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MAPPING THE SPATIOTEMPORAL DYNAMICS OF SURFACE WATER AREA OF THE DABERAM WETLAND RESERVOIR USING DIGITAL EARTH AFRICA SANDBOX

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ABSTRACT

A wetland reservoir is an area of land covered by water from rivers, lakes, aquifers, or springs. This research aimed at mapping the spatiotemporal dynamics of surface water extent of the Daberam wetland reservoir using Digital Earth Africa Sandbox, over 12 years. Multitemporal Landsat datasets and Water Observation from Space products were used. The data analysis and result presentation were carried out in the Jupyter Lab Environment of the Digital Earth Africa Sandbox. The result shows that the highest upward trend corresponds to only three 3 years of the study period, while the downward trend was observed in nine 9 years. The year 2015 is the period that the reservoir experienced maximum surface water extent, while 2019 is the year of the highest decline in the surface water extent. The maximum possible area extent of the surface water is 2.69 km^2, but it declined to 0.71 km^2. This shows a significant loss of 1.98 km^2. The study established that the Daberam wetland reservoir has severely dried up due to the impacts of climate change and anthropogenic activities. Therefore, the study recommended that water extraction from the Daberam Wetland Reservoir for irrigation and other activities should be regulated, and encroachment on the floodplains of the reservoir should be discouraged. Lastly, the Katsina State Government should declare a state of emergency on the Daberam wetland reservoirs and initiate a rehabilitation project.

Keywords: Daberam, Wetlands, Water Resources, Katsina State, Irrigation Farming

INTRODUCTION

Wetlands, as defined by the Ramsar Convention Secretariat (1971), are areas of marsh, fen, water, or peatland, either artificial or natural, temporary or permanent, with water that is flowing or static, salt or fresh brackish, including areas of marine water where the depth at low tide does not exceed 6 meters. These wetlands may cover a large area, ranging from a small number of hectares to hundreds of square kilometres in size (Moser, 2021). The water in wetlands can be from groundwater seepage from an aquifer or from a nearby lake or river (Abubakar & Abdussalam, 2024). Wetlands are formed or modified by human activity to supply a reliable and controllable water resource that provides different services (Prasanya et al., 2024). The services include, but are not limited to: providing habitats for various animal and plant species; serving as a source of water for irrigation, fishery; as well as use by pastoralists for domestic purposes and watering of livestock (Essien et al., 2019; Moser, 2021; Pi et al., 2022).

In many places around the world, wetland reservoirs are severely affected by anthropogenic activities, climate change, and other environmental hazards (Abubakar et al., 2025b), making them highly dynamic and subject to rapid changes in conditions and periodic fluctuations such as changes or declines in water quality, water level, and/or extent (Cui et al., 2024). These changes are especially great in semiarid areas such as sub-Saharan countries (Moser, 2021). These changes or declines manifest in low productivity in irrigated fields and the disappearance of aquatic animals of high socio-economic value, such as fish.

Climate change has a pervasive effect on wetlands and other water resources in Nigeria (Abubakar et al., 2025a; Bello et al., 2025a). Reduced rainfall would cause physical changes in the hydrological cycle, while increased evaporation would disconnect rivers from their wetlands and floodplains, slow water velocity in riverine systems, and convert them into a chain of connected pools (Shanafield et al., 2024). Nigeria, for example, has multiple huge river and lake systems (for example, the Niger River Basin) that have seen significant reductions in flow rates and network lengths as a result of decreased rainfall and increased evaporation. As a result of the projected effects of climate change, more losses are anticipated (Abubakar & Abdussalam, 2024).

