ECO-HYDROLOGICAL CHARACTERISTICS AND HABITAT SUITABILITY MODEL FOR AQUA TOURISM DEVELOPMENT IN AIBA AND OKINNI DAMS

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ABSTRACT

Wetlands serve as prime aqua tourism destinations for leisure activities and provide critical ecosystem services. However, increasing human population pressure, grazing, and adverse climatic conditions have resulted in unsustainable land use practices in Nigeria. This study assessed the eco-hydrological characteristics of Aiba and Okinni dams. It identified key factors affecting habitat suitability, and developed a suitability model for aqua tourism development. Data collection involved water sampling across three different courses of the dams, mapping of the wetlands using Global Positioning System, and acquisition of Landsat satellite imageries from the U.S. Geological Service. Semi-structured interviews of stakeholders and experts in tourism and wetland management were also conducted. Analytical tools included t-tests, Analytical Hierarchical Process and GIS-based approaches. Findings revealed no significant variation in physicochemical parameters except coliform, which was higher at Okinni. In addition, microbiological analysis revealed higher fungal and yeast counts at Okinni. Although both dams hold strong potential for aqua tourism, poor management practices have reduced suitability levels and solar radiation was a major factor influencing habitat suitability. There is a need for the development of policy frameworks that address wetland protection, collaborative stakeholder planning, and comprehensive aqua tourism management plans for the wetlands.

Keywords: Aqua tourism, Wetlands, Habitat suitability modelling, Aiba Dam, Okinni Dam

INTRODUCTION

Aqua tourism has become an increasingly popular and lucrative industry, offering opportunities for economic growth and development in coastal communities (Karani and Failler, 2020). This subset of ecotourism is a dependable method suitable for promoting socioeconomic development (Sarma *et al.,* 2018). Globally, wetland habitats are the primary habitat involved in aqua tourism and recreational activities. Wetlands are transitional areas between terrestrial and aquatic ecosystems, where the water table is usually at or near the surface or the land (Balwan and Kour, 2021). These vital habitats harbour high levels of floral and faunal biodiversity (Mitsch and Gosselink, 2015; Saenger*,* 2017). Hence, the rapid expansion of aqua tourism in wetlands pose a significant threat to the marine ecosystem (Salimi *et al*., 2021).

Habitat Suitability Models (HSMs) are scientific approaches used for forecasting and effectively managing aqua tourism activities in wetland environments. Habitat suitability models (such as ecological niche, envelope, or species distribution models) are used to predict the current potential suitability of areas to invasive species (Srivastava *et al.,* 2019). The models help to develop correlative relationships between species location or occurrence data and the environmental or climatic conditions in which those occurrence points are found (Cerasoli *et al.,* 2022).

In Nigeria, aqua tourism is underdeveloped and presently at infancy, a stage where water bodies are either un-utilised or underutilised for tourism purposes (Digun-Aweto and Oladele, 2018). Poor planning and integration of aqua tourism development with local values and the environment further limit socio-cultural, environmental and economic benefits (Mejjad *et al.,* 2022). Most wetlands have been significantly altered by anthropogenic activities such as oil exploration, industrial waste pollution, population growth, rapid urbanisation, mining, dam construction and transportation (Newton *et al.,* 2020; Hoque, 2023; Leka-Oscar *et al.,* 2023; Omosulu *et al.,* 2023; Aransiola *et al.,* 2024).

Wetlands in Osun state, Nigeria have received little to no attention from researchers, with limited information on their suitability for aqua tourism. Therefore, this study mapped out two habitats suitable for aqua tourism activities and provided empirical information on their status. Specifically, the study determined the eco-hydrological characteristics and factors influencing habitat suitability for aqua tourism development. It also developed habitat suitability models for aqua-tourism development in Aiba and Okinni dams.

