

Dams and Sustainable Development Goals: A Vital Interplay for Sustainability

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Abstract
The dawn of civilization has seen more advancements in numbers and technology of dam across the globe than any other. The reservoir has been a decent source of water for domestic, industrial, recreational and agricultural usage. The failure of any dam structure has diverse ramifications on the natural environment and biodiversity. This work studied the role of dam in the realization of the sustainability agenda of the United Nations. The seventeen (17) Sustainable Development Goals (SDGs) are linked to the proper functioning of dams as a source of municipal and rural water supply. Effect of climate change on dam, its failures and operational impact on agriculture and biotic and abiotic ecosystem were also considered. It was noted that the interaction between this water source and SDGs are direct and indirect, positive and negative. The conclusion drawn was that water structure such as dams has main roles to play in sustainability and many of the SDGs can be achieved by functional water system at all levels. Developing good maintenance culture is essential.
Keywords: *Biodiversity, Climate Change, Dam, GHG, Reservoir, Sustainability, SDGs, Water*

1.0 Introduction

Dam and the resulted reservoir remain one of the earliest man-made structure, an engineering grandeur for over three millennia. The Egyptians and the Assyrians were believed to be the first architect of this water structure. For instance, the Assyrians built many water structures in around 1500 BC across river Euphrates and Tigris. Sadd-el-kafara dam constructed in ancient Egypt was believed to be almost 300 years old holding the Nile River waters which drive the economy of the North African nation. Babylonia and Persians were also recorded to have built earth dams around the 1000 BC. The relics of earth embankment built for diverting water to large community reservoirs still scatters across Israel and some Middle East countries (McCully, 1996). The Ancient built dam due to purposes ranging from water diversion to irrigation (Schnitter, 1994). The Scripture recorded how the Persians built a small diversion dam across Tigris during the battle to take the City of Babylon about 3000 years ago. The Greek's prominence in water structure is exemplary while Roman Empire advanced the techniques of dam and reservoir construction using materials such as earth, and mortars. However, after the fall of the Roman Empire, the act of building dams hardly advanced until the end of the 16th century, the construction of dams of appreciable heights and storage capacity became possible after the development of cement concrete and the mechanization of earth-moving and material-handling equipment (Uyigue, 2006).
By the middle of 19th century, about 5000 large dams had been built across the globe, three-quarter of them in industrialized countries. This figure has increased to over 45,000 large dams in over 140 countries of the world before the end of last millennium (ICOLD, 1998). Water impounded are now been used to drive turbines to generate power. In Nigeria, over 323 dams have been constructed (Uyigue, 2006).

1.1 Water and Sustainable Development

Water resources management and service are essential for sustainable development. Goal 6 of United Nations' Sustainable Development Goals (SDGs) focuses on the significance of water supply. A reservoir is a major source of water in every part world. The essentiality of the dam for SDGs cannot be overemphasized (ICSU and ISSC, 2015). Abdullateef and Ifabiyi (2012) suggested that overall sustainability rests on the excellent relationship between three dimensions of sustainability namely: social, economy and the environment. Water is a factor for economic development at all levels and for all users (Goal 1) and global needs are not showing any sign of plummeting due to population growth. Seasonal variation as a result of climate change has led to water scarcity globally especially in developing and underdeveloped world. For instance, in Nigeria, Figure 1 - 3 reveals almost 10 percent of the population depend directly on the surface water and many are still without adequate access to improved water sources. Women and children, who most time are saddled with responsibilities of getting water are consumed in water-stress. Relieving the burden of women in many countries who spend excessive time accessing safe water for their families can be achieved with dam construction (Goal 5).

