ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT
AZOJETE June 2020. Vol. 16(2):321-336
Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

ORIGINAL RESEARCH ARTICLE

INVESTIGATION OF SMALL HYDROPOWER POTENTIAL OF RIVER OSHIN IN KWARA STATE, NORTH CENTRAL, NIGERIA

A. S. Oladeji[1,2], M. F. Akorede[2], A. A. Mohammed[1], A. G. Adeogun[3], and A.W. Salami[1]

([1]National Centre for Hydropower Research and Development
University of Ilorin, Ilorin, Nigeria
[2]Advanced Power and Green Energy Research Group, Department of Electrical and Electronics Engineering,
University of Ilorin, Ilorin, Nigeria.
[3]Kwara State University, Malete, Nigeria)
**Corresponding author's email address: akinsun3k@yahoo.co.uk*

ARTICLE INFORMATION

Submitted 20 Sept., 2019
Revised 02 February, 2020
Accepted 08 February, 2020

Keywords:
Flow duration curve
Hydropower potential
River Oshin
Budo Umoru

ABSTRACT

This paper presents the investigation of hydropower potential of river Oshin via Babaloma in Ifelodun Local Government Area of Kwara State, North Central, Nigeria. The inhabitants of the study area which is a cluster of three off-grid rural communities: Sangotayo, Budo Umoru and Idi Isin lack access to electrical energy despite the huge potential for renewable energy resources most especially, the hydropower potential. Water velocity of the river was measured using Flow Probe FP211 model. The measured water velocity was converted to discharge using relationship between the channel geometry and velocity. Relationship between measured discharge and water level was used to develop rating equation for the river. Net head was estimated using Digital Elevation Model (DEM) embedded in ArcGIS (ArcMap 10.3) software. The results revealed that the average water level and discharge were high in the month of May through November with discharges varying between 3.48 to 11.90 m^3/s while water levels ranged between 0.79 to 1.84 m. The relationship between the water level and discharge revealed a correlation coefficient of 0.99 with positive upward trend. The design flow of 4.63 m3/s was determined from the flow duration curve (FDC) while the net head was estimated as 7.62 m. The hydropower potential of the river at the sub-basin 9 was estimated as 363.36 kW which is in the range of mini hydropower plants (MHP). Annual energy generation from the river is estimated as 2624482.08kWh. The estimated hydropower potential can satisfy the present and future electricity needs of the inhabitants of the cluster of the three rural communities under consideration.

1.0 Introduction

Presently, electrical energy demand in Nigeria is being met largely with conventional sources of energy such as oil, gas and coal which lead to emission of greenhouse gases into the atmosphere. This results in negative effect of climate change. The world is going green, therefore there is need for assessing and harnessing all the renewable energy sources. But, as the electrical energy demand increases on yearly basis, the conventional sources decreases. Consequently, several countries have focused on renewable energy sources, like hydropower, wind and tidal (Agiralioglu et al., 2017). Renewable energy sources such as hydropower, wind, solar and biomass are important technology options for reducing greenhouse gas emissions and local air pollutants associated with the burning of fossil fuels. Hydropower is currently the dominant renewable energy source accounting for 18% of the world total electricity supply (Zhou et al., 2015). Hydropower is also technically mature and economically competitive. Moreover, hydropower plants can help balancing electricity supply and demand. Therefore, improving the efficiency of thermal power plants and reducing the impacts of variability in other renewable energy resources (Zhou et al., 2015). Increasing the amount of renewable energy for electricity generation (RES-E) is a major target within the European Union as well as global scale (Haas et al., 2011).

Nigeria has been facing serious electrical power shortage due to inadequate power generation, lack of strong political will to develop power system infrastructure, unstable government policies in power sector reform, corruption, in-efficiency in electrical power generation, transmission and distribution among others. According to the Nigerian energy policy report of 2003, it is estimated that the population connected to the national grid system is short of power supply over 60% of time. The estimated long-term power demand of Nigeria was put at 25GW for the year 2010 to sustain industrial growth (Okanefe and Owolabi, 2001). The Power Holding Company of Nigeria (PHCN) has an installed capacity of 6 GW, but the actual available output is less than 2.5 GW out of which thermal plants provides 61%, while hydropower generation is about 31% of the power generation (Okpanefe and Owolabi, 2002). According to Bilewu et al., (2011), the total estimated hydropower potential of Nigeria is 11 GW. This implies that less than 20% of the hydropower potential of the country has been harnessed (Bilewu et al., 2011). Small-scale hydropower is a good and reliable form of sustainable energy supply in rural areas (Reichl and Hack, 2017). It generally has no artificial storage and relies solely on the river flow to generate electricity (Rees et al., 2004).

