area is further characterized by warm climate conditions, with an average environmental temperature of 30.62°C and moderate humidity levels at 55.51%. This study highlights the critical role of the Hadejia-Nguru Wetlands in supporting both ecological diversity and local human activities. However, it also underscores the impact of human activities on water quality, which could threaten the ecological balance. Conservation programs aimed at protecting and restoring wetland habitats are recommended to preserve biodiversity and ensure the sustainability of ecosystem services.

Keywords: Aquatic Ecosystem, Biogeochemistry, Climate, Hydrology

Introduction

The Hadejia-Nguru Wetlands represent a complex and dynamic landscape where human activities and natural processes intersect (Omijeh, 2021). The presence of various types of vegetation, including dense and open forests, shrubs, and specific plantations, indicates the ecological diversity of the wetlands. Maintaining this vegetation is crucial for biodiversity, carbon sequestration, and providing ecosystem services. True wetlands, with their hydrophytic vegetation and seasonal or permanent waterlogging, are critical for supporting unique plant and animal species (Balwan and Kour, 2021). They also offer important ecosystem services such as flood mitigation and water filtration (Agaton and Guila, 2023). However, the integrity and functionality of these wetlands are heavily dependent on hydrological conditions, particularly the surrounding water table.

In recent years, northern Nigeria has experienced significant environmental changes driven by both natural and human factors (Okon et al., 2021). The climate variability, agricultural expansion, urbanization, and water extraction have led to major alterations in water table levels in this region. These changes pose a threat to the delicate balance of wetland habitats, potentially leading to adverse impacts on aquatic ecosystem of this habitat. Despite the recognized importance of wetlands and the known influence of hydrology on these ecosystems, still there are a few studies on the specific effects on significant impacts of hydrology and biogeochemistry of the aquatic ecosystem in the Hadejia-Nguru wetlands of the northern part of Nigeria.

Study Area

The study was carried out at the Hadejia-Nguru Wetlands, located in northeast Nigeria. The Hadejia-Nguru wetlands in Yobe State of northern Nigeria, which include Nguru Lake, are ecologically and economically important. The wetlands lie in the Yobe-Komadugu sub-basin of the Chad Basin. They are formed where the Hadejia and Jama'are rivers meet lines of ancient sand dunes in a northeast-southwest alignment and break into numerous channels. They are drained by the Yobe River, which flows east towards Lake Chad. They lie between the Sudanian Savanna to the south and the drier Sahel to the north. Some of the land is permanently flooded, while other parts are flooded only in the wet season (August and September). Annual rainfall ranges between 200 and 600 mm, during the period from late May–September (Ringim et al., 2015).

Sample Collection

A series of 20-cased boreholes were drilled at an approximate distance of 10 meters across the settlement line into the wetland forest. These boreholes were positioned perpendicular to the creek, specifically after the point where it transitions into a channelized ditch running along the perimeter or just inside the forest, adjacent to meadow land extending towards the wetland.

In each borehole, the soil was logged, documenting the different layers and characteristics encountered during drilling. This logging process was followed by further analysis and classification of the soil samples to create a detailed stratigraphy profile. The soil classified from each borehole was matching up to achieve accurate data tolerance and depict the horizontal stratigraphy of the area. This approach allows for a comprehensive understanding of the soil composition, structure, and stratigraphy across the wetland forest and adjacent areas. It also aids in assessing how the soil characteristics may influence water movement, recharge/discharge patterns, and overall ecosystem dynamics within the wetland environment

Determination of Physico-Chemical Parameters

Physiochemical parameters of the water and environmental physical conditions were measured which include temperature, total dissolved solid of in the water, dissolved oxygen, pH, and turbidity.

Determination of Temperature (^{O}C)

Digital thermometer (Jenway 100 model) was used to measure the water temperature by immersing the thermometer into the water surface for about 30 seconds and allowed until stabilized readings were taken twice as described by Rabiu et al. (2018).

Total Dissolved Solids (TDS)

This was measured using TDS meter (HANNA HI96301 Model) by dipping the probes into the water until the screen show a stable reading as described by the manufacturers. Readings were expressed in mg/L (Walker and Ullery, 2002).

Dissolved Oxygen (DO)

It was measured using portable DO meter (JPB-607 model) in which the probe was inserted into the water until DO reading in (mg/L) was recorded as described by the manufacturers (Wetzel et al., 2000).

Determination of pH

The pH was measured using a pH meter model British Milwaukee Smart Meter S2O4. 50 ml of sample water was poured into a 100 ml beaker and part of the meter electrode was inserted into the water. Readings were taken after one minute (Sonkar and Kumar, 2022).

Turbidity

The turbidity of the water in Nephelometric Turbidity Unit (NTU) was measured using 20cm diameter Secchi disc, which was dipped into the water until the disc disappeared and the depth was recorded. It was dipped further and then withdrawn carefully and the depth at which it becomes visible was also recorded. Actual measurement was obtained by taking the average of the two readings (West and Scott, 2016).

Data Analysis

The data generated in this study was expressed in simple descriptive statistics using excel spread sheet for Window Version 20.

RESULT

The study area is characterized by the cultivation land covered with annual crops, vegetables, fruits, and Big Trees, including irrigated land. The grazing land is primarily covered with grasses and some scattered trees. The dipper part of the area is covered with relatively dense forest, open forest, shrubs, and trees scattered. The wetland of the area consisted of papyrus and phragmite swamps along with the river banks and the lakeshore areas. Swampy areas, meadows, either seasonal or permanent waterlogged, supporting hydrophytic plants degraded with human activities considered as wetlands (Table 1)

The study area experiences a warm climate with an average environmental temperature of 30.62°C, fluctuating by ±1.79°C. This translates to a range of 23°C during the colder, rainy season and reaching a maximum of 33.10°C during the dry season. Humidity levels are also relatively high, averaging 55.51% with a standard deviation of ±3.95%. This means humidity levels can vary between 49% and 64%, likely influenced by seasonal changes (Table 2).

