



IRRIGATION POTENTIAL OF THE OYUN DAM RESERVOIR

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ABSTRACT

Water resource management includes the optimization of the uses of a dam reservoir for various human benefits. This study attempts to contribute to a better understanding of the smallholder irrigation sub-sector by evaluating the water resources and irrigation potential of Oyun Dam in Offa, North Central Nigeria. The water resources potential for the dam was analysed by considering the rainfall, evaporation, population and sedimentation and the irrigation potential by considering the irrigation command area, using the sequent peak analysis and the flow duration curve. The potential of using the irrigated land for rice was also investigated. Rice was used as a preferred crop because it has a high water requirement. The study revealed that apart from fulfilling its primary function of water supply, the Oyun dam reservoir has an excess available water of $2.04 \times 10^6 \text{ m}^3$. This is exclusive of all losses based on reservoir storage capacity, therefore there is an irrigation command area potential of up to 160 hectares.

Keywords: Irrigation Potential, Oyun dam, Reservoir, Rice production

1.0 Introduction

Dams as impounding structures create reservoirs. These reservoirs serve multiple purposes which include: electricity production, reducing discharge variability for improved navigation, or to supply water for irrigation and other uses (ICOLD, 2007; WCD, 2000). The total cumulative storage capacity of large dams increased from less than 100 km^3 in 1900 to around 8300 km^3 in 2000 (Chao et al., 2008; ICOLD, 2007). Globally, the irrigation water supply from reservoirs increased from around 18 km^3 per annum (adding 5% to surface water supply) at the beginning of the 20th century to 460 km^3 per annum (adding almost 40% to surface water supply) at the end of the 20th century (Biemans et al, 2011). Nigeria is not left out in this contribution as there are a total of over 200 dams, some of which are ongoing projects while others are yet to be constructed (FAO et al., 2014). The bulk of the dam construction took place in the late 1970s and in the 1980s. In 1993, the total active reservoir capacity was 30.3 km^3 , while the water allocation from reservoirs was as follows: 10.9 km^3 (36 %) for irrigation, 0.8 km^3 (3%) for water supply, and 18.6 km^3 (61 %) for hydropower (FAO, 1995).

Irrigation is required to supply water for the proper growth of crops outside the rainy season. Irrigation systems have made dry areas suitable for agricultural production, with the total global irrigated area increasing from around 40 Mha in 1900 to 215 Mha in 2000 (Fader et al., 2010). Water is supplied at regular intervals depending on the type of crop, nature of soil and the amount of precipitation. Water from a

reservoir is transported through canals and distributary channels to the field where the crops are planted. Smallholder irrigation development has shown throughout the developing world that it can be used as a key drought mitigation measure and as a vehicle for the long-term agricultural and macro-economic development of a country. Successful smallholder irrigation schemes can result in increased productivity, improved incomes and nutrition, employment creation, food security and drought relief savings for the government.

Nigeria has several completed and ongoing projects on expanding irrigation to achieve the goals of the vision 20: 2020 aimed at transforming Agriculture to a sustainable profitable sector. About 221 km^3 of water resources are produced annually while total renewable water resources are estimated at 286.2 km^3 . About 214 km^3 makes up surface water and the exploitable surface flow is about 96 km^3 per annum while the volume of available groundwater stands at 87 km^3 . Extractable ground water is 59.51 km^3 (FAO et al., 2014).

Estimating irrigation potential can be challenging, despite the considerable data available on surface water resources. FAO (1997), while reporting the irrigation potentials in Africa, Nigerian national water resources master plan (NWRMP), stated that the Niger River Basin has an irrigation potential of 1678510 ha. In order to estimate water available for irrigation, consideration must be given to the demands on

the reservoir, sedimentation and water loss. Considerable quantity of stored water in a reservoir is lost due to evaporation, seepage and leakage. The most active of these is evaporation. The main factors which determine its rate include net radiation, water availability, wind velocity, atmospheric temperature and “reflexibility” of land surface (Fetter, 2007). The irrigation potential of a scheme is directly proportional to the available flow to meet the crop water requirement. To fairly estimate a dam's potential, the water resources analysis must take into consideration the following: the water requirement to meet the primary responsibility of the dam if different from irrigation; the evaporation losses over the reservoir area; the reservoir sediments which may have reduced the storage capacity of the dam; the direct rainfall on the reservoir; and the inflow into the reservoir.

A study by Ugahali *et al.* (2016) reviewed the irrigation subsector in Nigeria and revealed the prospects of achieving rice self-sufficiency through irrigation farming. The study reported that Nigeria has abundant land and water resources to embark on irrigation schemes to ensure all year round rice production. Additional yield to annual rice production through dry season farming in 2012 in 10 pilot states of the country was found to be over 1 million metric tonnes. This shows that an intensive and consistent irrigated rice production scheme will set Nigeria on a pathway to rice self-sufficiency thereby bringing an end to the gross loss in foreign exchange due to importation and smuggling of the commodity. This study is an attempt to contribute to a better understanding of the smallholder irrigation sub-sector by evaluating the water resources and irrigation potential of a dam using the Oyun dam in Offa, Nigeria as a case study.

