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A Review on Dam Engineering Practice and Sustainability in Nigeria

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ABSTRACT

This study focuses on dam structures in Nigeria, its availability, features, usefulness, benefits and costs, functionality and sustainability. The gap found in World Commission on Dams (WCD) Report on Dam Development being inability to proffer solutions to problems encountered by the downstream population was highlighted and discussed also. The procedure for this research work involved use of journals, books and other related literature. It was observed that many dam projects in Nigeria are lacking in areas of feasibility studies, design and construction procedure, operation and maintenance, which resulted to dam related problems like flooding and sometimes collapse of some dams. Downstream population rather than reaping abundant dam benefits record costs since their means of livelihood is hampered, affecting their social, environmental and economic well-being. This study observed that Nigeria has large, medium and small dams which are also single and multipurpose. Environmental Impact Assessment (EIA) is recommended for each dam project and a committee should be set-up to monitor its implementation to the later, from inception to end of the project for its sustainability. This paper recommends fresh attention to dam impacts on upstream and downstream population to enable them benefit immensely from these river valley projects.

Keywords: Dam Engineering, World Commission on Dams, Benefits and Costs, Downstream, Environmental Impact Assessment, Sustainability.

INTRODUCTION

Development of water resources is paramount for socio-economic advancement of all nations of the world. Water being a vital natural resource forms regional landscapes and is important for the working of the ecosystem and comfort of humans (Adebayo, 2013). Dams are constructed to form reservoirs by obstructing natural flow of water (Bilyaminu, et al. 2019). They are gigantic structures built across rivers to serve as barriers to water flow aimed at impounding water for various water uses including water supply, storage, hydro power development, irrigated agriculture, navigation, flood mitigation and control, tourism and sanitation, wild life development, groundwater recharge, among others. Interestingly, the duties of a dam engineer have changed over the years. Emerging technologies have resulted to remarkable improvement in the investigation, design, analysis, monitoring of dam projects. Dams are large, medium or small based on the International Committee on Large Dams (ICOLD) criteria for classifying dams (McCartney et al, 2001). The dam categories and types are according to construction material, sizes, and purpose. Most dams in Nigeria are housed in Northern Nigeria to serve for mostly hydropower supply and irrigated agriculture (Obialo, 2020).

It is evident that Nigeria has potentials for water resources development in view of its numerous rivers and streams in different parts of the country. Nigeria houses over eighty (80) major rivers (See Figure 1). Factually, rivers Niger and Benue are the largest rivers in Nigeria. The world has been witnessing many problems arising from the construction of dams including flooding, displacement of dam communities and their losing of their means of livelihood, dam failures, among others. The World Commssion on Dams was founded and given the mandate to research the effectiveness of large dams and the social, economic and environmental impacts of these dams globally especially in dam affected communities. This was commissioned in 1997 and they wrapped up their work in 2001 having twelve members drawn from the academia, civil society, professional associations, private sector, and one government representative. In a press conference by Chairman, World Commission on Dams (2000) Report, it was said that currently, 45,000 large dams produced over 19 per cent of the world's electricity, generating about $38 billion in economic activity, also accommodating food

production and other essential activities. Globally, the number of large dams is more than 50,000 (Berga et al., 2006).

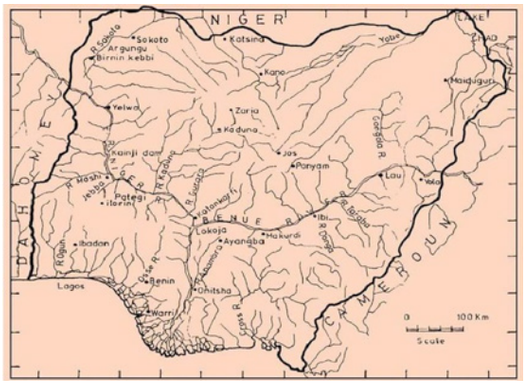

FIGURE 1. Map showing Rivers in Nigeria.
Source: Taiwo et al (2012)

Water as it occurs naturally cannot be put to much use without collecting it in large quantities and sufficient heights. This is made possible by constructing dam structures across rivers. Water can be seen as a resource, flood or as a scarce commodity. As an asset, it is a resource, as a flood it is a threat, and as a scarce commodity it causes drought. Consequently, water can create positive or negative impact on the environment it exists depending on its form or availability.

The objectives of this research work are determining dam structures in Nigeria, their features, purposes, locations and sustainability, operation and maintenance, and problems with downstream population arising from construction of these dams. This work also calls for a further holistic study of dam impacts on downstream populations to go beyond what was done in WCD (2000) report.