The definition of a small hydro project differs from one country to another, but a generating capacity not exceeding 10 MW is generally accepted as the upper limit of what can be defined as a small hydro plant in Nigeria (Sambo, 2005; Bilewu et al., 2011; Shobayo et al., 2014). From economic perspective, the cost of developing a small hydropower generating system is considerably low as compare a large hydropower generating systems which usually require the construction of a large dam that usually gulp larger percentage of the overall project cost (Basnyat, 2006; BHA, 2005; Shobayo et al., 2014). Likewise, most small hydropower plants does not require dam construction (without significant water storage facility) hence, the negative environmental impacts such as, ecological disruption; flooding and social conflicts associated with large scale hydro projects are drastically reduced (BHA, 2005; Shobayo et al., 2014).

Small hydropower plants have emerged as a source of renewable energy, which can be easily developed, inexpensive and harmless to the environment. The accurate estimation of discharge is an essential component of hydropower design and constructions for energy generation capacity estimation as well as environment protection on ungauged river basins (Tuna, 2013). In Nigeria, streamflow measurements are carried out by government through River Basin Development Authority (RBDA) and State water boards, which established gauging stations on rivers within their catchment areas and streamflow data can be obtained from them. However, in the past fifteen years it was reported that there was no been streamflow measurements along major rivers in Nigeria due to lack of funding (Adedokun et al., 2013). This is quite worrisome as availability and reliability of hydro-meteorological data are very critical to hydropower potential assessment of rivers globally (Kling et al., 2016).

In a related research, Khan and Zaidi (2015) determined the hydropower potential of Kunhar river in Pakistan using geospatial data and techniques. Satellite data used in the study included ASTER Digital Elevation Model (DEM). Streamflow data was obtained from regional hydrologic gauges. Remote Sensing (RS) and Geographical Information Systems (GIS) tools were used for processing the satellite images, delineation of watershed, stream network and identification of potential sites for hydropower projects. Emeribe et al. (2016) assessed hydropower potentials of some rivers in Edo State, Nigeria for small-scale development. Four rivers namely: Ovia, Ikpoba Edion and Orlie were investigated. Discharge measurement was carried out for 12 calendar months (January to December, 2013) using velocity-area method while gross hydropower potential (GHP) was determined using model developed by United Nations Industrial Development Organization (UNIDO). Results revealed that Ovia river recorded the highest power yield of 61.619 MW due to its high flow rate, making it suitable for a medium hydropower scheme.

Abebe (2014) carried out feasibility study of small hydropower schemes in Giba and Worie sub-basins of Tekeze river in Ethiopia. Discharge for ungauged hydropower potential sites was estimated using the runoff coefficient method. Topographical map and Digital Elevation Model (DEM) of the study area were used for analyzing watershed delineation, river networks, location of the potential sites and gauging stations. The viability of the hydropower potential sites was analysed using RETScreen software. Results revealed that five locations namely: Meskila-1, Meskila-2, Meskila-3, Genfel-1, Genfel-2 and Suluh were feasible with total power of 3591kW. In a similar vein, Prajapati(2015) studied the hydropower potential of the run of river in Karnali Basin in Nepal using GIS and Hydrological Modeling System (HMS). DEM was used to estimate the elevation of upstream and downstream ends of the reaches and daily discharges of the reaches were derived from precipitation data using HMS model with Nash efficiency ranging from 61.7 to 82.02 %. Results showed that design discharge corresponding to 40th percentile flow had total hydropower potential of 14150.80 MW.

Gumindoga et al. (2016) estimated runoff from ungauged catchments for reservoir water balance in the lower middle Zambezi basin in Zambia. This study applied a rainfall-runoff Hydrologic Engineering Centre-Hydraulic Modelling System (HEC-HMS) model with GIS techniques to estimate both gauged and ungauged runoff contribution to the water balance of Cahora Bassa reservoir. The rivers considered in the study were the Zambezi, Kafue, Luangwa, Chongwe, Musengezi and Manyame. DEM hydro-processing technique was used to determine the spatial extent of the ungauged area. A hydrological model, HEC- HMS, was used to simulate runoff from the catchments. Results revealed that the catchment contributed about 12% of the total estimated inflows into the reservoir.