2.0 Description of study area

The catchment of River Oyun is approximately 106 km², it lies almost entirely in Kwara State, Nigeria. The Oyun dam is located between longitude 08°30' N and latitude 08°15' E and it is shown in Figure 1. The catchment experiences two main seasons, the rainy and dry seasons respectively. The

rainy season commences in April and ends in October while the dry season extends from November to March. Rainfall on the average is between 1200 mm and 1400 mm annually. Within the region, the major river system is the Oyun River and has numerous short tributaries joining the main river at intervals along its length. Most of the tributaries are however intermittent and therefore active during the rainy seasons. However, the river Oyun is perennial having its water table always above its bed even during the most prolonged dry season. The groundwater runoff makes continuous contribution to the total runoff. The slope in most parts of the catchment area is gentle thereby ensuring sufficient time for water to infiltrate into the soil. River Oyun originates at an elevation of 490 m above sea level, close to Ila-Orangun and flows in an approximately north-west direction for about 80 km before joining River Asa. The primary function of the Oyun River Dam is water supply and it has continued to serve that singular purpose till date. There exist a lot of small-holder farmers in the area who essentially engage in rain-fed farming only while the excess water in the Dam is unused during the dry season.

Oyun River dam is located about 5.5 km north of Offa town. Offa is situated in the south-central part of Kwara. Figure 1 presents the Map of Nigeria showing the study area and delineated river Oyun catchment. The dam has a height of approximately 9.8 m and consists of a central free overflow concrete spillway 80m long between two earth fill embankments. There are two water treatment plants, commissioned in 1967 and 1990 respectively. The two treatment plants receive their raw water from the Oyun dam reservoir. The treatment plants have a capacity of 180 m³/hr and 660 m³/hr respectively. Two local governments get water supply from Oyun dam water treatment plant, their population as at 2006 Census, (NPC, 2006) is given as: Offa = 88,975; Oyun=94,454 making a total of 183,429 people. At a growth rate of 2.8% given by the National population Commission, the population in the year 2020 is expected to be 272,611. The salient features of the Oyun reservoir are presented in Table 1.

Table 1 Salient features of Oyun Reservoir and Dam

Description of features	Values
Dam Height (m)	9.8
Location	5.5 km north of Offa
Catchment area (km ²)	106
Surface area (m ²)	690000
Spillway crest elevation (m a.s.l)	406.58
Spillway length (m)	80
Embankment (m.a.s.l)	409.5
Gross storage volume (x10 ⁶ m ³)	3.50
Net storage volume (x10 ⁶ m ³)	2.90

Source: Okeola & Balogun (2015)