MATERIALS AND METHODS

Description of Study Area

Aiba dam is a water reservoir located in Iwo, Iwo local government, Osun State. It is located along latitude 7°38" to 7°39" N and longitude 4°11" to 4°13" E, with a total land area of 245 km². The dam is 11.58 m high and 455.2 m long, with a mean depth of 0.75 m. It is a freshwater storage dam that holds 1.91 billion cubic meters, supplied by a 53.39 km^2 catchment area. It started operation on 01 June 1958, making it the second largest impoundment of the Osun River Basin (Atobatele, 2013).

The Okinni dam is situated in Okinni, Egbedore local government, Osun State. It is located along latitude 7°53'32" to 7°53'38" N and longitude 4°32'19" to 4°32'05" E, and covers a total land area of 250 km², with gentle undulating terrain and trending ridges. The dam is situated on the Erinle streamline, featuring gently undulating terrain characterised by trending ridges to the west and south. Geologically, it is underlain by thin recent alluvial clean gravel deposits over massive pegmatite, which belongs to the Precambrian crystalline basement complex of southwestern Nigeria (Odunfa *et al.*, 2022). The surrounding area of the dam contains schists and quartzite.

Data Collection

Water samples were collected across three courses (lower, middle and upper) of Aiba and Okinni dams. The water samples were transported to the laboratory for physical, chemical and microbial analyses. Geo-coordinate points were collected for the wetland dedication using the Random Forest

Classifier. Data from the United States Geological Service (USGS) and cloud cover less than 10% at 30 m spatial resolution were used for the extraction of land use and land cover, and the Normalised Difference Vegetation Index (NDVI) maps, using Landsat 8 OLI/TRIS satellite imageries. The land cover classification scheme adopted included categories such as wetland/ waterbodies, built-up areas, forest, farmlands, grassland, degraded vegetation etc. The identification of suitable locations for aqua tourism was based on eleven factors namely: land use land cover, soil, elevation, water quality, altitude, rainfall, solar radiation, wind speed, distance to roads, distance to host communities and distance to river.

A semi-structured expert's opinion interview session was used to obtain sociodemographic data and information on factors determining the choice of location suitable for aqua tourism activities. An in-depth interview was carried out with stakeholders from the Ministries of Water and Environment, as well as experts (n=20) on tourism development and wetland management in Osun State.

Data Analysis

The Student's T-test was used to determine if there was a significant difference in the eco-hydrological characteristics of Aiba and Okinni dams. The Analytical Hierarchical Process and GIS approach were used to integrate factors that predicted the habitat suitability models for the wetlands.

RESULTS

Physicochemical Parameters of Water in Aiba and Okinni Dams

Okinni dam had higher values for five physicochemical parameters (MPA coliform: 118.33±38.44; conductivity: 135.08±17.61 µS; colour: 1.33±0.21; dissolved oxygen: 19.35±1.36 mg/L; total dissolved solids: 61.53±13.70 ppm). But, only MPA coliform significantly differed in the two wetlands.