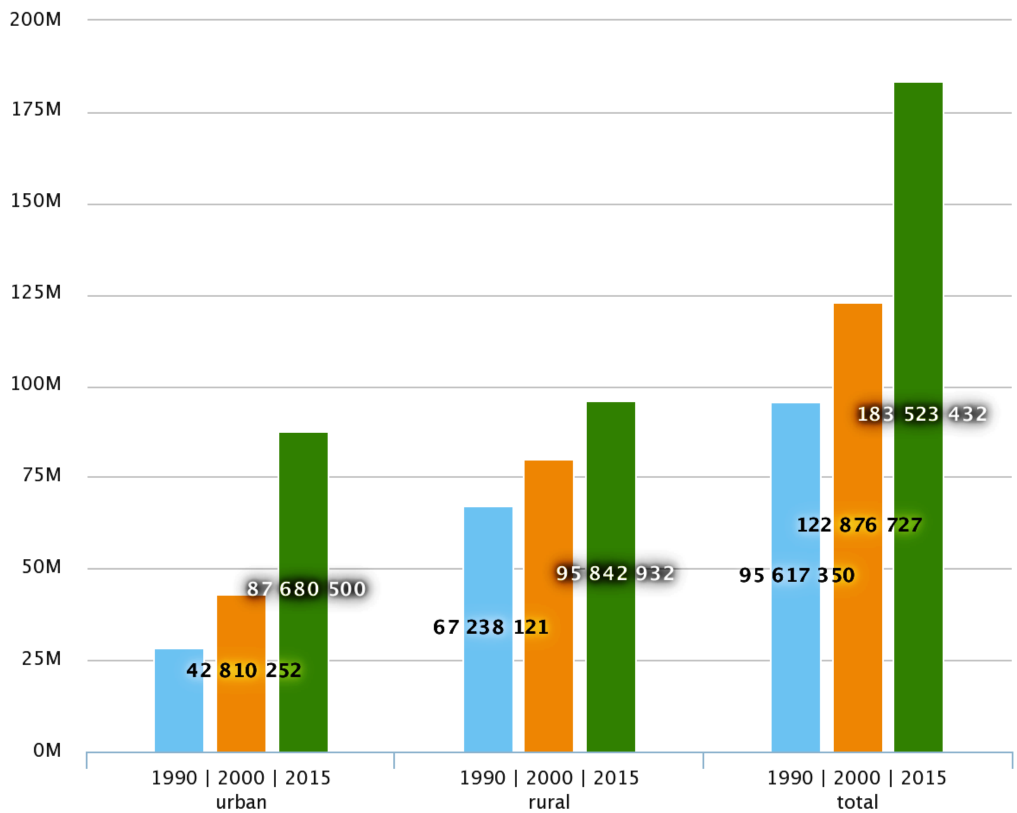


Figure 1:Population in Nigeria 1990-2000-2015

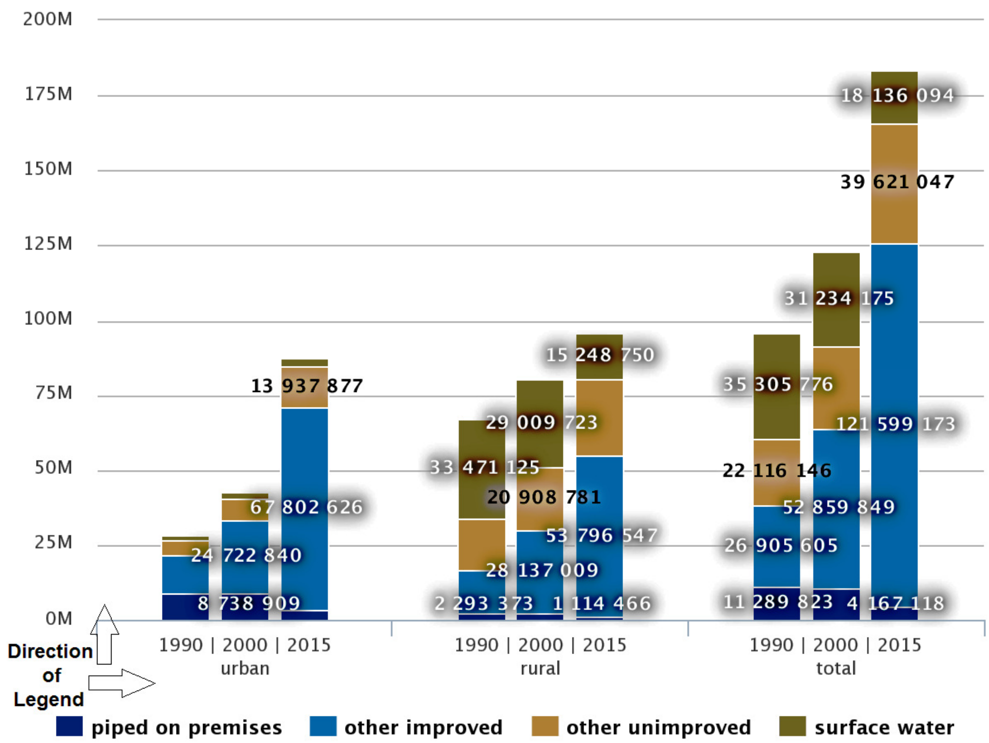


Figure 2: Population with access to drinking water in Nigeria 1990-2000-2015

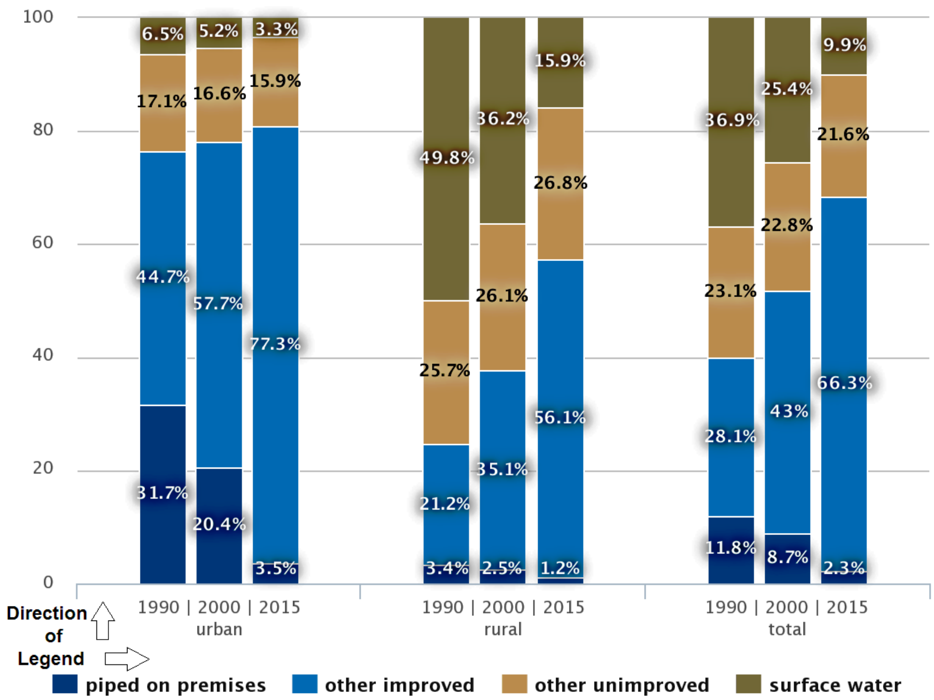


Figure 3:Percentage of population with access to drinking water in Nigeria 1990-2000-2015

2.0 Operations and Purpose

The three largest dam in Nigeria (Jebba, Kainji on River Niger and Shiroro on River Kaduna) has prime purposes of hydropower generation and irrigation. Some other dams in Nigeria are the Ede-Erinle reservoir (Osun State), Bakolori and Goronyo dam in Sokoto (Figure 4), Tiga dam and Challawa Gorge in Kano state (Figure 5), Oyan river dam and Asejire dam in Oyo State. Katsina States' Jibiya dam supplies 142 million m^3 of water for municipal use and irrigation. The water from the dams is essential to increase agricultural productivity and industrial food processing (Goal 2), its availability enhances better production practices (Goal 12). In addition, Dadin Kowa dam with 2,800 million m^3 capacity is located in Gombe State, while Kiri dam (Adamawa State) covered 11,500 hectares and has 615 million m^3 capacity. In addition to Jibiya dam, Katsina State has Zobe Dam (177 million m^3) for water supply, fishing and agricultural purpose.

Figure 4: Catchment map of Sokoto basin showing Bakolori and Goronya dam (Kmusser, 2010)