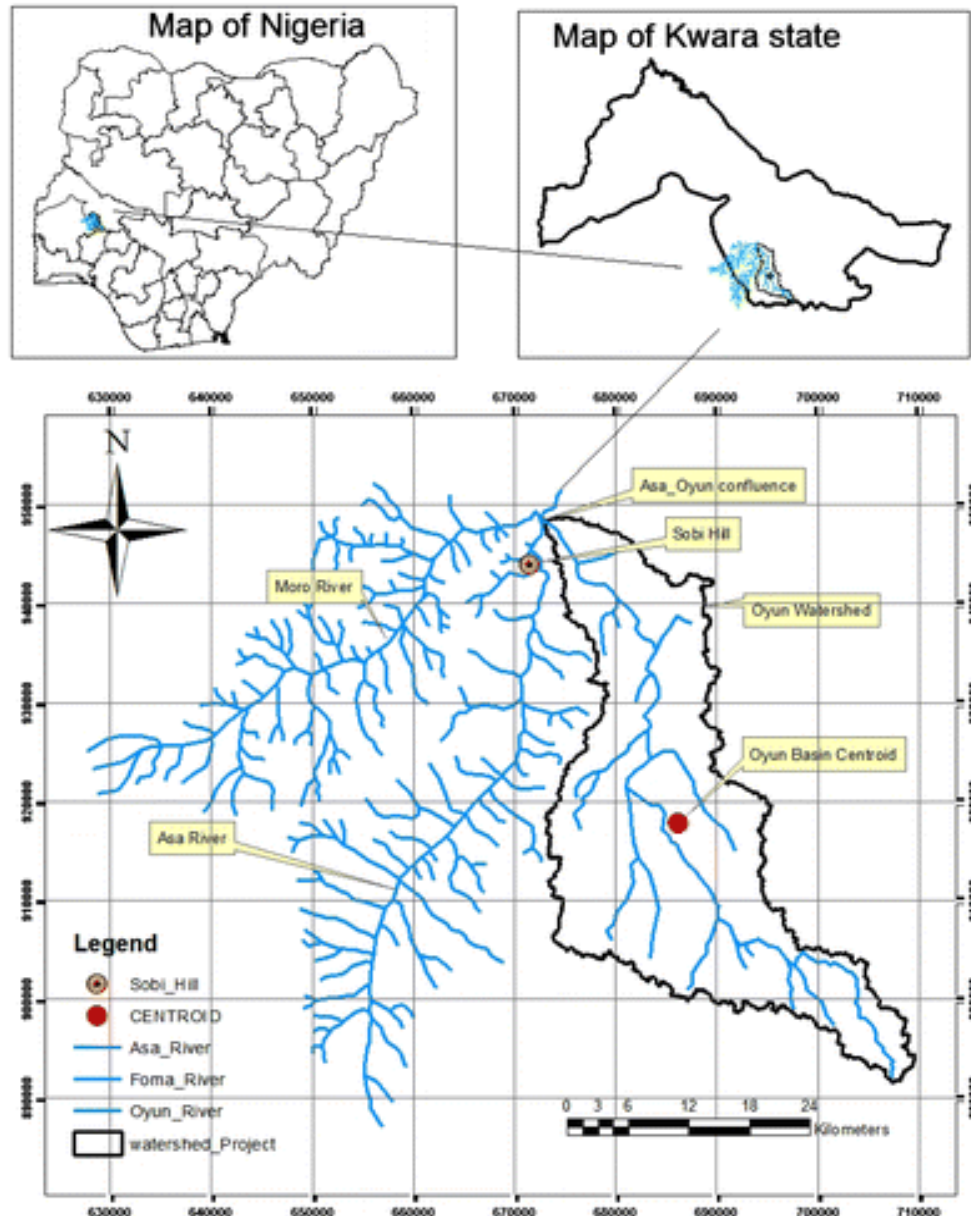


Figure 1: Map of Nigeria showing the study area and delineated river Oyun catchment

3.0 Methodology

To decide on the irrigation potential of the dam, an evaluation of the available water resource of the river was first done. The irrigation potential of the scheme is directly proportional to the available flow to meet the crop water requirement. To fairly estimate the Dam's potential, the water resource analysis took into consideration the following:

The water demand to meet the primary responsibility of the Dam, which is domestic water supply.

The evaporation losses over the reservoir area

The reservoir sediments which may have reduced the storage capacity of the dam

The direct rainfall on the reservoir and

The inflow into the reservoir.

Water Demand

It is necessary to determine the amount of water needed to fulfill the primary mandate of the dam which is water supply. The projected population of the people expected to rely on the dam for water supply by the year 2020 is 272, 611. This was based on the population figures obtained from the

National Population commission. The per capital consumption recommended by the World Health Organization (WHO) for urban areas is 120 l/d.

$$\begin{aligned} & \text{Total Water Demand, } W \\ &= \text{Population} \\ &\times \text{Per Capital Consumption} \end{aligned} \quad (1)$$

Reservoir Inflow Analysis

Monthly inflow data at the Oyun dam from 1972 to 1981 was obtained from the Kwara State Water Corporation (KWWC), the owners of the Dam. In modeling the monthly reservoir inflow, the Thomas – Fierring model based on a first order Markov model was adopted and the synthetic flow series were calculated using observed historical monthly stream flow sequences (Salami, 2007). The monthly flow parameters of the observed flow for the River at the dam location when the monthly inflows are described as first order autoregressive normal and log-normal is presented in Table 2 and the model developed was used to extend the flow up to the year 2020 and the results are shown in Tables 3 and 4.

Evaporation Losses Over reservoir Area

The monthly evaporation was obtained at Nigerian Meteorological Agency (NIMET) for Ilorin, Ibadan and Osogbo which are the cities close to the study area. The monthly evaporation for Offa was estimated based on weighted average method. The estimated average evaporation for Offa was adjusted by multiplying it with the pan coefficient of 0.8. In practice, the reservoir evaporation is taken as a product of monthly evaporation and reservoir surface area at $\frac{3}{4}$ maximum capacities. From data presented in Table 1 and the topographical data used to establish the Elevation-Surface Area-Capacity curve, the reservoir surface area corresponds to about $0.52 \times 10^6 \text{ m}^2$ (75% of Dam surface area of $6.9 \times 10^6 \text{ m}^2$). This value was used in the computation of the monthly evaporation losses and the results are presented in Table 5.

Reservoir Sediment

The storage capacity of the Oyun dam is expected to reduce with time based on the accumulation of sediments. A check was carried out using the Flemings equation and the Brune Curves for reservoir trap efficiency (Linsley et al, 1992). The sediment yield range of solids concentration is usually given for many rivers and streams in similar region to the location to be between 1.0 g/l to 2.0 g/l and higher values for areas further north. The same report gives a regional sediment rating curve, that is sediment S per unit discharge as

$$S = e^{(-0.0124R+11.81)} + 1.0 \text{ g/l} \quad (2)$$

Where R = annual rainfall in mm for the project area (1200 mm)

Available Flow for other uses

It is not economically feasible to harness the entire runoff of a river during flood as this will require a huge storage. In the case of Oyun reservoir, the storage area is defined and fixed. Therefore the yield to meet crop water requirement is dependent on the excess quantity available from the reservoir without infringing on its water supply requirement.

The storage capacity of the reservoir was estimated using two methods which are the Sequent Peak Analysis and the Flow duration curve. The values obtained from the two methods were compared to each other to establish the appropriate range for the storage.