Governments at different levels made efforts through policies to increase food security following the effects of the Sahelian drought of the 1970s, which brought food scarcity (Bjornlund et al., 2022; Ukwe, 2025); thus, dam and reservoir construction in Nigeria began with vigour. Dams and wetland reservoirs are seen as a major means to provide enough water for irrigation and livestock watering in order to improve agricultural productivity throughout the year (Adeniran et al., 2021). In Katsina State specifically, several dams and wetland reservoirs have been constructed by both federal and state governments, such as the Daberam Wetland Reservoir, Jibia Dam, Zobe Dam, etc, all for the purpose of providing water for various purposes (Ladan, 2019). Despite all the efforts, it has been reported that there is a deteriorating condition of irrigation farming, fishery, and pastoralism in Katsina State, as the sources of water are drying up, especially the Daberam wetland reservoir, which is almost the major contributor in terms of fishery and irrigation farming in Katsina State (Bala et al., 2011; Sadauki et al., 2022). Therefore, several measures were taken by the farmers to cope with the shortage. The measures include digging wells, rationing water, leaving nearby dams, or the whole dry season. These led to crop stress, low farm productivity, and loss of income generation by the people (Ladan, 2019). In view of the foregoing issues on wetland reservoirs, this work focuses on mapping the spatio-temporal dynamics of a wetland reservoir using earth observation technology.

The relevance of this study lies in its potential to provide timely and spatially explicit information on the changing extent of surface water in the Daberam Wetland Reservoir, which has significant ecological and socioeconomic implications. By leveraging the Digital Earth Africa (DEA) Sandbox and Earth observation datasets, this research offers a cost-effective, reproducible, and data-driven approach to monitor water dynamics over time. Such insights are vital for sustainable water resource management, climate adaptation planning, and the protection of wetland ecosystems in northern Nigeria. Furthermore, the findings can serve as a scientific basis for local and regional authorities to design targeted conservation and rehabilitation interventions, ensuring the long-term resilience of the Daberam Wetland Reservoir and the communities that depend on it.

MATERIALS AND METHODS

Study Area

The specific study area is Daberam wetland reservoir, which is a water body situated in a settlement called Daberam, in Daura LGA of the north-western state of Nigeria, i.e., Katsina. It is positioned between Latitude 12^{o} 53' 51'' and Latitude 12^{o} 56' 47" North of the equator and Longitude 8^{o} 12' 40" and Longitude 8^{o} 14' 16" East of Greenwich. The Daberam is located 16 km off the Katsina – Daura Trunk A highway from the ancient town of Daura (Ladan, 2019), precisely along the 26 km Dan'nakola to Fago Road (Bala et al., 2011).

The climate is part of the tropical continental climate region of northern Nigeria, which is characterized by a short-wet season from May to August and a long dry season from September to April of every year (Ladan, 2019). The average annual rainfall ranges between 600 and 640mm (Abdulaziz et al., 2019).