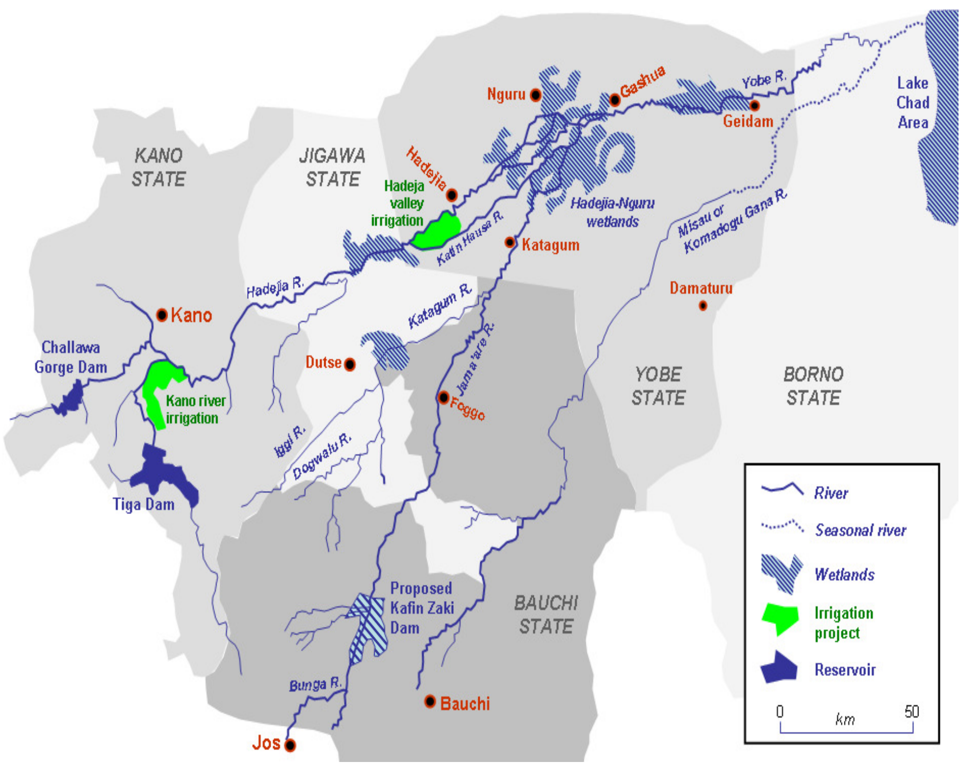


Figure 5:Tiga dam and Challawa Gorge in Kano state

2.1 Kainji Dam

Kainji dam, the largest dam in Nigeria situated in 09°51′45″N, 04°36′48″E was commissioned four years after independence with an estimated construction cost of US$209 million (US$2.8 billion - 2015 estimate). It impounds Niger River in the central part of Niger state. Its primary section is over half a kilometre although the dam extends for over 9 km in length and 65m in height with spillways. The structure was basically constructed of earthen materials and concretes. The crest extends a few meters with the main power generation section. The lake created by the dam extends about 135 km long and about 30 km at its widest point and supports irrigation and a local fishing industry (Uyigue, 2006). The power generated can reach 960 megawatts when the conditions are favourable. In view of its enormous size and operational capacity, it contributes more environmentally induced problems than other dams in the country.