Sequent – Peak Analysis

The Sequent – Peak method computes the cumulative sum of the inflows minus the reservoir releases over the time interval chosen for analysis. The analysis assumes that the time interval includes the critical period which is the time period over which the flows have reached a minimum causing the greater drawdown of the reservoir. The other assumption is that the total release over time interval of analysis does not exceed the total reservoir inflow (Mays and Tung, 1992). In this case, the Sequent – Peak method is implemented using the following equation:

If positive

$$S_t = W_t - I_t - R_t + E_t + S_{t-1} \quad (3)$$

Otherwise

$$S_t = 0$$

Where S_t = Storage at time t, W_t = Water Supply demand, I_t = Inflow, R_t = Direct Rainfall on river, E_t = Evaporation from reservoir, S_{t-1} = Previous storage

Flow duration curve analysis for Oyun River flow

The flow duration analysis was carried out in accordance with the method established by Oregon State University (<http://water.oregonstate.edu/streamflow/>). The method involves establishment of relationship between discharge and percent of time that the indicated discharge is equaled or exceeded (exceedence probability).

Crop water requirement

The water requirement of crops (ET_c) is the amount of water that is required to meet the evapotranspiration rate so that crops may thrive. In order to estimate the water requirement of a crop, there is a need to estimate the evapotranspiration rate. The reference rate, ET_o , is the estimate of the amount of water that is used by a well-watered grass surface that is roughly 8 to 15 centimeters in height.

$$ET_c = K_c * ET_0 \quad (4)$$

Climatic effects are incorporated into ET_0 , while the effect of the crop characteristics is incorporated into K_c . The reference evapotranspiration can be estimated by a number of methods but the Blaney-Criddle method was used because it provides an estimate of potential evapotranspiration based on average monthly temperature and climatologic indices such as daylight hours. This method is approximate but provides a reasonable estimate where sophisticated measurement equipment is not available. The equation is presented as follows (Michael, 1999), and the result shown in Table 7:

$$ET_c = \sum \frac{kt_p}{100} \quad (5)$$

Where,

k = empirical consumptive use crop coefficient for the month,
 t = mean monthly temperature, °F

p = monthly daylight hours expressed as percent of daylight hours of the year

Mean temperature used in the Blaney-Criddle model was obtained at Nigerian Meteorological Agency (NIMET) for Ilorin, Ibadan and Osogbo which are the cities close to the study area. The average temperature for Offa was estimated based on weighted average method.

4.0 Results and Discussion

Water Resources Potential of Oyun Reservoir

The Oyun reservoir water is viable for drinking water, Irrigation as well as fish farming as the ranges of physico-chemical properties were comparable to those found in non-polluted African reservoirs, and are within the allowable limits recognized by WHO (1997), (Mustapha, 2008).

There is no good record of monthly inflow into the reservoir since 1981. It is therefore necessary to establish the current inflow and the possible inflow for a few years to come. Using the available data of 1972 – 1981, this extension was done as described above with the help of the statistical data obtained in Table 2, and the amount of water to be expected in the reservoir is stated. This data was used to plot the hydrograph of the Oyun River at the dam site on a monthly basis from 1972 - 2020.

By applying Eqn. (1), the total water demand for the populace denoted by W was equal to 32713.32 m³/d or 981,400 m³/month or 0.38 m³/s (Assume a value of 0.40 m³/s). The hydrograph of the extended river flow is presented in Figure 2. Table 2 shows the monthly inflows as observed and as described by first order autoregressive normal and log-normal. Each column considers the total contributions over the years for each specific month. The statistical summary of the extended stream flow for River Oyun based on Markov is presented in Table 3 and 4.

Table 5 shows the estimated monthly evaporation losses from the reservoir based on available evaporation data of 1980 - 2010. The mean annual value of evaporation loss was given as 632303.36m³. With the annual rainfall projection over the area being 1200 mm, the sediment yield range of solids concentration was 1.0464 g/l. Given the annual inflow = 50.53 x 10⁶ m³, the annual sediment inflow is 1.0464 g/l x 50.53 x 10⁶ m³ which is 52.88 x 10⁶ kg.

Taking the value of the density of consolidated sediment as 1500 kg/m³, the sediment volume per year is 52.88 x 10⁶ /1500 which is equal to 35.250 x 10³ m³.

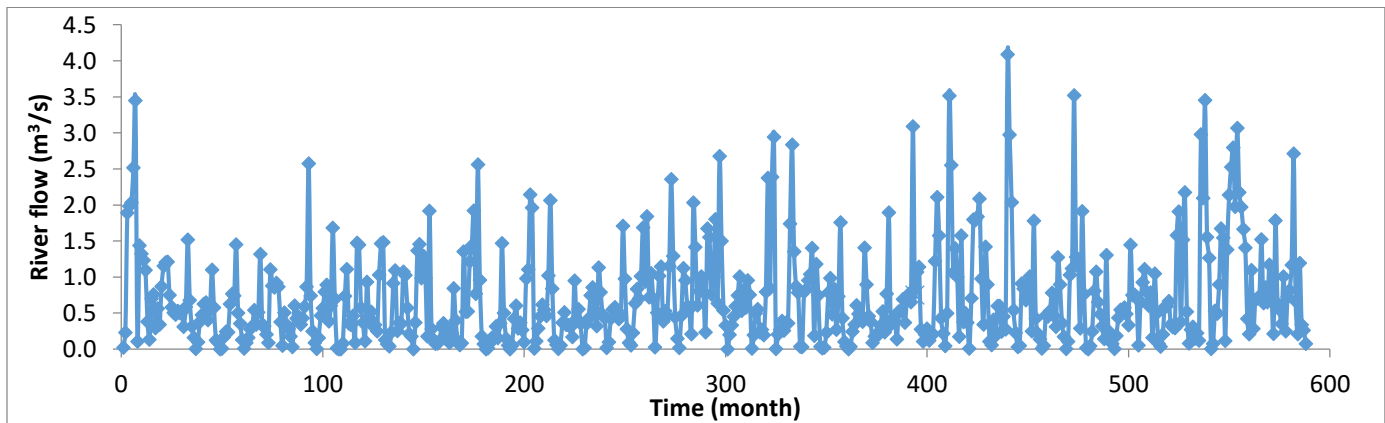


Figure 2: Hydrograph of the extended Oyun river flow (1972 -2020)

