PERFORMANCE EVALUATION OF OKUTA OJA IRRIGATION EARTH DAM USING COMPARATIVE INDICATORS

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ABSTRACT

Okuta oja earth Dam was constructed over Bariba River in Kwara state to enhance dry season agriculture farming in the area. Research was conducted to investigate the performance of the dam with respect to agricultural and environmental aspects and improvement in the socio-economic status of rural life. Both primary and secondary data were collected by conducting focus group discussions (FGD) with the 192 stakeholders using questionnaires and people of relevant local organizations of the dam area. The parameter such as Annual income, Employment opportunity, Agricultural production, Fish production, Command area Efficiency (CAE), Management Performance Ratio (MPR), and Benefit-Cost Ratio (BCR) were calculated. The result showed that about 79 % increased annual income, 91 % Employment opportunity, 74 % agricultural production, 93% fish production increased that of earlier situation. However, it is observed from the study that the cost to benefit ratio is not encouraging due to peasant nature of agricultural tools being used by the farmers. Agricultural indices (percent sodium, %Na, sodium absorption ratio, SAR, permeability index, PI and magnesium hazard, MH) employed to study the suitability of the water for irrigation revealed that the analyzed surface water samples are suitable for irrigation purposes.

Keywords: Irrigation, dams, performance evaluation and Water quality indices

1 INTRODUCTION

Introduction

Nigeria is an agricultural country where 77 percent of the workforce lives in rural area and engages in agricultural practices (Adefemi *et al,* 2007). Irrigation plays a vital role in the countries agricultural productivity as well as overall economic growth and groundwater is the main source of irrigation water which accounted for 83% of total water uses and rest 17% of surface water sources and very limited (Mustapha, 2008). However, excessive groundwater abstraction for irrigation has posed a great challenge to the water table, which has greatly declined especially in the Northern region of Nigeria. Therefore, people take to uses of surface water being feasible option to augment water demand which minimizing pressure on groundwater especially during dry season. Under these circumstances, earth dam has evolved as a cost-effective new type of hydraulic structure for conserving surface water in the medium and small rivers which shows extra advantages over the conventional gated structures like sluice gate, regulator, and barrage (Abedur and Hasan, 2016).

Agriculture is by far the largest user of the world's water, but it is still a limiting factor for agriculture and some 80% of agricultural land worldwide is under rain-fed cultivation (Nweke *et al.* 2013). Water is also increasingly scarce resources and therefore limiting agricultural development in many regions and country of the world. The water development process therefore consists of transferring water from high supply season to high demand season. In the past building new physical system to harness additional water resources has been the standard approach. However, with increasing demand of water by agricultural users due to increase in food demand, there is need for building of agricultural dams as to impound water to be used for irrigational farming. During dry season, the impounded water could be used for farming activities such as growing of crop and enrichment of soil moisture.

The major constraint to increased agricultural production in Nigeria is inadequacy of rainfall, most especially in the Northern States, (Ogunfowokan *et al.* 2013). Large areas of land are left uncultivated, especially in the Sahel region of the North. Irrigation in Nigeria has become an issue of vital importance considering present population growth rate. Recent report shows that Nigeria population is increasing by 3.5% annually, while food production is increasing by only 2.5%. The Food and Agriculture Organization (FAO) for instance, has warned that by the year 2020, Nigeria will no longer produce enough food to feed herself, solely from rain fed agriculture (Shankar *et al.* 2022). One of the complimentary measures that could be taken is to intensify irrigated agriculture (Akpan *et al*, 2008). Irrigation largely contributes to expansion of crop production and development of the nation. Like normal good, the demand for irrigation in any agrarian society increases steadily at initial stages of development. Mustapha, (2008) observed that improved availability of irrigation water in agriculture will increase crop yield thereby increasing income and alleviating poverty among the adopting producers. It is perhaps the recognition of the above stated roles of irrigation that the Nigerian government embarked on irrigation development through River Basin Authorities, for example, the Okutaoja Dam and irrigation project. This is one of the multi-purpose projects embarked upon by the Lower Niger River Basin Development Authority with the aim of providing farm efficiency and income, through optimum water conservation and utilization practices. The Authority realized that agriculture remains dominant in the region and is a strong influence on the region's economy. Agricultural dams are mainly constructed for irrigational farming though dam could be used to serve diverse purposes such as hydroelectric power supply, water supply, control of flooding, crops irrigation.