The results of the physicochemical parameters of the water body in the study area indicate that the water is generally alkaline, with a pH of 9.45. The mean temperature was found to be 16.61°C, and the average dissolved oxygen level was 4.97 mg/L, suggesting healthy conditions. The mean turbidity level recorded was 108.67 NTU, with a range from a minimum of 8.00 NTU to a maximum of 145.00 NTU (Table 3).

Table 1 Hadejia-Nguru Wetlands Descriptions

	Descriptions
Cultivation Land	Areas covered with annual crops, vegetables, fruits, Big Trees, including irrigated land
Grazing Land	Land covered primarily with grasses having scattered trees serving as pasture and grazing cattle
Vegetation	Land covered with relatively dense forest, open forest, shrubs, trees scatted in the city, riverine forests and Eucalyptus plantations
Water Body	Refers to river and stream courses, lakes, ponds and open water in the wetland. Irrigation canals also included
Wetland	Areas consisted of papyrus and phragmites swamps along with the river banks and the lakeshore areas. Swampy areas, meadows, either or seasonal or permanent waterlogged, supporting hydrophytic plants degraded with human activities considered as wetlands

Table 2 Hadejia-Nguru Wetlands Climate Conditions

Variables	**Mean**	**STD**	**Minimum**	**Maximum**
Temperature (°C)	30.62	1.79	23.00	33.10
Humidity (%)	55.51	3.95	49.00	64.00

Table 3 Physiochemical Parameter of the Water in the Hadejia-Nguru Wetlands

Variables	Mean	STD	Minimum	Maximum
pH	9.45	0.34	9.00	10.00
Temperature **(°C)**	16.61	0.83	15.00	18.00
Dissolve Oxygen	4.97	2.12	1.50	7.40
Turbidity	108.67	47.35	8.00	145.00

Discussion

The report of this study observed Hadejia-Nguru wetlands covered by cultivation land dedicated to the growth of annual crops, and vegetables. The cultivation of land is crucial for local agriculture, providing food and economic resources to the local communities (Giller et al., 2021). The grazing area is characterized by grasses with scattered trees, that serve as pasture for grazing cattle and supports livestock farming, which is an important livelihood for many local communities in the region. The water body in the area encompasses rivers, streams, lakes, ponds, and opens water within the wetland, including irrigation canals. These water bodies are critical for sustaining the wetland ecosystem, providing water for irrigation, supporting aquatic life, and offering resources for domestic and agricultural use (Jisha and Puthur, 2021).

The climate conditions of an environment are essential tools that provide valuable insights into the environmental factors and influence the region (Bramer et al., 2018). The report of the climate conditions of the Hadejia-Nguru Wetlands was recorded as characterized by warm temperatures and moderate humidity, which create a stable environment that can support agriculture, biodiversity, and human activities in the area. The result of the present study agreed with what was recorded by Ringim et al. (2015), Dami et al. (2017) and Gujja et al. (2023) all recorded a temperature range between 22.32C to 38.17C.

The water quality of the wetlands is critical for maintaining the health of its ecosystem and supporting various uses such as agriculture, fishing, and domestic (Nayak and Bhushan, 2022). Physiochemical parameters that describe the water's characteristics in any of these regions include pH, temperature, dissolved oxygen, and turbidity (Jaffar et al., 2020). The water in the Hadejia-Nguru Wetlands shows distinct characteristics that reflect both natural conditions and potential human impacts. The mean± standard deviation pH of 9.45±0.34 indicates that the water in the Hadejia-Nguru Wetlands is alkaline. This could influence the types of aquatic plants and animals that can thrive in this environment (Pinheiro et al., 2021). The temperature of the water was recorded at 16.61°C±0.83°C, which can be conducive to the health of various aquatic organisms. Stable and cool temperatures are generally favorable for aquatic life, reducing the risk of thermal stress (Currie and Schulte, 2014). These conditions are suitable for certain fish species and other aquatic organisms that thrive in cooler waters. Temperature stability is also crucial for maintaining dissolved oxygen levels and overall water quality (Li et al., 2022). The mean±standard deviation dissolved oxygen (DO) level of 4.97±2.12mg/L obtained indicated the moderate oxygen availability in the water and adequate for the survival of fish and other aquatic organisms (Bulbul and Mishra, 2022). The turbidity of 108.67±47.35 NTU suggested that the water is quite turbid, with significant suspended particles. However, a high standard deviation of 47.35NTU indicates substantial variability in turbidity levels and highlights periods of both low and extremely high turbidity. The outcome of this study is in line with the results of Abubakar and Abubakar (2013), Abubakar and Yakasai (2015), and Musa and Iman (2021).

Conclusion

The Hadejia-Nguru Wetlands exhibit a rich and diverse ecosystem characterized by various vegetation types, including forests, shrubs, and plantations. The climate of the Hadejia-Nguru Wetlands, marked by warm temperatures and moderate humidity, supports diverse human and ecological activities. Water quality, indicated by parameters such as pH, temperature, dissolved oxygen, and turbidity, shows that the wetlands maintain a conducive environment for aquatic organisms, though human impacts are evident.

Recommendations

Based on the outcome of this study the following recommendations were made:

There is need for

1. Implement conservation programs to protect and restore critical wetland habitats, ensuring the preservation of biodiversity and ecosystem services.
2. Encourage sustainable agricultural practices that minimize environmental impact, such as crop rotation, organic farming, and efficient water use.
3. Establish regular monitoring of water quality parameters to detect and address pollution sources promptly.

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