Table 2: Statistics of monthly reservoir volume (Mm³) for Oyun River at Offa dam (1972-1981) and model parameter

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.2998	0.7283	1.6848	1.8802	1.7180	2.0578	1.9923	1.3252	3.6848	2.0995	1.2115	0.8235
Median	0.0423	0.3495	1.2605	1.4200	1.1495	1.5395	1.0580	1.4985	3.7466	1.8420	0.8200	0.4540
S.D	0.5424	0.8295	1.3421	1.3328	1.4434	1.6320	2.5749	0.8362	1.3463	1.0744	1.0981	0.9336
C.V	1.8095	1.1390	0.7966	0.7089	0.8402	0.7931	1.2924	0.6310	0.3654	0.5118	0.9063	1.1337
Min	0.0010	0.0210	0.4320	0.6310	0.6350	0.8790	0.8350	0.1260	1.3170	0.8740	0.0320	0.0041
Max	1.5620	2.6780	5.0702	5.1399	5.4425	6.5241	9.2432	2.3260	6.6710	3.8720	3.1933	2.9409
Skew	1.9476	1.7142	1.9934	1.8379	2.2348	2.7357	3.0435	-0.4316	0.7252	0.6577	1.2849	1.7076
Correl, r	R _{1,2}	r _{2,3}	r _{3,4}	r _{4,5}	r _{5,6}	r _{6,7}	R _{7,8}	r _{8,9}	r _{9,10}	r _{10,11}	r _{11,12}	r _{12,1}
	0.21	0.19	0.98	0.84	0.96	0.94	-0.40	0.51	0.19	0.73	0.97	0.13
Slope, b	b ₁	b ₂	b ₃	b ₄	B ₅	B ₆	B ₇	b ₈	b ₉	b ₁₀	b ₁₁	b ₁₂
	0.3164	0.3079	0.9720	0.9095	1.0891	1.4906	-0.1291	0.8182	0.1512	0.7413	0.8215	0.0750

When the monthly inflows are described as first order autoregressive log-normal, where $x_i = \ln q_i$ the parameters $U_{x,i}$; $S_{x,i}$; $r_{x,i}$ and $b_{x,i}$ are determined as follows

$U_{x,i}$	-2.6574	-1.1488	0.0303	0.2243	0.0070	0.2337	-0.2929	-0.0535	1.1789	0.5091	-0.4077	-1.0207
$S_{x,i}$	1.2053	0.9120	0.7010	0.6381	0.7308	0.6985	0.9911	0.5789	0.3540	0.4823	0.7744	0.9091
$r_{x,i}$	0.3561	0.2653	0.9832	0.8647	0.9712	0.9558	-1.1110	0.5498	0.1994	0.7477	0.9744	0.1856
$b_{x,i}$	0.4721	0.2007	0.7557	0.7871	1.1124	0.9136	-1.5762	0.3211	0.1219	1.0187	1.5644	0.2179

C.V = Coefficient of Variation

S.D = Standard deviation

b = slope of regression equation

$U_{x,i}$ =Mean of natural logarithms of the monthly flows

$S_{x,i}$ = Standard deviation of natural logarithms of the monthly flows

$r_{x,i}$ = Correlation coefficient of natural logarithms of monthly flows

$b_{x,i}$ = Slope of regression equation of natural logarithms of the flows

Table 3: Statistical summary of extended monthly river flow (10^6m^3) at Oyun dam Offa (1972-2020)

MONTH	MEAN	MEDIAN	S.D	C.V	MIN	MAX	SKEW
JAN	0.4366	0.076	0.9388	2.1501	0	5.2882	3.5402
FEB	0.876	0.4773	1.2589	1.437	0.021	7.4184	3.4586
MAR	1.9412	1.4201	1.647	0.8485	0.2229	9.4124	2.5282
APR	2.0272	1.5502	1.3151	0.6487	0.418	6.6175	1.5697
MAY	1.8116	1.5517	1.5838	0.8743	0.3225	9.4318	2.8333
JUN	2.0592	1.4999	1.4495	0.7039	0.5626	7.0359	1.7841
JUL	1.7796	1.1278	1.6302	0.916	0.2344	9.2432	2.5071
AUG	1.8477	1.362	2.0123	1.089	0.126	10.95	2.7215
SEP	4.2475	3.8105	1.5286	0.3599	1.317	8.0089	0.6921
OCT	2.2919	1.982	1.5707	0.6853	0.6829	9.255	2.2452
NOV	1.5089	1.101	1.5496	1.027	0.032	6.5493	1.7995
DEC	1.3423	0.546	1.8424	1.3726	0.0041	7.8842	2.2545
ANNUAL TOTAL	22.2979	19.014	8.7069	0.3905	7.9362	45.7212	0.7782
ANNUAL MEAN	1.8582	1.5845	0.7256	0.3905	0.6614	3.8101	0.7782