Okorafor et al. (2013) evaluated the hydropower potential of Otamiri river in Imo State, Nigeria for electric power generation. The study involved the estimation of maximum design floods for the watershed using the Gumbels probability distribution method for various return periods (Tr) with the development of unit hydrograph, storm hydrograph, runoff hydrograph and flood duration curve for the catchment area of the river. Soil Conservation Service (SCS) method and other empirical formulas were used to determine peak flow (Qp), lag time (Tl), time of concentration (Tc) and rainfall intensity (Ic). The available flow for power generation, the head of the river was estimated from records provided by the Anambra-Imo River Basin Development

Authority (RBDA) and flow duration analyses were carried out. The results indicated that flows of 50, 75 and 100% chance of occurring had the following 34.5, 11.3 and 1.5 MW power generation respectively.

Kling et al. (2016) assessed the regional hydropower potential of rivers in West Africa. The study covered more than 500,000 river reaches. The theoretical hydropower potential was computed from channel slope and mean annual discharge simulated by a water balance model. The model was calibrated with observed discharge at 410 gauges using precipitation and potential evapotranspiration data as inputs. The results showed that the West Africa regions are classified to have hydropower potentials varying between < 1MW to > 30 MW. Most of the hydropower projects especially small hydropower projects are constructed on ungauged river and consequently hydrologists have for a long time applied streamflow estimation methods to simulate streamflow (Kasamba et al., 2015). The power potential of flowing river is a function of the discharge (Q), the specific weight of water and the difference in head (H) between intake point and turbine (Kasamba et al., 2015). In summary from the literature reviews, it can be concluded that assessment of hydropower of rivers is very vital to design and development of hydropower scheme.

It is a common knowledge that the output of small hydropower plants changes with the hydrological cycle of a river (BHA, 2005; Natural Resources, 2004). Hence, a reliable assessment of available small hydro resource cannot be accomplished without a prior assessment of the hydraulic turbine's response to the annual variability of river flow (Shobayo et al., 2014). It is this assessment that will determine the available of electrical energy at any hydro site. The study area is a cluster of three communities which are located closed to one another but are not connected to the national grid. River Oshin flows along the communities with high hydropower potential before finally discharged into the river Niger. The objective of this study is to investigate the small hydropower potential of the river Oshin in Kwara State, North Central, Nigeria. The small hydropower potential of the river if assessed and harnessed will solve the power challenges of the area.

2. Materials and Methods

2.1 Characteristics of Study Area

The study area is located in Ifelodun Local Government Area of Kwara State, Nigeria and comprises of three (3) rural communities namely: Sangotayo, Budo Umoru and Idi Isin. The study area is a complete off-grid location. The features of each of the rural community are shown in Table 1. The primary source of energy is fuel wood for cooking and secondary source is kerosene for lighting and security in all the three rural communities. The significant commercial activity in these communities is agriculture which involves crop production and animal husbandry. The main crops grown are corn, millet, yam, beans and cassava. The study area is rich in hydro, solar and wind renewable resources.

Table 1. Features of the study area.

Features	Sangotayo	Budo Umoru	Idi Isin
Number of Houses	14	63	9
Number of Shops	3	4	-
Number of Primary Schools	1 shared Primary School	1 shared Primary School	1 shared Primary School
Number of Mosque	1	3	-
Number of Church	-	-	2
Number of Households	70	158	45

Map of Nigeria showing the case study river is presented in Figure 1. The DEM of the river Oshin was geo-processed in ArcGIS tool (ArcMap 10.3). The entire river course was delineated into 11 sub-basins as shown in Figure 1.