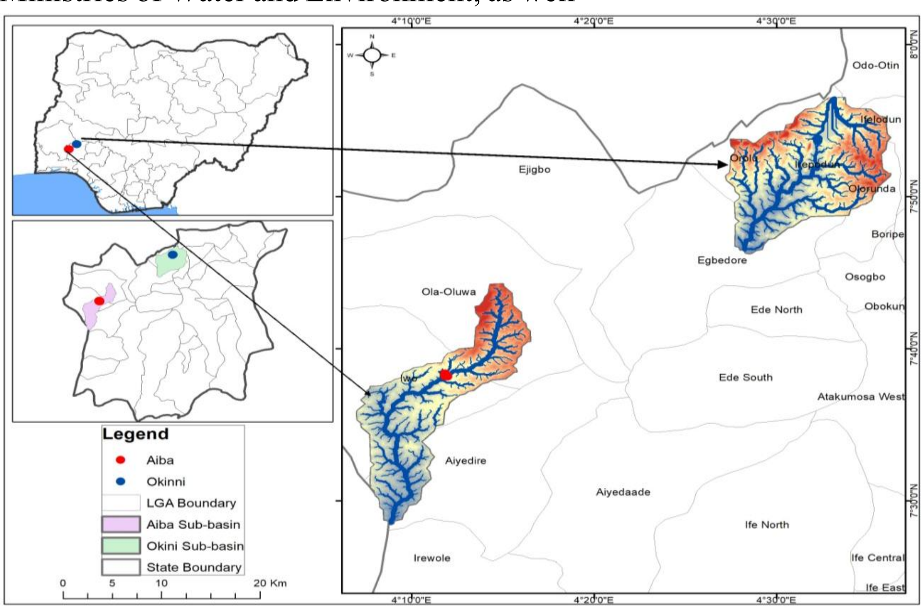

Figure 1. Maps of Okinni and Aiba Dams (inset: Maps of Nigeria and Osun state)

Six physicochemical parameters (Chemical Oxygen Demand, COD: 253.62±13.64 mg/L, salinity: 28.17±6.56 ppm, turbidity: 6.37±0.90 NTU, pH: 5.50±0.13, water temperature: 28.36±0.34°C and total suspended solids: 0.21±0.03 mg/L) were higher at Aiba wetland (Table 1).

Microbial and Water Quality Parameters from Aiba and Okinni Dams

Okinni dam had higher yeast (28.67±10.64) and fungi (49.00±18.26) counts. However, bacteria count (476.6± 50.18) was higher in Aiba wetland. Nevertheless, there was no significant difference in the population of the microbes (Table 2).

The upper course had higher values for some physicochemical and microbial parameters (conductivity: 145.50±25.6 µs/cm, temperature: 28.38±0.81°C, total dissolved solids: 61.90±19.87 mg/L, turbidity: 6.30±0.82 NUT, dissolved oxygen: 18.68±1.62 mg/L, yeast: 44.25±10.71 and fungi: 67.50±22.67 mm, COD: 277.70±10.07 mg/L). Although, only yeast significantly differed across the three courses. The pH (5.66±0.15) and bacteria (480.00±32.02) were higher in the middle course. These parameters were similar in the two dams (Table 3). Three parameters were found to be higher in the lower course of the dam (total suspended solid: 0.24±0.02, salinity: 35.40±10.66 ppm and MPA coliform: 114.50±64.90 mg/L).

Analytical Hierarchical Process of Aqua tourism suitability in Aiba and Okinni dams

The analytical hierarchical process revealed that solar radiation (20.86%) was the most influential factor determining the suitability of the wetlands for aqua tourism (Table 4). This implies that areas receiving higher solar energy were more favourable. Sunlight enhances visibility, comfort and aesthetic value. Wind speed, distance to roads, distance to host communities, and distance to river, each had 11.36%. In contrast, land use and land cover (3.8%), water quality (3.85%), and soil type (3.95%) had the least influence. The AHP model’s consistency ratio (0.0575), being less than 0.10, confirmed that the weight assignments were logically consistent and statistically reliable.

DISCUSSION

The presence of coliform bacteria in water indicates general pollution; which could negatively impact tourists' health with illnesses such as diarrhea and cholera. The higher coliform bacteria growth at Okinni dam revealed contamination due to human, animal and livestock wastes as well as low pH level at the wetland. Aram *et al.* (2021) stated that faecal coliforms died more rapidly when the pH condition of a water body increases above 8.5. Microbial assessments revealed that Okinni’s water system was more polluted, with fungi and yeast counts exceeding the limits set by international microbiological standards for recreational waters.