Table 4: Statistical summary of extended monthly river flow (m^3/s) at Oyun dam Offa (1972-2020)

MONTH	MEAN	MEDIAN	S.D	C.V	MIN	MAX	SKEW
JAN	0.163	0.0284	0.3505	2.1501	0	1.9744	3.5402
FEB	0.3621	0.1973	0.5204	1.437	0.0087	3.0665	3.4586
MAR	0.7248	0.5302	0.6149	0.8485	0.0832	3.5142	2.5282
APR	0.7821	0.5981	0.5074	0.6487	0.1613	2.553	1.5697
MAY	0.6764	0.5794	0.5913	0.8743	0.1204	3.5214	2.8333
JUN	0.7944	0.5787	0.5592	0.7039	0.217	2.7145	1.7841
JUL	0.6644	0.4211	0.6086	0.916	0.0875	3.451	2.5071
AUG	0.6899	0.5085	0.7513	1.089	0.047	4.0883	2.7215
SEP	1.6387	1.4701	0.5897	0.3599	0.5081	3.0899	0.6921
OCT	0.8557	0.74	0.5864	0.6853	0.255	3.4554	2.2452
NOV	0.5821	0.4248	0.5978	1.027	0.0123	2.5267	1.7995
DEC	0.5012	0.2039	0.6879	1.3726	0.0015	2.9436	2.2545
ANNUAL TOTAL	19.8318	18.3616	9.9459	0.5015	4.4105	40.7078	0.2731
ANNUAL MEAN	1.6526	1.5301	0.8288	0.5015	0.3675	3.3923	0.2731

Table 5: Mean Monthly Evaporation at Oyun Dam Reservoir

Month	Mean (mm/month)	Evaporation (mm/month)	Adjusted mean (mm/month)	Reservoir mean Evaporation (m ³)
January	212.12	169.696	88241.92	
February	224.09	179.272	93221.44	
March	200.33	160.264	83337.28	
April	141.83	113.464	59001.28	
May	98.68	78.944	41050.88	
June	75.19	60.152	31279.04	
July	64.08	51.264	26657.28	
August	61.63	49.304	25638.08	
September	60.8	48.64	25292.8	
October	74.99	59.992	31195.84	
November	130.4	104.32	54246.4	
December	175.82	140.656	73141.12	
Total	1519.96	1215.968	632303.36	

Irrigation Potential of Oyun Reservoir

The maximum value of S_t (Eqn. 3) is the required active reservoir storage capacity for the flow sequence and the considered releases. Table 6 shows the computation of storage required at Oyun dam to meet the specified obligations using the Sequent – Peak method. Based on this method, the total storage required considering the mean river flow is 831,663.36 m³. The net storage capacity of the Oyun Dam reservoir is 2.9×10^6 m³. The estimated sediments yield in the reservoir has been established as

35,250 m³ and the storage required to meet water demand obligation for the dam was established as 831,663.36 m³. This leaves a balance of $2900000 - 35250 - 831663.36 = 2,033,086.64$ m³ for other uses. The Sequent – Peak analysis was done on a monthly basis; thus the amount of water for other uses translates to 0.7844 m³/s. A quick check using the estimated flow data for Oyun dam for a flow duration curve (FDC) method is subsequently presented.

Table 6: Computations of Sequent – Peak Analysis for Oyun Dam

Month	Water Supply (m ³)	Mean Reservoir Inflow (m ³)	Evaporation (m ³)	Losses	Initial Storage (m ³)	Required Storage (m ³)
January	981400	436600	88241.92	0	633,041.92	
February	981400	876000	93221.44	633,041.92	831,663.36	
March	981400	1941200	83337.28	831,663.36	0.00	
April	981400	2027200	59001.28	0.00	0.00	
May	981400	1811600	41050.88	0.00	0.00	
June	981400	2059200	31279.04	0.00	0.00	
July	981400	1779600	26657.28	0.00	0.00	
August	981400	1847700	25638.08	0.00	0.00	
September	981400	4247500	25292.8	0.00	0.00	
October	981400	2291900	31195.84	0.00	0.00	
November	981400	1508900	54246.4	0.00	0.00	
December	981400	1342300	73141.12	0.00	0.00	
Storage Required = 831,663.36						

The FDC is a plot of the number of times a particular flow in a River can be equaled or exceeded. Using the estimated flow data for Oyun dam, the flow duration curve obtained is presented in Figure 3, the 50% dependable flow for the Oyun River is obtained as 0.60 m³/s (1,555,200 m³). Hence the estimated reservoir yield available for other uses is 0.7844 m³/s (2,033,086.64 m³) based on mean flow and corresponds to 40% reliable flow. Again, this information is important as it helps to decide on how much quantity of water can be considered as dependable as a firm flow at any point in time. It helps to determine how much risk can be taken in planting if irrigation is the only source of water especially during the dry season. The estimated average temperature records from 1980 - 2010 for Offa were used to obtain the Crop consumptive use (ET_c) for rice and presented in Table 7. Rice was chosen for this analysis because of its high-water requirement. This implies that the investigation would be valuable for many other crops with lower water requirements. There are two categories of rice; the short-duration varieties mature in 105 – 120 days and

the long – duration varieties mature in 150 days. The crop water requirement throughout the entire growing period is estimated as 1.31 m from Table 7.