The Bariba river is a transboundary river between Okuta and Kosubosu The characteristic of the river is 24km in length, 50m in width and 5 m depth with a basin area of 120 sq. Km. The river has been facing the large reduction of water flow in the summer season and a frequent tidal flood occurs in the rainy season that causes serious water tragedy of farmers for cultivating rice and other crops. As a temporary solution of the irrigation water, earthen dams were built on their own initiative and with the assistance of local administration that supply very limited amount of water. Consequent upon this, Government therefore took it upon herself to build a bigger earth dam to supply surface water as irrigation water during the whole year by increasing cultivable command area, to control the flood at the rainy season, to enhance the socio-economic condition of the local farmers by improving the total agricultural conditions. It will also serve to improve fish cultivation by providing enough water upstream of the dam. Therefore, a performance analysis of the dam site is really needed to know the effects of the earth dam and to study how its construction has contributed to the socio- economic life of the rural populace. Considering the above-mentioned importance, a study was carried out to investigate the performance of the okuta oja dam in terms of agricultural and environmental aspects.

2 METHODOLOGY

Study area

The study was okuta oja dam site located between the latitude 24.04'N and longitude 91.35'E and it is located in the Okuta Local Government are of Kwara State. Local farmers are being able to divert the small water flow of river either by gravity flow or by using low lift pumps and use it to cultivate grains and vegetables. The study site is characterized by the hot temperature between October and April and heavy rainfall in the rainy season which sometimes leads to tidal flood. Out of total 342,178 holdings of the district, 57.61% holdings are agrarian.

Okuta Oja Irrigation dam was constructed in1988. It has a dam height of 11.75m, width of 6 m with a length of 3.3km. It has a design capacity of 23x106m^3covering a land area of average of 900m^2. It has presently employed a total of 264 people. This dam has contributed to national income, and to the communities involved. The main aim of the dam is for crop irrigation and fishing.

Field data collection

Data gathering process involved the collection of both primary and secondary data. The technical data of relevant to the dam were collected from Lower Niger River Development Authority. Based on the anticipated indicators, a questionnaire was developed for primary data collection. Other information was sought for through non-formal field inspections and interviews with block organizers, Chairman, farmers, and beneficiaries through the Focus Group Discussion (FGD). The sample size, who responded to the questionnaire, of this study was 100. The respondents were selected from among the beneficiaries and stakeholders of the project living in the project area. Besides, groups of stakeholders, NGO people, agriculture extension people and people related with fisheries were consulted to get qualitative data for conducting the study. The secondary data were also collected based on the identified indicators by both quantitative and qualitative types of inquiry for assessment of the impact of the dam on the socio-economic status of the beneficiary as well as local agriculture and environment. Finally, the indicators such as annual income, cultivable land, an opportunity of agricultural productions and social communication were selected as future performance analysis of the project. The indicators used are as stated below:

Indicators Analysis

The performance of the rubber dam project was evaluated based on the equations reported by Sarker *etal,* (2011)

(i) Command Area Efficiency (CAE)

It is the ratio of actual command area to the potential command area under the irrigation project which expresses as follows.

$$CAE = \frac{Actual\ command\ area}{Potential\ command\ area} * 100 \qquad 1$$

(ii) Management Performance Ratio (MPR)

It is the ratio of total volume of water supply to total volume of water demand.

$$MPR = \frac{Total\ Volume\ of\ water\ supplied}{Total\ Volume\ of\ water\ demanded} * 100 \qquad 2$$

Where, total volume of water supply = Actual discharge capacity× total operating time and total volume of water demand = irrigation water requirement × actual command area.