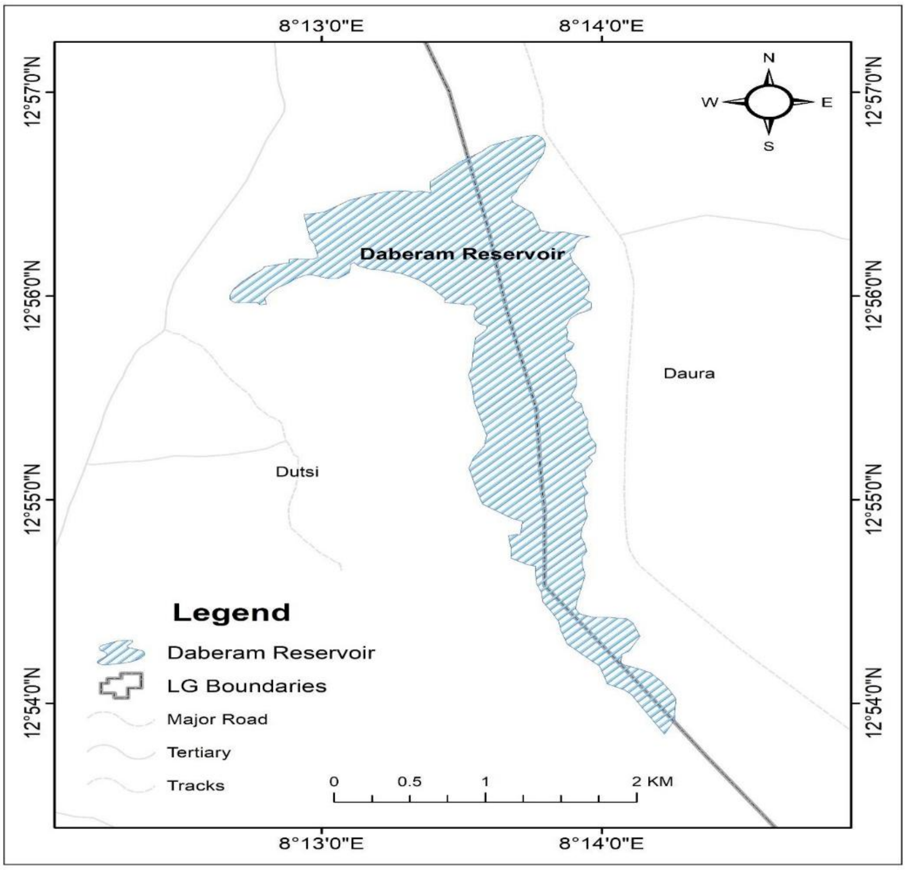

Figure 1: Map of the Study Area
Source: Adapted from Abdulaziz et al. (2019)

The relief of the area is characterized by localized steep topography, especially along the river valley. The character of the valley gives rise to extensive floodplains. Upstream of the Daberam reservoir has a dendritic drainage pattern (Usman et al., 2018). The Kigo and Riniyal rivers form the drainage of the area, which serves as the major source of water for the Daberam wetland reservoir and four streams that empty their waters into the reservoir (Ladan, 2019). The soils of the area are predominantly sandy because of the accumulation of aeolian drift material of varying thickness (Usman et al., 2018). The capacity of the reservoir is more than 12 million cubic meters, which covers around 400 hectares of land, and a depth of more than 42 meters with a crest length of 2377.44 meters (Abdulaziz et al., 2019). Sudan savanna is the vegetation type of the area, which consists of shrubs with very thick bark and short grasses (Ladan, 2019). The predominant trees around the area are the neem tree, *Azadirachta indica,* and the *baobab* tree (*kuka*) (Usman et al., 2018; Ladan, 2019), which are respectively used for medicinal and food purposes (Usman et al., 2018).

The whole of Daura LGA (Daberam inclusive) has a total population of 224,884 people according to the 2006 census (Ladan, 2019). The people of Daberam are fishermen, farmers (for both livestock and crops), and a few who are into trading activities in weekly markets within Katsina State and beyond (Ladan, 2019). Agricultural practices are the predominant socioeconomic activities in the Daberam area. The people are highly engaged in fishery and farming (both wet season and dry season). This makes the people of the area among the major producers/suppliers of fish and fresh vegetables in Katsina state, as well as to some other parts of the country (Usman et al., 2018). Therefore, this research aimed at mapping the spatiotemporal dynamics in the surface water extent of Daberam wetland reservoir using an earth observation technology.

Data Types and Sources

The DE Africa Sandbox uses Landsat and Sentinel data sets, and different products or notebooks. However, for this research work, Landsat datasets and Water Observation from Space products were used.

Data Analysis

This research was conducted using the open-access cloud computing platform Digital Earth Africa Sandbox (DE Africa Sandbox). DE Africa Sandbox is a cloud computing earth observation platform that operates through a Jupyter Lab environment using notebooks or products developed in the Python programming language. The DE Africa Sandbox was established or created by Geoscience Australia for earth observation enthusiasts and data scientists to be able to use satellite images and data, at no cost (i.e., free) for analysis, interpretation, or monitoring the changes on the Earth's surface and resources.

RESULTS AND DISCUSSION

Trend of Observed Annual Area of Water Extent

To determine the condition of the surface area of the water by plotting time series facets and observed annual trend charts from 2010 to 2021: This was achieved by running a cell in the notebook and plotting time series facets and the trend of observed annual water extent of the acquired area of study. The results can be seen in Figure 2.