Irrigation command areas

(1) Based on sequent peak analysis:

The available water for other uses as already estimated is 2033086.64 m³.

Therefore, the command irrigation area is $2033086.64 / 1.31 = 1551,975 \text{ m}^2 = 155.20 \text{ hectares}$

(2) Based on flow duration curve analysis

The 50% dependable flow for other uses as estimated above is 1555200 m³.

Therefore, the command irrigation area is $1555200 / 1.31 = 1187176 \text{ m}^2 = 119.0 \text{ hectares}$

This is an indication that the irrigation command area of between 119 – 155 Hectares of land can be supplied water from the Oyun Dam after satisfying the primary water supply to the populace. The amount of water available for irrigation and other uses constitutes 57% of the gross storage.

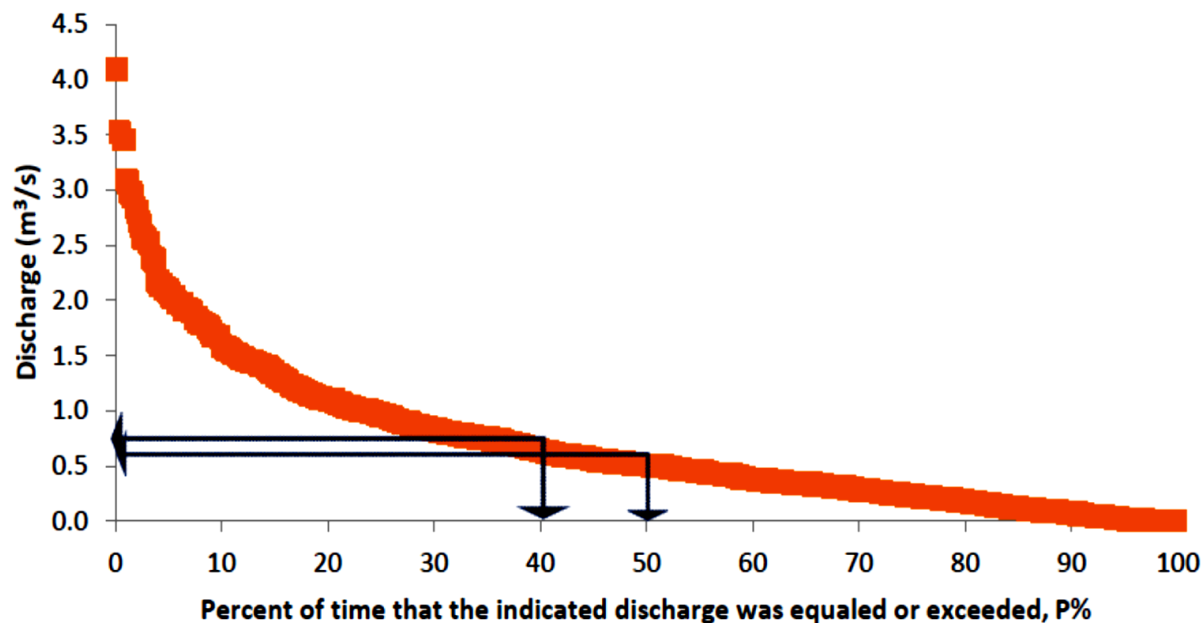


Figure 3 Flow Duration Curve for Oyun River at the Dam location

Table 7: Blaney-Criddle model for calculating monthly consumptive use for Rice

Location: Offa (Lat 8.1393 ° N ; Long 4.7174 ° E)							
Month	Mean monthly temperature (°C)	Mean monthly temperature (°C)	Monthly crop co-efficient (k _c)	Percent day light , hrs (P)	Monthly consumptive use u=k.t.p/100 (in)	Monthly consumptive use u=k.t.p/100 (mm)	
Jan	26.84	80.31		8.12	0.00	0.00	
Feb	28.88	83.99		7.41	0.00	0.00	
Mar	29.41	84.94		8.45	0.00	0.00	
Apr	28.62	83.52	0.85	8.41	5.97	151.75	
May	27.42	81.35	1.00	8.78	7.14	181.53	
Jun	26.27	79.29	1.15	8.54	7.79	197.93	
Jul	26.47	79.64	1.30	8.81	9.12	231.70	
Aug	24.99	76.99	1.25	8.72	8.39	213.29	
Sep	25.58	78.04	1.10	8.26	7.09	180.11	
Oct	26.43	79.57	0.90	8.30	5.94	151.07	
Nov	27.28	81.10		7.89	0.00	0.00	
Dec	26.62	79.92		8.10	0.00	0.00	

$$ET_c = U = 51.44 \text{ in}$$

$$= 130.74 \text{ cm}$$

$$= 1307.38 \text{ mm}$$

5.0 Conclusion

Agriculture will remain the dominant user of water at the global level. In many countries, in particular those situated in the arid and semi-arid regions of the world, this dependency will increase. Water demand for agricultural purposes, among other competing interests, will intensify.