(iii) Benefit Cost Ratio (BCR)

Benefit cost ration is the gross return to total cost of the project that can be expressed as follows.

$$Benefit - cost\ Ratio = \frac{Gross\ return}{Total\ Cost} \quad 3$$

Net return = Gross return – total cost

Where total cost included seed/seedling, fertilizer, plows, labor charges, irrigation, insecticides, tax and operation and maintenance cost in N ha^{-1} and gross return include the value of crops and straws N ha^{-1}.

Twenty Water samples were also collected from major command area of this dam and analyzed for metallic radicals. Average values of these radicals were determined and used to estimate indices that determine the appropriateness of water from the study area for agricultural purposes. The indices are percent sodium (%Na), sodium absorption ratio (SAR), permeability index (PI), and magnesium hazard (MH). Computed values of the respective indices and statistical summaries were presented for interpretation. Empirical equations employed in the computation of these indices are as follows:

(iv) Percentage Sodium (PS)

The amount of sodium expressed in percentage, that can replace Mg^{2+},Ca^{2+}andK^{+}existing in water samples were computed using the equation after Xu, *et al.* (2019) as follows:

$$PS = \frac{Na^{+}+K^{+}}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}} * 100 \quad 4$$

Sodium absorption ratio, SAR

SAR is used to estimate alkali hazards in irrigation water, and it is associated with the absorption of $Na^{+}$by soil. The SAR was computed using the equation according to Nematollahi *et al.* (2016) as follows:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad 5$$

Permeability index (PI)

Farid *et al.* (2015) developed the concept of PI which is used to evaluate water quality for irrigation purposes. It is computed using:

$$PI = \frac{Na^{+}+\sqrt{HCO_3^{-}}}{Ca^{2+}+Mg^{2+}+Na^{+}} * 100 \quad 6$$

(v) Magnesium hazard, MH

Excess $Mg^{2+}$and Ca^{2+}will adversely impact the soil by making it more alkaline, thus decreasing crop output (Nematollahi *et al.* 2016). This can be estimated in terms of the MH by the following equation

$$MH = \frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} * 100 \quad 7$$

3 RESULTS AND DISCUSSION

Results and Discussions

Annual income increase

The impact of the dam on socio-economic status was assessed based on annual income increase of the beneficiary and employment level. This was done in terms of increase or decrease in annual income of the beneficiary communities. The result is presented in Table 1. Most of the respondents expressed that their yearly income increased after the construction of Okuta Oja Dam Project and less than of one fifth reported no increase in their income level. Out of 162 respondents, larger percentage as shown in figure 1 reported that construction of the dam has generated employment opportunity for the rural populace.

Table 1 showed levels of income increase of the beneficiaries. In total all the farmers reported that there was a significant increase in their income due to the earth dam construction. It is therefore evident that the construction of the dam has impacted positively on the socio-economic life of the communities within the catchment of the dam.

Table 1. Amount of annual income increase due to construction rubber dam project.

Level of income Increase (N)	No. of Beneficiary	Percentage (%)
10,000 – 50,000	18	11.1
51,000 – 100,000	36	22.2
101,000 – 200,000	24	14.8
201,000 – 500,000	33	20.3
501,000 – 1,000,000	39	24.1
Above 1,000,000	12	7.4
Total	162	

Employment opportunity

The benefits of irrigation go beyond impacts on yields, with large potential benefits for nutrition security, health, and women's empowerment. To assess the of socio-economic condition due to the construction of Okuta Oja dam project the respondents were asked whether their employment opportunity increase or not as a result of the construction of the dam, The result is presented in Figure 1. 74 %

answered positively and 36 % answered negatively. Due to the construction of the dam, they have access to more volume of irrigation water in dry season, they as a result have the opportunity to engage in all year round agriculture and this leads to better socio-economic lifestyle.