Table 1. Physicochemical parameters of Aiba and Okinni Dams in Osun State, Nigeria

Parameter	Wetlands	Mean±SE	F Statistics	T value	p value
MPA Coliform	Aiba	10.33±2.22	41.01	2.81	0.00*
	Okinni	118.33±38.44			
Conductivity (µs)	Aiba	130.25±3.84	3.22	0.27	0.10^{ns}
	Okinni	135.08±17.61			
COD (mg/L)	Aiba	253.62± 13.64	1.30	0.85	0.20^{ns}
	Okinni	228.38±26.23			
Colour	Aiba	1.17±0.17	1.61	0.62	0.23^{ns}
	Okinni	1.33± 0.21			
Dissolved Oxygen (mg/L)	Aiba	16.28±0.88	0.58	1.90	0.46^{ns}
	Okinni	19.35±1.36			
Salinity (ppm)	Aiba	28.17±6.56	0.51	0.31	0.49^{ns}
	Okinni	25.47±5.88			
Total Dissolved Solids (ppm)	Aiba	20.17 ± 4.99	5.03	2.84	0.49^{ns}
	Okinni	61.53 ± 13.70			
Turbidity (NTU)	Aiba	6.37 ± 0.90	4.56	0.66	0.59^{ns}
	Okinni	5.41 ± 0.31			
pH	Aiba	5.50 ± 0.13	0.07	1.04	0.72^{ns}
	Okinni	5.31 ± 0.13			
Water temperature (°C)	Aiba	28.36 ± 0.34	0.09	1.20	0.78^{ns}
	Okinni	27.67 ± 0.47			
Total Suspended Solids (mg/L)	Aiba	0.21 ± 0.03	0.08	0.39	0.79^{ns}
	Okinni	0.20 ± 0.02			

Table 2. Microbial parameters of Aiba and Okinni dams in Osun State, Nigeria

Parameter	Wetland	Mean±SE	F Statistics	T value	p value
Yeast (SFU/ml)	Aiba	25.33±4.98	5.34	0.43	0.28^{ns}
	Okinni	28.67±10.64			
Fungi (SFU/ml)	Aiba	32.00±5.18	17.39	0.00	0.90^{ns}
	Okinni	49.00±18.26			
Bacterial (CFU/ml)	Aiba	476.67±50.18	9.45	0.12	2.86^{ns}

Table 3. Water quality parameters for different courses in Aiba and Oki dams, Osun State, Nigeria

Parameter	Water course	Mean±SE	F Statistic	P value
Yeast (SFU/ml)	Lower Course	24.25±7.73[ab]	4.39	0.05*
	Middle Course	12.50±1.26[a]		
	Upper Course	44.25±10.71[b]		
Fungi (SFU/ml)	Lower Course	33.75±8.00[ab]	3.07	0.10[ns]
	Middle course	20.25±0.25[a]		
	Upper course	67.50±22.67[b]		
COD (mg/L)	Lower course	205.45±32.19[a]	2.22	0.12[ns]
	Middle course	239.85±18.32[a]		
	Upper course	277.70±10.07[a]		
pH	Lower course	5.36±0.58[a]	2.62	0.13[ns]
	Middle course	5.66±0.15[a]		
	Upper course	5.19±0.19[a]		
Total Suspended Solids (mg/L)	Lower course	0.24±0.02[a]	1.85	0.21[ns]
	Middle course	0.17±0.03[a]		
Salinity (ppm)	Upper course	0.20±0.03[a]		
	Lower course	35.40±10.66[a]	1.58	0.26[ns]
	Middle course	17.95±2.19[a]		
	Upper course	27.10±5.17[a]		
Bacterial (CFU/ml)	Lower course	345.00±32.02[a]	1.15	0.26[ns]
	Middle course	480.00±32.02[a]		
	Upper course	375.00±49.91[a]		
Total Dissolved Solids (ppm)	Lower course	29.85±11.12a	1.35	0.31[ns]
	Middle course	30.80±14.81[a]		
	Upper course	61.90±19.87[a]		
MPA Coliform	Lower course	114.50±64.90[a]	1.14	0.36[ns]
	Middle course	28.00±7.55[a]		
	Upper course	50.50±33.40[a]		
Dissolved Oxygen (mg/L)	Lower course	18.68±1.62[a]	1.12	0.37[ns]
	Middle course	15.94±2.20[a]		
	Upper course	18.83 ± 0.16[a]		
Conductivity (uS)	Lower course	131.00 ± 5.82[a]	0.61	0.57[ns]
	Middle course	121.50 ± 5.22[a]		
	Upper course	145.50 ± 25.6[a]		
Water temperature (°C)	Lower course	28.09 ± 0.38[a]	0.57	0.58[ns]
	Middle course	27.58 ± 0.24[a]		
	Upper course	28.38 ± 0.81[a]		
Turbidity (NTU)	Lower course	5.64 ± 1.10[a]	0.17	0.84[ns]
	Middle course	6.23 ± 0.62[a]		
	Upper course	6.30 ± 0.82[a]		