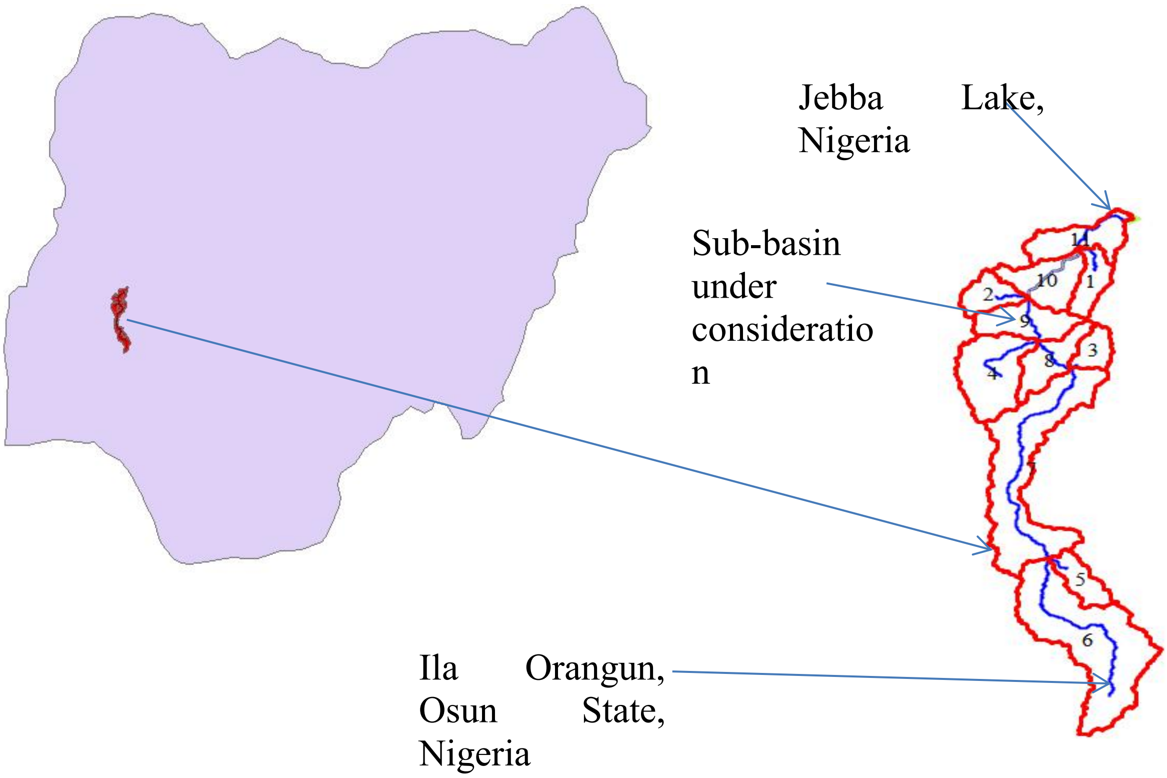

Figure 1: Map of Nigeria showing the case study river catchment

The river has its source from Ila, Orangun, Osun State and flows into Jebba lake. The direction of flow of the river from Ila Orangun to Jebba Lake is presented in Figure 1. The total area of the river course and total stream length was estimated as 2121.86 km2 and 225.77 km respectively. The sub basin that is located near the rural off-grid communities (sub basin where forebay and powerhouse will be located) is sub basin 9. This sub-basin also has a reasonable drop of 28 m and stream length of 13481.00 m with area of 141. 95 m2

2.2 Measurements of stream discharge

River Oshin is an ungauged perennial river. In order to determine its hydropower potential, a hydrological gauge station was installed along a uniform reach of the river to measure the daily water level for a period of one year. A hydrological gauge reader was engaged for a period of one hydrological year to measure daily water level of the river. The flow velocity of the river was measured using Flow Probe model FP211. The Flow Probe model FP211 operates using the principle of water current as a distance which one length of water covered in one second. The velocity of water was measured by dipping the Flow Probe into the river at the various sections of the river channel and readings were taken until the end of the channel. The measure flow velocity at the various section of the river was converted to river discharge using the relationship between the flow velocity and channel cross-sectional as shown in Equation (1) (Wali, 2013). FDC of the river was plotted using the measured discharge data and the corresponding return period estimated using the Equation (2) (Booker and Snelder, 2012). (Oregon State University, 2005; Rajput, 2008; Shobayo et al., 2014).

$$Q = AV \qquad (1)$$

where: A is sectional area (m^2),V is flow velocity (m/s) and Q is discharge (m^3/s).

$$P = \frac{R}{N+1} 100\% \qquad (2)$$

where: P is the percent of time during which specified discharges were equaled or exceeded in a given period (%), R is the rank of observed data and N is total observation. The discharges were arranged from maximum to minimum and ranked from R = 1 to N (Castellarin et al., 2004; Castellarin; 2014).