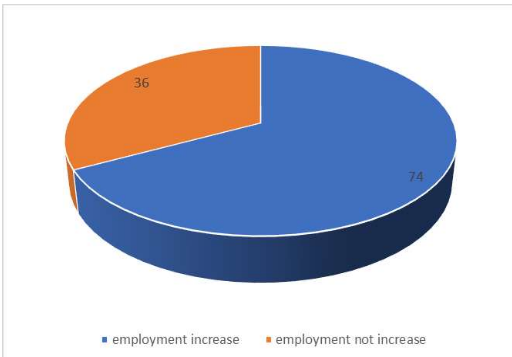

Figure 1: Employment Opportunity due to the Dam Construction

Agricultural Production

To assess the impact of the dam on local agricultural production, the respondents were asked whether their agricultural production was affected in terms of increase in production of agricultural product like fruit, vegetables and grains. They were also asked if there was increase in their fish production as a result of the construction of the dam, if increased then to what extent it increased and how was the amount of increase of different agricultural products. The respondents who answered positively were further asked the actual amount of increase in the production in ton per acre. The results are presented in below Table 2. All the respondents attested to an increase in their hectarage because of the siting of the dam.

Table 2. Amount of annual increase in agricultural production.

Hectarage Increase	No. of beneficiary	Percentage(%)
1 - 3	26	25.0
3 - 6	22	21.1
6-9	14	13.5
9-12	18	17.3
12-15	9	8.6
15 -18	9	8.6
Above 18	6	5.7

The findings clearly indicated a very positive impact of the dam on the agricultural production of the catchments areas.

Fish Production

Okuta Oja dam construction created water head at the upstream and therefore provides access to more fish production. As shown in Figure 2, 91 % of the respondents reported increased fish production and 9% reported otherwise. The respondents who reported non-increase in their fish production gave access to only a small portion of land as a possible reason for not feeling the positive impact of the dam with respect to fish production.

Command Area Development (CAE)

Command area efficiency of of the dam is tabulated in Table 3. Command area efficiency depends largely upon the irrigated area and potential command area. Actual command area depends on a wide variety of factors like farmer's involvement in irrigation, favorable soil conditions, interest for cultivation, regular maintenance of water conveyance system, and efficient water management practices. These factors have not allowed for higher command area efficiency. As such, there is need for expansion and provision of more irrigation accessories for increased dry season farming.

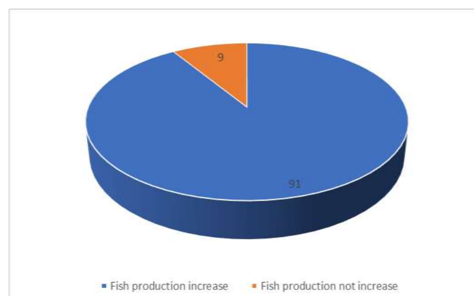

Figure 2: Impact of Okuta Oja Dam on Fish Production

Table 3 . Command area efficiency of the Dam.

SN	Names of irrigation schemes	Irrigated Area (ha)	Potential command area (ha)	Command Area Efficiency (%)
1	Oja Ile	70	270	25.9
2	Moba	48	440	10.9
3	Okuta	69	417	16.5
4	Kbs	73	281	26.0
5	Yipata	81	336	24.1

Management Performance Ratio (MPR)

The management performance ratio (MPR) is presented in table 4. The irrigation project performed poorly in this regards due to higher farm canal loss; lower operating times and delay in starting of irrigation activity. The discrepancy calls for better water management practices in these existing schemes and also calls for establishment of more irrigable land for the farmers.

Benefit-Cost Ratio (BCR)

Benefit-Cost ratios of the irrigation schemes is presented in Table 5. The results are not quite good due to high investments cost on the dam. Effective marketing system should be developed for the farmers to be able to sell their product at a more competitive price. Good road networks and other amenities are needed to transport agricultural product to nearby markets. Modern storage facilities need to be built also to prevent the observed post harvest loss

Table 4. Irrigation water management performance ratio of the Dam.