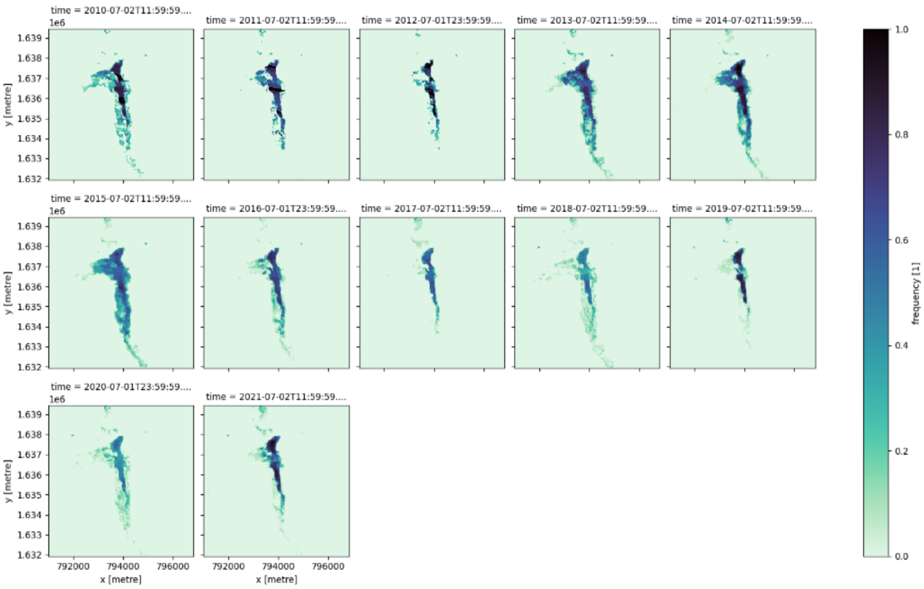

Figure 2: Observed Annual Water Extent Plotted in Time Series Facets

Figure 3 reveals the trend in fluctuations in the observed annual area of water from 2010 to 2021 in the Daberam Wetland Reservoir. The largest positive anomalies corresponded to 2010–2011, 2011–2012, 2014–2015, 2015–2016, and 2020–2021. While reduced water extent or negative surface water anomalies could be observed in 2013–2014, 2017–2018, and 2019–2020. This shows fluctuations or a lack of stable water availability.