Siltation is enemy to dam existence and sustainability. Sediment accumulation in reservoirs depletes its water storage capacity (Ezugwu et al, 2013). Siltation of each dam must be monitored periodically to ensure that life span of dam reservoirs are not impeded. As death is to humans, so is sedimentation to reservoirs (Ezugwu, 2013). All reservoirs must ultimately silt-up. Areas close to dam site should be grassed to reduce erodibility of the soil to curtail siltation and prolong life of reservoirs.

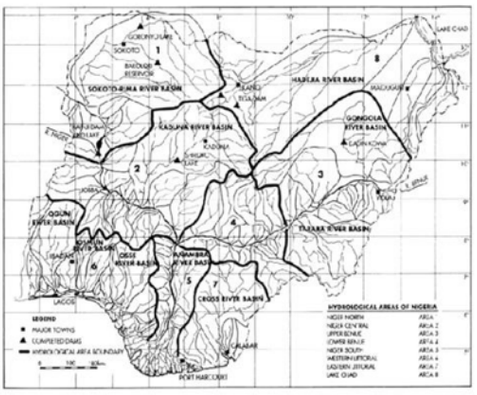

FIGURE 2. Hydrological map of Nigeria showing the large dams and their locations in their respective river basins (Akindele, and Indabawa, 2015).

The hydrological map of Nigeria is also presented here, showing large dams and their locations in their respective river basins (See figure 2). This work suggests that all impacts of dams on communities and ways of mitigating them are to be highlighted in the EIA, and implementation monitored. According to Ezugwu (2013), these impacts include ecological, greenhouse gas emission from reservoirs due to rotten vegetation, alteration of flow regime, biodiversity loss, social impacts, gender-related impacts, cultural heritage, and health-related impacts. The WCD report only focused on physical displacement of people without recourse to the cost of these projects to the downstream communities. It is noteworthy that these projects enrich the urban areas that enjoy the various water uses like water supply, irrigation, hydro power generation, etc., while the downstream population becomes poorer. This river dependent population continues to be impoverished with the construction of more new large dams. This work suggests a review of the WCD 2000 Report to seek ways of improving living conditions of this downstream population. As long as new and existing dam projects continue to make poorer millions of river dependent people downstream, it will be extremely tasking for the world's governments to strive to achieve poverty mitigation targets, including halving number of people that suffer from extreme hunger and poverty by 2015 as spelt out in the Millennium Development Goals (United Nations, 2008).

Environmental Impact Assessment (EIA) of each dam project must be carried out during the planning stage of the project, with all issues addressed holistically and implemented to the later. EIA is aimed at predicting the environmental impacts of the project at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and opinions of decision makers to public domain. This will suggest if the proposed work is worth embarking upon. The social, economic environmental impacts of the project on the host communities are captured and analyzed. Engineers have roles to play in dam planning and development for sustainable development. Engineering education is a driver for sustainable development.

LITERATURE REVIEW

Water which is without doubt the most important natural resource in Nigeria is the most overlooked and ignored natural resource (FMWR, 2016). Improved access to water supply and sanitation remains one of the primary ways of addressing poor health in developing countries (Samuel et al, 2018).

According to Okoye (2004), without water there will be no life and people cannot survive. River systems in Nigeria are to be managed well and be sustainably advanced for increased economic upliftment of the nation (Ezenweani, 2017). In line with climate projections, water resources is seen to be vulnerable and can be influenced in a big way with resultant great consequences on the ecosystem and human population (Oki, 2006; Haddeland, 2013). Development of rivers for construction of large dams is one of the most important and outstanding tools for the management of water resources (Mul et al, 2018). According to Keiser et al (2005), there is in existence 40,000 large dams, 800,000 small dams, whereas 272 million hectares of land have been employed for irrigated agriculture globally. It has been affirmed that man can stay without food for 5weeks but can only survive maximum of 5 days without water. It is the most important raw materials for mankind, called "Liquid Gold" (Olalekan et al, 2019).

According to a study, dams are defined as structures that regulate, store and divert water from rivers (Wong, 2013). Surely, there cannot be life without water. Also, no productive venture can take place on earth without water. Olalekan, 2019 asserts that there will be increase in demand for freshwater globally due to expected rise in global population to about 8 billion by 2023. This is underpinned in United Nations (2015) Sustainable Development Goals (SDGs) no 6, which is access to affordable, reliable and sustainable water for all. It is necessary to strengthen our national capacities towards provision of potable water to enhance sustainable development globally. Water is critical to sustainable development. Man needs about 150 to 300 liters of water every day for domestic purposes such as drinking, cooking, washing utensils, bathing, flushing toilet, air-cooling, gardening, etc (Olalekan et al. 2018). The flow pattern of rivers is altered by construction of dams thereby changing the water quality of the downstream river (Zhao, et al, 2012). Impacts of dams take place at both upstream and downstream ecosystems (Siciliano et al, 2018).