Based on the outcome of the study, the available water for other uses for the Oyun River Dam was estimated to range from $1.56 \times 10^6 \text{ m}^3$ to $2.04 \times 10^6 \text{ m}^3$ with an irrigation command area ranging between 119 to 155 hectares of rice plantation. The estimation done with the FDC takes into consideration the environmental flow as not more than 50% of the available water resources, outside the domestic water supply requirement, is to be utilized. This depends on the varieties of rice planted. Rice plants take around 3-6 months to grow depending on the varieties and environmental conditions. It is to be noted that as the demand for domestic

water supply increases, available water for irrigation, especially during the dry season, will continue to reduce. It is quite significant that at least half of the gross storage of the reservoir can be used for some other beneficial purposes without negatively affecting the primary purpose of the reservoir.

This analysis is based on the long term water supply requirement of the Dam. Rice has been used for this study as the crop water requirement for rice is higher than for most other crops. It is therefore reasonable to conclude that more land can be brought under irrigation if other crops with less water requirement is to be planted. The Sequent-Peak analysis also provides a practical method for the estimation of irrigation potential and exploitation of reservoirs where the primary function of the reservoir does not include agricultural use.

References

- Biemans, H., I. Haddeland, P. Kabat, F. Ludwig, R. W. A. Hutjes, J. Heinke, W. von Bloh, and D. Gerten (2011), Impact of reservoirs on river discharge and irrigation water supply during the 20th century, *Water Resour. Res.*, 47, W03509, doi:10.1029/2009WR008929
- Chao, B. F., Y. H. Wu, and Y. S. Li (2008), Impact of artificial reservoir water impoundment on global sea level, *Science*, 320(5873), 212–214, doi:10.1126/science.1154580.
- Fader, M., S. Rost, C. Müller, A. Bondeau, and D. Gerten (2010), Virtual water content of temperate cereals and maize: Present and potential future patterns, *J. Hydrol.*, 384(3–4), 218–231, doi:10.1016/j.jhydrol.2009.12.011.
- Fetter, C.W. (2007) *Applied Hydrogeology*. 2nd Edition, Merrill Publishing, Columbus.
- Food and Agriculture Organization of the United Nations FAO, (1995), *Irrigation in Africa in figures - L'irrigation en Afrique en chiffres*, Water Reports / Rapports sur l'eau, ISSN 1020-1203, M-54
- Food and Agriculture Organization of the United Nations FAO (1997), *Irrigation potential in Africa: A basin approach*, FAO Land and Water Bulletin 4, FAO Land and Water Development Division, ISBN 92-5-103966-6 Food and Agriculture Organization of the United Nations FAO, AgWA, IFAD (2014). *National Investment Profile: Water for Agriculture and Energy, Nigeria*. [Online] [www.FAO.org/fileadmin/user_upload/agwa/docs-NIGERIA MAY%202014-BTI-AM-DM-v6.pdf](http://www.FAO.org/fileadmin/user_upload/agwa/docs-NIGERIA_MAY%202014-BTI-AM-DM-v6.pdf)
- International Commission on Large Dams ICOLD, (2007), *The World Register of Dams*. ICOLD, Paris. Available at <http://www.icold-cigb.net>.
- Okeola, O. G & Balogun, S.O. (2015), *Estimating a Municipal Water Supply Reliability*, Cogent Engineering, Volume 2, Issue 1.
- Linsley R. K, Frazini J.B., Freyberg D.L. and Tchobanoglous G. (1992), *Water Resources Engineering*, Published by McGraw Hill Publishing Company, New York, USA.
- Micheal A.M (1999), *Irrigation Theory and Practice*, Published by South Asia Books, Hong Kong.
- Mays W.L. and Tung Y.K. (1992), *Hydrosystems Engineering and Management*, Published by McGraw Hill, New York, USA.
- Mustapha M. K. (2008), Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, Using Selected Physico-Chemical Parameters, *Turkish Journal of Fisheries and Aquatic Sciences* 8: 309-319pp
- National Population Commission NPC, (2006) *Population and Housing Census, "Population distribution by Sex, State, LGA, and Senatorial district"*, <http://www.population.gov.ng/images/Vol%2003%20Table%20DSx%20LGAPop%20by%20SDistrict-PDF.pdf>
- Oregon State University (<http://water.oregonstate.edu/streamflow/>)
- Salami A.W. (2007), Fitting Probability Distribution Models to Peak and Low Flows in Selected Rivers in South West Nigeria, *Nigerian Journal of Technological Development (NJTD)*, 5(2), 50-63pp.
- Ugalahi, U. B., Adeoye, S. O. and Agbonlahor, M. U. (2016), Irrigation potentials and rice self-sufficiency in Nigeria: A review, *African Journal of Agricultural Research*. Vol. 11(5), pp. 298-309, DOI: 10.5897/AJAR2015.10284
- World Commission on Dams (WCD) (2000), *Dams and development: A new framework for decision-making*, Earthscan, London.
- World Health Organization (WHO) 1997. *Guidelines for drinking water quality* 2nd edition. World Health Organization. Geneva, 249 pp.