2.3 Measurement of head

Head is defined as the loss of elevation by the river over its stretch between the water surface at the proposed intake and the river level at the point where the water entered the proposed turbine location (Shobayo et al., 2014; BHA 2005; ESHA, 2004). Contours were generated from 30 m x 30 m DEM of the case study area obtained from United State Geological Survey (USGS) online database. The contours were used to determine the possible location of turbine and forebay. The gross head was estimated using topographical map of the study area, as the vertical distance between the proposed forbay and turbine location. The actual head available for the turning of the turbine is called net head. The difference between the gross head and losses gives net head as presented in the Equation (3). All the losses were estimated using the Equations (4), (6), (7) and (8). The input parameters used in computing the head losses are presented in Table 2 (Ratnayake and Pitawala, 2014). The expression for estimating frictional losses *(h_f)* is presented in Equation (4) (Wali, 2013). The net head is always less than the gross head due to losses suffered when moving the water into and away from the turbine through water carriage arrangements.

$$H_n = H_g - \{h_f + h_{tr} + h_b + h_o\} \qquad (3)$$

where: H_n is net head (m), H_g is gross head (m), h_f is a frictional loss (m), h_{tr} is a trash rack loss (m), h_b is loss due to bend (m) and h_o is outlet loss (m).

$$h_f = \frac{L \times 10.29 \times n^2 \times Q^2}{D^{5.333}} \quad (4)$$

where: *L* (m) is length of penstock, *D* (m) is pipe diameter, *n* is the Manning coefficient for different type of pipes and *Q* (m^3/s) is discharge. The pipe diameter was estimated using Equation (5) (Wali, 2013).

$$D = 10.3 \times 100 \times \frac{n^2 Q^2 L^{0.1875}}{H_g y} \quad (5)$$

where: n is Manning roughness coefficient for commercial pipes, Q is discharge (m^3/s), L is the length of the penstock, H_g is the gross head, *y* is the percent loss of the total gross head due to friction. Raynal et al., (2013) formulated h_{tr} as shown in Equation (6). The expressions for estimating h_b, h_o, velocity in tube (v) and entrance velocity (v_o) are presented in Equations (7) to (10) (Raynal et al., 2013).

$$h_{tr} = K\left(\frac{t}{b}\right)^{4/3}\left(\frac{v_o^2}{2g}\right)\sin\alpha \quad (6)$$

where: K is the factor describing the shape of the rack, t is the bar thickness (mm), b is the width between the bars (mm), v_o is the entrance velocity (m/s), g is gravitational acceleration (m/s2), α is the angle between the grid and the horizontal reference.

$$h_b = k_b \frac{v^2}{2g} \quad (7)$$

where: h_b is losses due to bend, k_b is loss coefficients due to bends.

$$h_o = \frac{v^2}{2g} \quad (8)$$

$$v = \frac{4Q}{\pi D^2} \quad (9)$$

$$v_o = \frac{1}{K1} \times \frac{t}{(t+b)} \times \frac{Q}{S} \times \frac{1}{\sin(\alpha)} \quad (10)$$

S = total grid area

Table 2. Input parameters for estimating head losses.

Parameters	Unit	Value	Remarks
L	m	158	Using topography map of the area
α	(o)	60	
H_g	m	8	Using topography map of the area
t	mm	12	
b	mm	70	
S	m2	5	
K		0.8	Assuming an automatic cleaner is used for the trash rack

2.4 Determination of hydropower and energy potential

The mathematical expression used for estimating the hydropower potential of the river is presented in Equation (11) (Emeribe et al., 2016; Cyr et al., 2011; Raghunath, 2008) while, the annual energy output of the river (E_{ANH}) was calculated using Equation (12) (Cyr et al., 2011).

$$P = \eta \rho g Q H_n \tag{11}$$

Where P is power (W), η is overall efficiency (%), ρ is density of water (kg/m3), g is acceleration due to gravity is 9.81m/s2, Q is discharge (m3/s), H is effective head (m)

$$E_{ANH} = \sum_{t=1}^{8760} P_t \tag{12}$$

Where P_t is power demand at time t (W), η is overall efficiency (%), ρ is density of water (kg/m^3), g is acceleration due to gravity is 9.81m/s^2, Q is discharge (m^3/s), H_n is net head (m).