The technology of dam construction in Nigeria is still new (Youdeowei et al, 2019). According to United Nations (2020), by the year 2030 the population of Nigeria will increase to 258 million people using projection of the prevalent 2.33% growth rate. Majority of dams in Nigeria are located in Northern Nigeria for mostly hydropower supply and irrigation uses. As a result of the global issues of climate change and variability, dams are required to supply water to ever increasing population as a result of droughts experienced in most parts of the country (Ojo, et al. 2020). The increase in number of dam construction is essentially as a result of population growth, increase in water consumption, food and energy demands (Chen et al, 2016; Shi et al, 2019). According to UNECE (2020), erosion, water scarcity, reduced quality of water, flooding, reduction in groundwater sources, salt-water intrusion, and droughts are affected by climate change resulting to the vulnerability of communities, living and non-living aspects of the environment. In Nigeria, dam projects are seen as projects for economic empowerment through creation of employment, recreation and tourism areas, fisheries development, improved agriculture all year round, water supply and hydro power development. Dam engineering brings into play multidisciplinary areas, like water resources and environmental engineering, structures, geophysics, aquaculture, etc. Dam projects are very expensive projects that should be undertaken when it is visible that the benefits outweigh the cost. Consequently, engineering cost analysis must be properly carried out before embarking on this highly expensive project. According to Ho et al (2017), gains of dams notwithstanding, in many nations of the world proposals for new dams face great opposition arising from various economic and social arguments arising to oppose its construction. By far, the single most effective dam development strategy for protecting ecological and social values associated with river ecosystems is to avoid constructing dams in the wrong locations (Ledec and Quintero, 2003; Harrison et al., 2007). 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).

METHODOLOGY

The method for this study involves usage of textbooks, journals, internet materials and past works in this area in achieving the objectives of this work.

STUDY AREA

Nigeria is estimated to have a land mass of 923,768 km^2, and found to be located between Latitudes 4° and 14° N and Longitudes 3° and 15°E on the Gulf of Guinea (See figure 3). This signifies about 14% of the total land mass of West Africa.

Nigeria's population, as contained in the Nigeria Water Resources Master plan, stands at 183,523,432 people, and its estimated to rise to 380,394,709 by 2030 (Sola et al, 2020). Nigeria is endowed with huge water resources. Water is central and useful to other sectors of the economy, such as industries, agriculture, livestock farming, water transportation, and hydropower generation.

FIGURE 3. Map of Nigeria showing 36 states Source: Google Images

Nigeria is bounded in the East by Cameroon, in the West by Benin, in the North by Niger, and in the South by Atlantic Ocean.

CLASSIFICATION AND PURPOSE OF DAMS IN NIGERIA

Nigeria has witnessed construction of many dams ranging from large, medium and small dams depending on their heights and reservoir capacities. Large dams are those dams having heights above 15 metres. Moreover, dams not having heights up to 15 metres but has reservoir capacities up to 3,000 km^3 are considered to be large dams. Medium dams are those with heights from 10 metres to 15 metres. Small dams are those that are of heights from 0 – 5 metres. World dam construction countries in terms of number of dams constructed include China, United States of America, India, and Brazil. Large dams are those having heights up to or greater than 15 metres. Other hydraulic structures apart from dams include barrages, spillways and weirs. Dams can be classified as earthen dams, rock fill dams, concrete dams, arch dams, timber dams, steel dams, etc.

Dams are also classified as single purpose or multi-purpose. Table 1 summarizes the constructed dams in Nigeria with detailed information such as river, location, date built and its purpose.