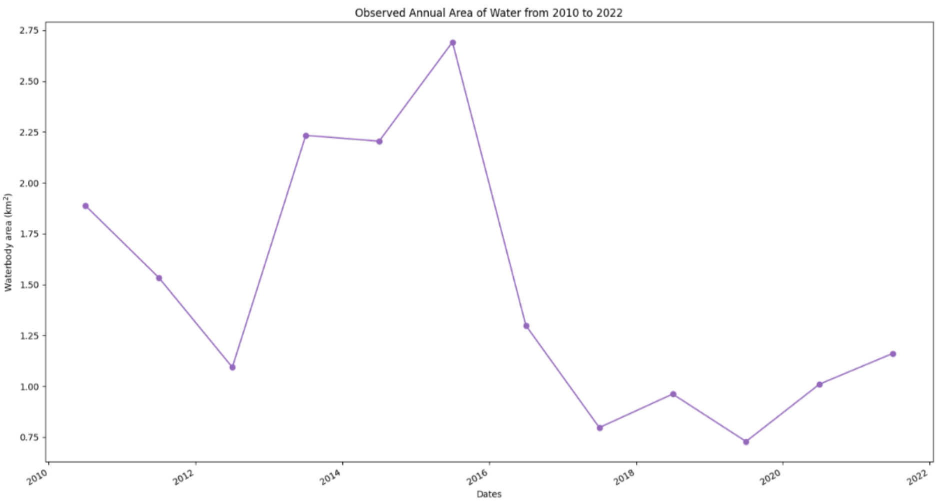

Figure 3: Trend of The Observed Annual Water Extent

Unlike the findings of Bello and Sani (2021), which revealed that the Goronyo Reservoir in Sokoto is continuously decreasing, this study revealed that the Daberam Reservoir is experiencing inter-annual fluctuation. Earlier, Mustafa and Noori (2013) established that a downward trend in surface water extent is attributed to changes in climatic conditions. Likewise, Qin et al. (2020) established that the impact of anthropogenic activities on surface water resources is increasing gradually, while the impact of climate has a weakening trend. Therefore, this long period of weakening/downward trend in the Daberam wetland reservoir is attributed to or can be translated to the effect of changes in climate conditions and anthropogenic activities, which led to a drought.

Average Period of Minimum and Maximum Extent in Daberam Reservoir

To examine the observed annual area of water plotted in time series facets to retrieve the year of minimum and maximum extent: To run a cell in the notebook and retrieve when the period of minimum and maximum extent occurred in the area from time series facets.

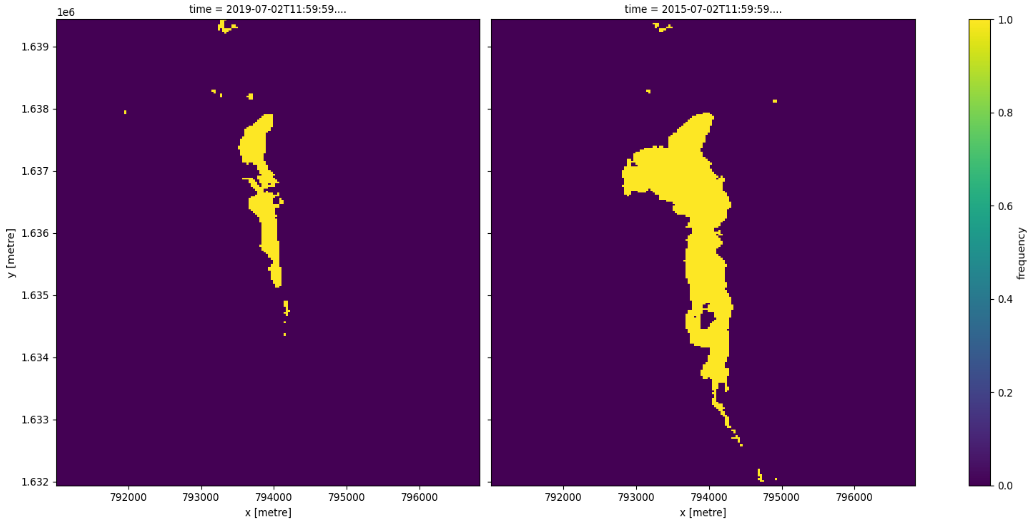

Figure 4: Showing 2019 On The Left as The Year of Minimum Water Extent and 2015 On The Right as The Year of Maximum Water Extent

For the minimum and maximum period of water, 2015 is the period that the Daberam wetland reservoir experienced maximum water extent, as geo-visualised on the right in Figure 4, while 2019 is the period that the Wetland reservoir experienced the highest decline in the extent of the water, as geo-visualised on the left in the above result. This fluctuation in surface water is paramount to crop yield production; thus, unfair and unreliable surface water distribution often results in crop yield reduction and economic damage (Avargani et al., 2022). Likewise, Wu et al. (2021) identified that surface water level fluctuations usually transpire in groundwater table fluctuations in near-bank aquifers. This is because the peak discharge of the near-bank aquifer decreases with the period of surface water level fluctuation (Wu et al., 2021).

Magnitude of the Changes in the Surface Water Extent

To determine the maximum possible area extent and the area loss extent of the surface water: Compare by running another cell, the identified time (i.e., period of minimum and maximum extent), from the time series facets, then calculate and geo-visualise the area of water to water (i.e., Calculated area of water availability in the wetland reservoir throughout the study period); and the area of water to no water (i.e., calculated area of decline in water availability wetland reservoir throughout the study period): This objective was achieved by running a cell which combined the year of highest decline in the water extent (i.e., 2019) and the year of maximum increase in the water extent (i.e., 2015); then calculate the areas.