2.5 Capacity factor

Capacity factor (CF) is defined as the fraction of total energy supplied from a facility over a period of time, divided by the highest energy that could have been delivered if the facility was used at its maximum capacity over the entire period (Jaramillo et al., 2004). The annual capacity factor was calculated using Equation (13) (Adejumobi and Shobayo, 2015). The expression for estimating highest energy (E_{RN}) is shown in Equation (14) (Adejumobi and Shobayo, 2015).

$$CF = \frac{E_{ANH}}{E_{RN}} \tag{13}$$

$$E_{RN} = P_R N_H T \tag{14}$$

where: E_{RN} is the highest energy that could have been delivered if the facility was used at its maximum capacity over period T , P_R is the rated capacity of a single hydro plant unit, N_H is the number of hydro plant units, T is the required annual operating period of time in hours which is equal to 8760 hours, that is the product of number of days in a year with number of hours in a day.

2.6 Relationship between the water level and discharge

The relationship between the water level and discharge for the study area was evaluated so as to validate the discharge data using the correlation coefficient (r) presented in Equation (15) (Giri and Singh, 2014). One way analysis of variance (ANOVA) in Statistical Package for Social Sciences (SPSS) version 16.0 was also used to examine statistical significant difference between discharge and water level at 0.05 level in order to check for variation in the data used.

$$r = \frac{\sum \left(y_{wi} - \bar{y}_{wi} \right)\left(y_{di} - \bar{y}_{di} \right)}{\sqrt{\left(y_{wi} - \bar{y}_{wi} \right)^2 \left(y_{di} - \bar{y}_{di} \right)^2}} \qquad (15)$$

where: y_{wi} is the observed water level, y_{di} is observed discharge , $\bar{y}_{wi}$ is mean of observed water level, $\bar{y}_{di}$ is mean observed discharge, n is total number of observations

3. Results and Discussion

3.1 River Water level and Discharge

The measured water level and corresponding discharge statistics of the river are presented in Tables 3 and 4 respectively. Statistics of the water level and discharge indicated that both hydrological parameters of the river vary with each other. Average water level and discharge were high in the month of May through November with discharges varying between 3.48 to 11.90 m3/s while water levels ranging between 0.79 to 1.84 m. This is due to high streamflow common during raining season. The least water level and discharge of 0.14 m and 0.22 m3/s respectively were observed in April and this may be due to the peak of dry season experienced at that period of the year. Maximum water level and discharge of 2.08 m and 14.3 m3/s respectively were noticed in September, this is as a result of high intensity of rainfall in the month.

Table 3. Monthly water level statistics of the river (m).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.42	0.23	0.19	0.18	0.79	1.03	0.96	1.6	1.84	1.75	1.08	0.618
Min	0.29	0.21	0.17	0.14	0.3	0.88	0.78	0.78	1.6	1.6	0.84	0.28
Max	0.5	0.27	0.2	0.3	1.4	1.48	1.04	2.06	2.08	1.88	1.54	0.84
Std	0.07	0.01	0.01	0.05	0.36	0.16	0.08	0.49	0.17	0.08	0.26	0.172

Table 4. Monthly discharge statistics of the river (m3/s).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	1.25	0.48	0.37	0.33	3.48	4.91	4.36	9.87	11.9	11	5.32	2.278
Min	0.69	0.42	0.3	0.22	0.73	3.8	3.16	3.16	9.55	9.55	3.54	0.652
Max	1.59	0.62	0.39	0.73	7.77	8.47	4.92	14.1	14.3	12.2	9	3.54
STD	0.29	0.04	0.03	0.15	2.29	1.22	0.52	4.33	1.73	0.81	1.98	0.9

Also, the relationship between the water level and discharge revealed a very strong relationship with correlation coefficient of 0.99. The discharge of the river is highly dependent on the water level. Seasonal variation of water level with highest water level in September and least water level in April is presented in Figure 2. Also, the runoff hydrograph for the river which shows the variation in hourly discharge for one year is presented in Figure 3. The variation of water level and discharge for the river shown in Figures 2 and 3 indicated that discharge increases with increase in water level. High discharge and water level were observed in the months of May through November while lower values noticed in January through April. This indicated that the river actually flowed throughout the year; this is an indication that the river can used for hydropower generation, domestic water supply and mini irrigation projects. These corroborate the results presented in Tables 2 and 3. The seasonal variations in the water level and discharge of the river are associated with the rainfall and groundwater contribution within the river catchment based on the available measured data and information received from the people living in the communities around the river catchment (Adedokun et al., 2013). Likewise, high electrical energy potential was observed in the months of May through November while lower values noticed in January through April based on the measured hydrological data of the study area (Salami et al., 2015).