TABLE 1. List of Dams/Reservoirs in Nigeria, Locations and Functionality

S/N	Dam	River built on	Location	Date built	Purpose/Function
1.	Kainji Dam	River Niger	Niger State	1964-1968	Hydro Electric Power, Irrigation
2.	Jebba Dam	River Niger	Niger State	1985	Hydro Electric Power, Irrigation
3.	Shiroro Dam	Kaduna River	Niger State	1990	Hydro Electric Power, Irrigation
4.	Asejire Dam Reservoir	Osun River	Oyo State	1960s	Water Supply
5.	Bakolori Dam	Sokoto Niger	Sokoto State	1978-1981	Irrigation
6.	Challawa Gorge Dam	Kano River	Kano State	1990-1992	Hydro Electric Power
7.	Dadin Kowa Dam	Gongola River	Gombe State	1984	Irrigation, water supply & Hydro Electric Power
8.	Goronyo Dam	Rima River	Sokoto State	1992	Flood Control
9.	Gusau Dam	Sokoto River	Zamfara State		Water Supply
10.	Ikere Gorge Dam	Ogun River	Oyo State	1983	Hydro Electric Power, Irrigation & Water Supply
11.	Jibiya Dam		Katsina State	1987-1989	Irrigation, Water Supply
12.	Kafin Zaki Proposed Dam	Jama'are River	Bauchi State		Irrigation, Hydro Electric Power
13.	Kiri Dam	Gongola River	Adamawa State	1982	Irrigation & Water Supply
14.	Mambilla Dam	Donga River	Taraba State	-	Hydro Electric Power
15.	Obudu Dam	Cross River	Cross River State	1999	Irrigation, Tourism, fishing, other recreational facilities

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16.	Oyan River Dam	Oyan River	Ogun State	1983	Water Supply, Irrigation, Hydro Electric Power
17.	Tiger Dam	Kano River	Kano State	1971-1974	Irrigation
18.	Zawo Polder (Dam) Project	Rima River	Kebbi State		Irrigation
19.	Zobe Dam		Katsina State	1983	Water Supply, Irrigation, Hydro Electric Power
20.	Ikpoba River Dam Reservoir	Ikpoba River	Edo State		Water Supply, Hydro Electric Power
21.	Tura Dam		Katsina State		Water Supply

Most dams in Nigeria are designed and constructed for multi-purpose while some are for Single-purpose. Multi-purpose dams are most preferred due to economics of scale. Some of them also operate as Multi-objective dams, where they practically derive benefits from other uses not in the original design. Tura Dam in Kankara Local Government area in Katsina State and Shiroro Dam in Niger State are all single-purpose dams. Shiroro Dam is for hydroelectric power generation while Tura Dam is built for water supply.

Nigeria was divided into eleven (11) River Basin (RB) areas/authorities, all to be controlled by the Federal Ministry of Water Resources. Each of these RBS is charged with different functions, including water supply provision, irrigation, among others. In Ogun-Oshun River Basin in the South western Nigeria we have Ikere-Gorge, Egbe, Asejire, Erinle, Eleyele, Ejigbo, Erelu, Oyan, and Ero dams. The Kafin Zaki Dam, the Challawa Gorge Dam, and the Tiga Dam, are located in the Hadejia – Jama' River Basin in Northern Nigeria. Kainji, Shiroro, and Jebba dams are domicile in the Niger Basin.

The Sokoto-Rima Basin Development Authority in Northern Nigeria houses the Bakolori dam. Remarkably, Nigeria has recorded a lot of successes in river-valley projects. We have Kainji, Jebba and Shiroro dams in Nigeria, generating electricity for most major cities in Nigeria. Kainji dam was designed to generate electricity with capacity of 960 megawatts. The length of the dam is 135 km and 30 km wide at its widest section. It functions as a multi- objective dam, being used for local fishing also (Awomeso et al, 2009). It is used successfully for irrigated agriculture and fish farming. This has helped in no small measure in the area of poverty alleviation, food production and fish farming. The Bakolori dam has a design capacity to irrigate 35,000 hectares of farmland, Challawa 40,000 hectares, Tiga 20,000 hectares and Kafin-zaki dam 125,000 hectares.

The costs arising from dam construction in Nigeria have been enormous – including environmental, social and economic costs especially to downstream populations. These negative impacts from dams include loss of lives, displacement of communities, loss of cultural heritage, destruction of villages arising from dam failures, among others (Ezugwu, 2013). Nigeria experienced some dam disasters in Nigeria including Obudu dam's spillway was destroyed by flood in 2013, flooding in Shiroro dam in same 2003, Guasu dam failed in 2006, Warawa dam in Kano failed in 2012, Igabi dam failure, among others (Ezugwu, 2013). Globally, dams are instruments for sustainable development.