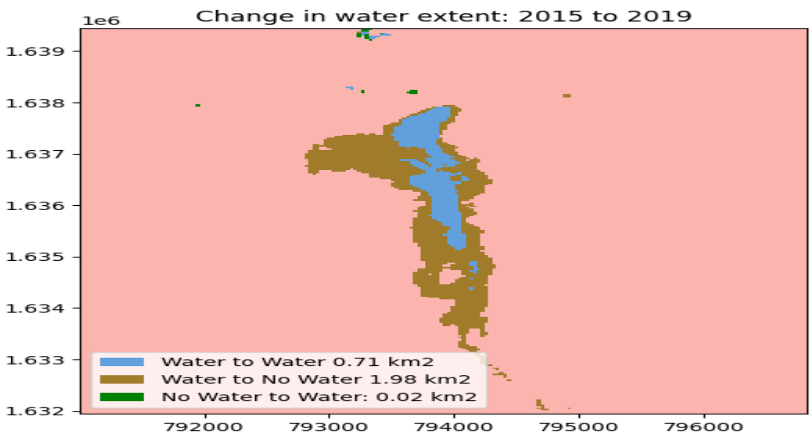

Figure 5: Changes in Water Extent from 2015 To 2019

This shows that the Daberam wetland-reservoir has been extremely affected as the maximum possible area extent of the surface water is 2.69 $km^{2,}$ but experienced an area loss extent of 0.71 km^2. This shows a significant loss of 1.98 km^2. This translates to a decrease of over 65% of the surface water area extent, which is the highest in the Daberam wetland reservoir throughout the 12-year study period. Therefore, this decrease in the water extent is going to seriously affect irrigation and other socio-economic activities in the area, as the Daberam wetland reservoir proves to be among the major contributors of vegetables and fish supply in Katsina State and other neighbouring states such as Kaduna.

Furthermore, this decrease in the surface water extent confirms the effect of drought and other climate-related problems. Palazzoli et al. (2022) established that a high frequency of surface water loss is found to be influenced by climatic conditions, with more widely distributed losses in arid regions with respect to temperate and continental climates. Also, Haruna et al. (2025) reported that in Nigeria, there is a decrease in rainfall (about 90 mm), while temperature increased (about 0.8 °C) since 1960. This has led to increased water stress, resulting in the drying up of water bodies such as rivers, wetland reservoirs, and lakes, thereby affecting many agricultural and socio-economic activities (Abubakar & Abdussalam, 2024).

Discussion

Surface water extent at Daberam Wetland Reservoir (2010–2021) showed significant inter-annual variability instead of a straightforward monotonic drop, according to the time-series study. Significant negative abnormalities were noted in 2013–2014, 2017–2018, and 2019–2020, while significant positive anomalies were noted in 2010–2011, 2011–2012, 2014–2016, and 2020–2021. The paired year comparison between 2015 and 2019 shows a loss of 0.71 km² from the maximum extent of 2.69 km², or about 65% of the surface area between the chosen extremes. This represents a significant short-term contraction with obvious effects on local livelihoods, irrigation, and fisheries.

In dry and semi-arid locations, remote sensing investigations frequently record significant temporal fluctuation in wetlands and tiny reservoirs (Roy et al., 2025). Surface water extent is highly seasonal and sensitive to long-term variations that vary by region and driver (human vs. climate), according to global assessments (Atashi et al., 2023). Global and regional findings that highlight the dynamic behavior of surface water resources under combined climatic and anthropogenic influences are consistent with the observed pattern, which shows sporadic big rises and drops rather than a constant decline.

According to Bello and Sani (2021), Goronyo Reservoir in Sokoto state has been steadily declining, whereas Daberam exhibits interannual variations with periods of significant losses. Reservoirs vary in catchment hydrology, management (release and abstraction regimes), sedimentation rates, and upstream water usage; therefore, these variations are to be expected (Salwey et al., 2023). As a result, not all reservoirs in the same nation will exhibit the same patterns. Satellite trends can have their sign and magnitude reversed by local management and catchment factors.