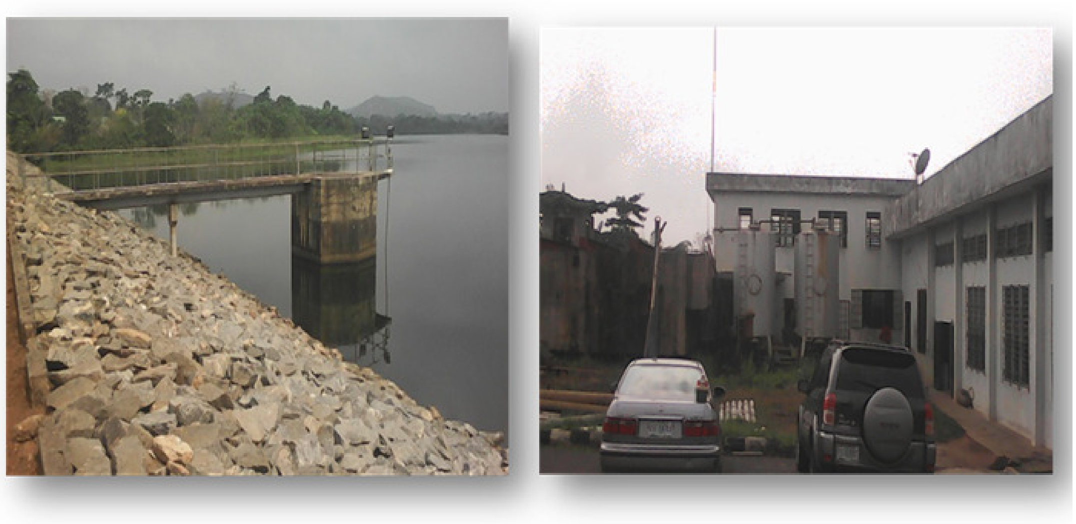
2.2 Shiroro Dam

Shiroro dam is sited in Niger State. It is located at latitude 9^o 58` 25`` N and longitude 6$^o$ 50` 6`` E and remains the third largest in the country. The reservoir covers 31,000 hectares compared to 130,000 hectares of Kanji dam. The rock fill dam has height of 115 m, over 650 m crest length, and 7 m width. It is primarily for hydropower, generating 600 megawatts when working at peak (Goal 7), water is also critical for most other forms of energy production. Abdullateef and Ifabiyi (2012) reported that the hydrological analysis of Shiroro dam operational data from 1990 to 2007 revealed a very high correlation between power generated and the inflows and turbine discharge. High discharge rate during the rainy season makes the turbine to function optimally bar other technical deficiency in the system. The analysis nonetheless, shows a poor correlation with energy produced and inflows data examined. This was deemed to be an indication that operation of the reservoir has not been consistent over the years suggesting that water in the reservoir has been grossly underutilized thus discharge through the spillways without serving the primary purpose. Another reason for this poor correlation is the availability of dead storage in some sections of the reservoir due to perpetual disturbance from upstream. Shiroro is situated just 550 m downstream of the major confluence of Kaduna River. Just like many other dams, Shiroro serves recreation, irrigation, research and developmental purpose thus promoting inclusive societies (Goal 16).

2.3 Opa Dam

Opa River is a non-perennial stream which flows within Ile-Ife, Nigeria, it has an earth dam constructed across. It flows through Obafemi Awolowo University (OAU) and many parts of Ile-Ife community. It is the only source of supply that could reasonably and feasibly be developed for the university's water consumption; hence, the waterworks on the campus takes its name after this stream Opa waterworks (Ogedengbe, 2001). According to Oke (2010), the earth structure has a capacity of 2.9 million m^3 and a depth of 8 m. It drains an area (catchment area) of 166 km^2. Figures 6 and 7 show some section of the dam as at February 2017. The dimension of the Opa earth dam is originally adequate for the campus because dry season is for a period fewer than 6 months (Akintola, 1980). The intake units (Figure 6b) is located perpendicular to the earth dam. It is protected intakes that consist of the opening, strainer or grating through which the water enters and the conduit conveying the water, usually by gravity to a well or sump. Water travels from there by gravity through the pipes to the treatment plant. The location of the intake is such that there is adequate flow at minimum cost of operation. Activities at the upstream of Opa dam results in deposition of debris and silts as flood carrying particles are not properly channelled away from the reservoir (Figure 6d). The dam is few kilometres from arable and residential areas which makes pollution of the stream inevitable. Eutrophication is typical of the various parts of the river especially close to the embankment (Figure 6c).

(a) **(c)**



(b) **(d)**

Figure 6: Opa dam and treatment (a) side of crest (b) intake structure (c) eutrophication at the extreme side of the impounded water (d) Opa water treatment building.

(a) (c)

(b) (d)

Figure 7: Different section of the dams (a) the crest, (b) side view of the spillway, (c) and (d) section of spillway with debris from upstream.

3.0 The Environment and Dam

Dam or its reservoir has momentous and unavoidable environmental impacts. The effect on man-made, natural ecosystems, climate and general hydrology of the area is significant. For instance, Zobe earth fill Dam in Katsina State in northern Nigeria has been a double edge sword to the resident. Water structures disaster reduce opportunities for development and on the other hand, unavailability of appropriate water source is a violation of basic human right (Goal 10). Ojirami dam located Edo State, Shiroro Dam and many dams had an indelible impact on the ecosystem, upstream and downstream.

3.1 Climate Change

Climate change affects sustainable water and sanitation development. The effect of climate change has been grossly felt in sub-Sahara Africa and Nigeria is not left out. In the early 1970s, climate change affected most of Nigeria's environment with intense drought, especially in the Chad basin. This challenges prompted construction of more water retaining structures. Infrastructure such as dam is necessary for flood and drought protection and water management (Goal 9). According to Imevbore *et al.* (1986), reservoirs were able to provide sufficient water for irrigation farming thus making food production possible all year round. Many river basin authorities came up during this period to manage the watersheds. Abdullateef and Ifabiyi (2012) reported that dam construction in Nigeria is given so much of structural or engineering consideration with an inadequate post-deployment environmental impact assessment. The authors opined that any water impoundment has the tendency to create both negative and positive effects on the environment, ranging from the resettlement problems to flooding, destruction of flora, fauna, loss of farmlands and fish species, and exposure to diseases. Climate change affects the quality and quantity of water that can be dammed while adaptation to climate change requires investment in resilient infrastructure such as dams and reservoirs (Goal 13).