Irrigation Schemes	Total water supplied (m^3)	Total Volume of water demand (m^3)	MPR
Oja Ile	385,441	21,097,000	1.83
Moba	540,336	24,700,000	2.19
Okuta	489,662	28,336,900	1.73
Kbs	453,882	31,213,554	1.45
Yipata	673,224	23,653,441	2.85

Table 5. Performance of benefit-cost ratio of the scheme

Names of irrigation schemes	Gross Return (1000N/ha)	Total Cost (N1000/ha)	Net Return(N1000/ha)	Benefit-Cost Ratio
Oja Ile	15,000	11,000	12,543	1.36
Moba	86,000	73,776	48,564	1.16
Okuta	33,261	24,616	26,342	1.35
Kbs	34,367	28,347	23,543	1.21
Yipata	29,445	22,500	21,902	1.31

Quality of Irrigation Water

An important parameter used in evaluating water for irrigation is the percentage of sodium. Table 6 presents the statistical summary of the water quality analysis and \table 7 showed the irrigation water quality class to which the water samples belong. About 15% of the water samples fall on excellent and good class while 85 % is very doubtful with respect to their usefulness for irrigation. The values of EC show a low presence of sodium salts in the water, which when in excess, limits air and water movement during the soil in the wet season (Musa *et al.* 2014). This indicates that water samples are suitable for agricultural purposes.

SAR is also significant in assessing irrigation water because an increased concentration of sodium is capable of reducing the permeability of soil structure (Nweke *etal,* 2013). As shown in Table 7, SAR for all the water samples is less than 10 indicating that 100% of the analyzed water samples are excellent for irrigation based on this index. Salinity, is also an expression of EC, and in turn a measure of the leaching of dissolved salts in water (Nematollahi *et al.* 2016). The water was classified as low salinity, low sodium hazard. This is an indication that most of the water samples are suitable for use as irrigation water on all types of soils devoid of the possible impact of exchangeable sodium (Akpan *et al*. 2008)

Table 6: Statistical Summary of the analysed Physicochemical Parameters

Parameters	Min	Max	Mean	SD	WHO
EC (µS/cm)	21.50	520.00	169.42	175.15	1500
pH	6.50	7.90	7.17	0.42	6.50–8.50
Ca^{2+}	4.00	27.27	9.30	8.19	100
Mg^{2+}	0.74	15.80	3.61	5.46	50
Na^{+}	16.10	75.90	29.40	20.92	200
K^{+}	0.50	2.35	1.36	0.78	12
Cl^{-}	24.85	117.15	45.83	32.13	250
CO_3^{2-}	3.05	10.55	6.53	2.77	600
HCO_3^{-}	6.35	94.30	42.49	27.21	600
SO_4^{2-}	0.01	0.08	0.03	0.02	250
NO_3^{-}	0.38	3.45	1.46	1.17	50

Table 7: Irrigation indices assessment for water within the Study Area

Indices	Sources	Range	Class	No. of sample	Percentage (%)
Percent sodium (%Na)	Mustapha, 2008	< 20	Excellent	3	15.0
		20–40	Good	3	15.0
		40–60	Permissible	5	25.0
		60–80	Doubtful	17	85.0
		> 80	Unsuitable	4	20.0
Sodium adsorption ratio (SAR)	Nematollahi *et al.* 2016	< 10	Excellent	20	100.00
		(10–18	Good	0	0.00
		18–26	Doubtful	0	0.00
		> 26	Unsuitable	0	0.00
Permeability index (PI)	Sarker *et al.*2011	< 25	Not suitable	0	0.00
		25–75	Moderate	3	15.0
		> 75	Suitable	8	40.0
Magnesium hazard (MH)	Xu *et al.*2019	< 50	Suitable	13	65
		> 50	Not suitable	7	35

Conclusions and recommendations

This study assessed the performance of Okuta oja Dam. The questionnaire survey indicates the performance of the dam in terms of socio-economic status and was considered satisfactory as the construction of the dam has helped to increase the annual income of the beneficiary and created more employment opportunity. The results of the survey showed that the dam had positively impacted on local agriculture through increasing cultivable land and various agricultural productions. However, the following recommendations will help to improve the scheme performance and contribute to better socio-economic conditions of the farmers. Necessary steps should be taken to restrict sand harvest from the downstream area. Irrigation water distribution system should be upgraded, and the silted canal clean up. More beautification works need to be done also for the dam to be a great attraction for tourists However, this investigation was carried out during dry period sampling alone, more investigation is recommended during the wet season and comparative study carry out.

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