Table 4. Analytical Hierarchical Process of aqua tourism suitability in Aiba and Okinni dams in Osun state, Nigeria

Factors	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Weight (%)	Rank
Land Use Land Cover	1	0.76	0.33	1	0.58	1	0.25	0.33	0.33	0.33	0.33	3.8	11
Soil	1.32	1	0.33	1	0.58	1	0.19	0.33	0.33	0.33	0.33	3.95	9
Elevation	3	3	1	3	1.73	3	0.38	1	1	1	1	11.09	6
Water Quality	1	1	0.33	1	0.58	1	0.25	0.33	0.33	0.33	0.33	3.85	10
Altitude	1.73	1.73	0.58	1.73	1	1.73	0.38	0.58	0.58	0.58	0.58	7.01	7
Rainfall	1	1	0.33	1	0.58	1	0.33	0.33	0.33	0.33	0.33	4.03	8
Solar Radiation	3.95	5.2	0.65	3.95	2.87	3	1	1.63	1.63	1.63	1.63	20.86	1
Wind Speed	3	3	1	3	1.73	3	0.61	1	1	1	1	11.36	2
Distance to roads	3	3	1	3	1.73	3	0.61	1	1	1	1	11.36	2
Distance to Host Communities	3	3	1	3	1.73	3	0.61	1	1	1	1	11.36	2
Distance to river	3	3	1	3	1.73	3	0.61	1	1	1	1	11.36	2

The pattern of faecal contamination and organic waste inflow into water bodies have been consistently reported to be driven by anthropogenic activities and continue to reduce wetland health (Akpor *et al.,* 2014; Potgieter *et al.,* 2020). Hence, without improved waste management and water treatment, Okinni's tourism potential remain limited.

Only two and three parameters were found to be higher in middle and lower courses, respectively. These could be attributed to the deposit of waste materials and pollutants at the mouth of the river. River mouths are mostly polluted with lower water quality. This usually constrains aqua tourism development (Liu *et al.,* 2003).

Solar radiation was a major factor that influenced site suitability for aqua tourism development. Shang *et al.* (2019) opined that solar radiation and temperature were very important factors that influenced tourist comforts in Haikou, China. The wind speed, distance to river, distance to roads, and distance to host communities were other factors that strongly influenced aqua tourism activities (Gursory and Rutherford 2004; Nunkoo and Ramkissoon, 2011; Khalid *et al.,* 2019). The low level of pollution in Aiba dam revealed its potentials for aqua tourism activities. Pollution index is used to determine the quality of a water body and its suitability for aqua tourism (Ramos-Pachecoet *et al*., 2023). Hence, for aqua tourism to thrive in Okinni and Aiba, the water quality and aquatic resources must be enhanced to meet the standards required for recreational waters.

CONCLUSION

The Aiba and Okinni wetlands hold considerable potentials for aqua tourism development in Osun State, Nigeria. By integrating eco-hydrological assessments with spatial modeling, this study identified environmental and infrastructural factors that collectively determine the suitability of these wetlands for water-based recreational activities. The analyses revealed that solar radiation, accessibility, and community proximity were the strongest predictors of habitat suitability, while poor water quality especially at Okinni dam remained a major limitation to safe and sustainable tourism.

Public institutions should implement political reforms and policy frameworks that enhance wetland protection and tourism stakeholders' involvement. The development of aqua tourism management plans is essential and the habitat suitability model would be an important tool for achieving this. Water-dependent tourism activities such as swimming, boating, water rafting and surfing could be developed around the two dams.

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