3.2 Agriculture

The impact can be economical, chemical and physical. Many towns and villages downstream of dams often experience low base flow because the water is withheld. Asejire reservoir in Oyo State has surface area 2,369 hectares supplies water to local and urban centres of the state. A little allowance is given for base flow downstream which are often not enough for crop and fishery especially during dry season when the seasonal effect is at its peak. The low volume of water release limits agricultural productivity and impact the economy of people downstream who are mostly dependent on the river for production all year round. The downstream floodplain farmers required large-scale water release before the growing season, with diminished flows later as they practised flood recession agriculture (Adams, 1993). According to Scudder, (2005, 1994) operators may not sensitive to this need, thus releasing insufficient water as base flow. Moreover, dam construction and operations can impact ancestral heritage sites (Inskeep, 2000; Gwala, 2000; Hassan, 2000).

3.3 Greenhouse Gases (GHG) Emissions

World Commission on Dams on dams estimate in 2000 suggests that the gross emissions from reservoirs may account for between 1% and 28% of the global warming potential of GHG emissions. This challenge the conventional ideal that hydropower produces only positive atmospheric effects, a reduction in emissions of carbon dioxide, nitrous oxides, sulphuric oxides and particulate when compared with other power generation sources that burn fossil fuels (Bosi, 2000). It implies that all reservoirs emit GHG (Uyigue, 2006). The positive environmental influence is that these emissions are infinitesimal and not toxic compared to other sources of energy (nuclear, fossil). Moreover, the development of dam and reservoir involves ecological destruction. This directly constitutes global warming. According to Yahaya (2002), construction of the dam, with land levelling, clearing and canal construction destroyed valuable farmland and trees. Trees serve as the lung of the planet and the deforestation releases CO_2 trapped within the trees into the atmosphere. Dams its holding reservoirs can enhance air quality and help shifts attention away from non-renewable fossil fuel resources. Better air quality is pivotal for life as clean and treated water from the dam is essential for human health (Goal 3). Non-production of any lethal waste does not make dam a renewable source of energy because of these minuscule GHGs emissions capacity (Louis *et al.,* 2003). Likewise, anaerobic decomposition of vegetation on the reservoir produces greenhouse gases with a high cost of cleaning up (Berkamp *et al.,* 2000).

3.4 Loss of Biodiversity

Dams whether during the project implementation or any subsequent failure has led to the loss or extinction of aquatic biodiversity, damage to forestry and wildlife habitat and species population in the ecosystem (Goal 15). For instance, during construction of Oyan dam in Ogun State, south-west Nigeria, over 20 villages were submerged, with the displaced people moving to settlement and camp. These made education more difficult as Internally Displace People (IDP) especially children were not able to gain access to school (Goal 4). Fishing would also not be protuberant as certain inhabitant fish in the river along the fertile shoreline recedes in the dry season (Kenweirwe *et al.,* 2007). Correspondingly, a dam would disrupt the life of many terrestrial animals which survived the deluge. The World Commission on Dams reported that the construction of storage dam and the subsequent inundation of the reservoir area effectively destroy terrestrial plants, forest and displace animals. The change in the natural composition of the water can also lead to an extinction of marine species due to ecological imbalance thus disruption of the intricate food web. Berkamp *et al.* (2000) affirm that the impact of dams on freshwater species is significant. The authors added that global estimates of endangered freshwater fish reached 30% of a known species. Nehlsen *et al.* (1991) reported that 67% of freshwater mussels are vulnerable to extinction or are already extinct, 40% of amphibians are imperilled or vulnerable and almost half of any fishes are vulnerable daily due to anthropogenic activities directly or otherwise.

More so, Reizer (1988) estimated that 11250 tonnes of fish per year from the Senegal river system is lost due to dam. Impounding fish and other aquatic life movement by dam and reservoir is also a major concern in Nigeria. Many other ecological effect of dam has been carried out. Baskaya *et al.* (2007) investigated effect of small dam on the environment in Turkey, and Abdullateef and Ifabiyi (2012), operational impact of Shiroro dam. Access roads to dam sites can also cause a significant direct impact on natural ecosystems, while also providing access to previously remote areas for settlers and hunters. Blasting at construction sites is a major source of disturbance in particular during certain times of the life cycles of animals.