NIGERIAN DAMS SUSTAINABILITY

Sustainability seeks human-ecosystem equilibrium, comprising of three pillars – environmental, social and economic (Jeronen, 2013). According to Brundtland Report (1987), sustainable development is development that meets the need of the present without comprising the ability of future generations to meet their needs." In line with global practice, United Nations pursues a set of seventeen (17) sustainable development goals Agenda (United Nations, 2019). Water is central to all these SDGs, thereby making it a necessity to prioritize water resources development through dams. Hence, dams are essential for the realization of all goals of the SDGs since none of these goals can be realized without water directly or indirectly. The major problem with water on earth is that it is not found in sufficient quantities at places they are available, and not evenly distributed. According to Oyekanmi and Mbossoh (2018), seasonal variation as a result of climate change has led to water scarcity globally especially in developing and underdeveloped world. Water stress is borne by women and children being responsible for getting water at most times. Dam reservoir infrastructure aims at bringing this water in sufficient amount in a location, then used for different purposes including electricity generation, water supply, wild life development, flood attenuation, erosion control, recreation and sanitation, navigation and groundwater recharge. Global population is on the increase and there is need to harness more and more water and energy through construction of dams for sustainable development. The importance of dams for SDGs cannot be overemphasized (ICSU and ISSC, 2015). Dams are necessary in other to actualize SDG no 6, which is availability of clean water for all.

Consequently, there is need to harness enough water to carter for this ever growing population. Greatest dams in the world are mostly used for food production (Boye and Vivo, 2016). Abdullateef and Ifabiyi (2012) suggested that overall sustainability rests on the excellent relationship

between three dimensions of sustainability namely: social, economy and the environment. Renewable energy is a sustainable energy alternative as against fossil fuel which is depleted as it is being used. The world is shifting from these CO_2 emitting resources (hydrocarbons like natural gas, oil and coal), which reserves are depleting at alarming rate, to a more environmentally friendly renewable energy sources of which hydropower is the most economical. Hydropower has special advantage over other renewables in that water can be stored in the dam's reservoir in sufficient quantity, and released at will to produce electricity by opening the gates. This cannot be realized with solar, wind or other renewable energy resources.

This work suggests urgent need for teamwork between federal and state governments, World Bank, Non-Governmental Organizations (NGOs) Food and Agricultural Organizations (FAOs), and other agencies to manage our water resources sustainably and effectively in order to curtail scarcity of this all-important resource. One of the ways is to encourage construction of more dams for storage of water for different water purposes. It is also suggested that a functional operation and maintenance works should be worked out for each dam in Nigeria to enhance sustainability.

CHALLENGES AND PROSPECTS

CHALLENGES

Most dams in the country are manned by inexperienced personnel resulting to inefficient operation and maintenance of the facility. Sedimentation in reservoirs is not monitored overtime and this could result to short-circuiting of the lifespan of reservoirs. The downstream population encounters problems arising from dam construction including loss of arable land for farming, reduction of fish farming output, lack of cultural heritage, and so on. Dams by obstructing fish migration downstream have affected residents' means of livelihood, the fishes being prevented from migrating to the downstream area. This development affects finances and nutrition status of people in the downstream environment, experiencing problem grazing their livestock during dry season due to low depth of river flow downstream. The rotten vegetation inundated by dams produce odour and greenhouse gasses produced by reservoirs increases global warming effect. Dams may have problems as a result of inadequate preliminary studies on the proposed dam site, poor deign, poor engineering applications during construction, inadequate qualified dam safety monitoring personnel on site, and bad maintenance culture.

PROSPECTS

There are prospects of poverty alleviation with the construction of large dams arising from various uses of the infrastructure for benefits in areas of water supply, irrigated agriculture, tourism and sanitation, hydro power generation, and so on. Flood-plains are among the most productive ecosystems on earth (Millennium Ecosystem Assessment, 2005; Opperman et al., 2009). Spawning of fish on a flood plain results in offspring with many advantages over other fishes born in the river. During floods, water spills into the flood plain resulting in the water becoming warmer and enriched with nutrients, making young fishes to grow. This is a source of nutrients to the communities in the area and environs.

CONCLUSION

This paper has reviewed dams in Nigeria, its features, availability and functionality, gains, problems and sustainability. It is a fact that Nigeria is a country housing many dams, but a pertinent question is: how many of these dams are operating at full capacity, meeting their purposes? The answer to this question is not impressive. Consequently, we are calling on the federal and state governments to partner immediately and put up structure to reappraise and monitor all dams in Nigeria, come up with their problems and possible solutions. An agency should be set up to address these problems immediately. This should be carried out periodically to enhance their sustainability since water is central to the realization of all the seventeen (17) SDGs by 2030. Environmental Impact Assessment (EIA) is also proposed for all dam projects in Nigeria in line with global practice. From these EIA studies, unjustifiable dam projects will be struck out from beginning and impact mitigation measures addressed for all projects. Problems encountered by the downstream population arising from construction of dams should also be reviewed and addressed to enable them enjoy the various gains of these projects.

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DECLARATION OF COMPETING INTEREST

None

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