One of the main causes of varying reservoir extents in semi-arid regions is climatic variability, which includes interannual rainfall variability and evapotranspiration anomalies (Bello et al., 2025b). By decreasing inflows and increasing evaporative losses, long-term changes in precipitation and temperature change the water balance. National evaluations in Nigeria show long-term decreases in rainfall and warming trends that will worsen reservoir shrinkage and drought risk (Bello et al., 2026; Sadiq et al., 2023). The noticeable negative anomalies that you see in certain years (like 2019) are consistent with these climatic trends.

Surface water loss can be accelerated or its spatial distribution altered by anthropogenic influences such as catchment urbanization, reservoir operation (release rules), changes in upstream land use, and enhanced abstraction for irrigation (Chaemiso et al., 2021). Recent research indicates that the frequency of surface water loss is higher in arid regions and close to growing metropolitan areas, and that human activities can still have a significant local influence even in locations with slower climate change (Ahmed et al., 2024). Therefore, a combination of increased local water demands, upstream land-use change, and climate stress is probably responsible for the Daberam losses.

Changes in near-bank groundwater dynamics are frequently correlated with variations in surface water extent (Irvine et al., 2024). Reduced surface water levels lead to equivalent decreases in near-bank groundwater peaks and can alter the recharge regime, which impacts shallow wells and riparian water availability, according to studies of managed aquifer recharge and river–aquifer systems. The anticipated groundwater reaction thus supports your finding that surface water variability endangers irrigation and livelihoods; extended low surface extent years (e.g., 2019) may result in decreased local water tables and decreased irrigation dependability.

A contraction of more than 65% (comparing 2015 to 2019) is a socioeconomic shock for populations that depend on fish and vegetables, as well as an ecological shock for habitats that depend on wetlands. Smallholders' access to irrigation water will be limited, habitat and fishable area will be diminished, and they may be forced to switch to other, frequently unsustainable water sources (Lawal et al., 2020). When there are ongoing losses, studies of reservoir and wetland dynamics highlight the effects on downstream and local livelihoods.

LIMITATION

This study has a few limitations. First, categorization criteria, seasonal phenology, turbidity, and cloud cover can all have an impact on area estimations generated from satellites. While they are helpful, multi-year composites and quality masks (cloud and shadow filters) cannot eliminate ambiguity. Secondly, using surface area time series alone to attribute causes (climate vs. anthropogenic) is intrinsically limited; combined with in-situ hydrometeorological records (precipitation, reservoir inflows/outflows, abstractions), and catchment land-use/management data, remote sensing provides robust attribution. Lastly, the area changes to volume change (and the resulting influence on the water supply) must be approximated because reservoir bathymetry and stage–area connections were not accessible.

CONCLUSION

The research concluded that the Daberam wetland reservoir has severely dried up, as proven by the research results. Furthermore, the researcher asserted that the drying up is mainly caused by the impact of climate change. This is because, since the 1960s, Nigeria has been experiencing an increase in temperature and a decrease in rainfall (Haruna et al., 2025). This have led to increased water stress resulting in the drying up of water bodies such as wetland-reservoirs, lakes, and rivers (Eze et al., 2022). This was also proven by the result obtained in the fifth objective, which shows that there is a decrease of over 65% in the water extent in the Daberam wetland reservoir, i.e., from 2.69 km^2 to 0.71 km^2.

The study recommended that water extraction from the Daberam Wetland Reservoir for irrigation and other activities should be regulated. Encroachment on the floodplains of the reservoir should be discouraged. Additionally, the Katsina State Government should declare a state of emergency on the Daberam wetland reservoirs and initiate a rehabilitation project. Further research should focus on exploring the spatiotemporal dynamics of the water extent in comparison to the land surface temperature in the Daberam wetland reservoir area from 2011 to 2020.

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