3.5 Dam Maintenance

World Bank (2014) reported that dams and reservoirs are large, multi-purpose public assets for which public funds are needed to maintain. Public funding for construction, operation, and maintenance is necessary for irrigation canals. A dam can help in reducing fluvial erosion along watercourse. Moreover, conservation and sustainable use the oceans, seas and marine resources can be achieved by building embankment across watercourse (Goal 14). Therefore, management strategies to reduce pollution must be put in place. This is to assure safety for the downstream populations and also safeguard the aquatic lives. Dams fail due majorly to human errors such as inadequate preliminary study on proposed construction site, discrepancies in the design, poor engineering applications during construction, absence of qualified dam safety monitoring personnel on site and bad maintenance culture (Umaru *et al.,* 2010). Despite the increasing safety of dams due to improved engineering knowledge and better construction quality, a full non-risk guarantee is not possible and an accident can occur, triggered by natural hazards, human actions, construction deficiencies and age of the structure (Umaru *et al.,* 2015). Dam failures has had grave environmental impact on the people and other biodiversity. Hydraulic, seepage and structural failure was responsible for failure of Cham dam in Gombe State which failed just 6 years after commissioning. Sherard *et al.* (1963), Burland (2006) and Punmia and Lal, (1992) suggested that failure in earth dams can be hydraulic - 40%, seepage - 30% and 30% structural. Natural disaster like earthquake and secondary effect of climate change can also immensely contribute to dam failure. Arora (2001) attributed 7% to natural disaster while the bulk of the failures were attributed to seepage, sliding, structural, overturning and overtopping as in case of Bagauda (Nigeria) embankment which failed after 18 years. Nigeria is free from faults that could trigger major earthquake in unforeseeable future thus dam failures can be greatly minimized. The failures above majorly occurs during design and construction stage then became obvious during operations. However, 1980 failure of Ojirami dam, across River Onyami which flows into River Ose in Edo state was purely due to operational maintenance. The dam failed just 6 years after many parts of the malfunctioning dam reached a crescendo. Opa dam in Ile Ife, Osun State struggles to serves the principal purpose of water supply to the campus community because of the dead storage has increased. Floating materials and silts also deposit at the spillway to reduce the storage capacity of the dam. Lack of periodic maintenance coupled with seasonal fluctuations and population growth is responsible for the inadequacy.

3.6 Dam Decommissioning and River Restoration

There is not enough data to support dam decommissioning and river restoration in Nigeria. Research has been silent about the aspect of its ecological impact. However, many dam failure has been indirectly responsible for unofficial decommissioning of such. The cost of repairing a dam is often significantly greater than the cost of removal. Therefore, dam are removed by erosion of the dilapidated structure through the river course. Studies on the environmental impact associated with dam removal is minimal (Berkamp *et al.,* 2000).

The primary concern of dam decommissioning and river restoration is the fate of sediment stored in the reservoir and the successive physical changes in the river channel that occur following removal of the dam. This ecological effect has long-term consequences.

4.0 Conclusion and Recommendation

Dams have major roles to play in sustainability. Many of the SDGs can be achieved by proper and functional water systems at all levels. Nonetheless, improper construction and poor attitude to maintenance from the general public and the policymakers could debar the attainment of these goals by 2030. There has been lack of timely and formal maintenance policy which institutionalizes maintenance with financial backing. The following recommendations are made:

- environmental impact assessment (EIA), soil and a material test should be made compulsory for all residential, industrial, institutional, and commercial water structures including dams and reservoirs so that their huge roles in the actualization of the SDGs are intact. Good water facilitates is pivotal to economic and also essential for development (Goal 8);
- in addition, all professionals in engineering should play key roles to actualize their respective obligations during construction and maintenance of water structures so as to maximize its ability to provide food, water and energy. Sustainable water infrastructure would go a long way to enhance water use efficiency (Goal 6);

- appropriate and timely maintenance should be practised on various water structure in the country. The maintenance activities must well be planned and adequately funded. Water services (water supply and sanitation) must also be a central part of urban planning and development. Water infrastructure determines the sustainable use of other resources (Goal 11).
- without the implementation of sustainable infrastructural development for water, sustainable development in many other sectors would fail (Goal 17).

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