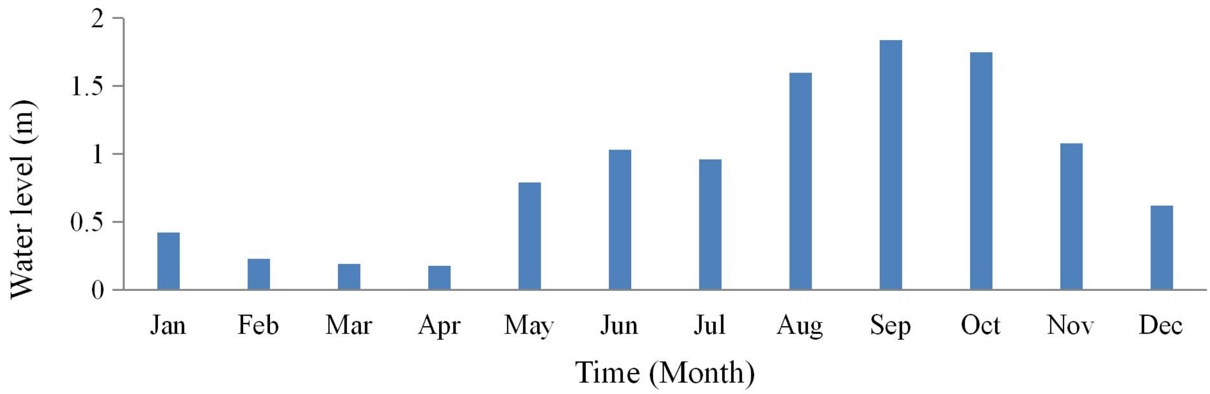

Figure 2. Seasonal variation of water level in theriver.

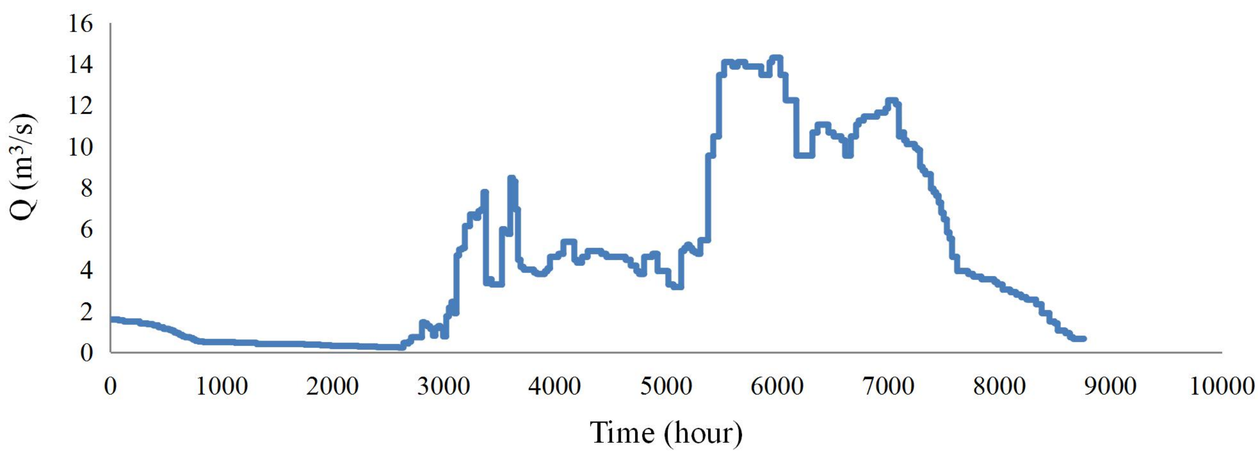

Figure 3. Hourly variation of discharge in the river for one year (January to December, 2017)

ANOVA result for comparison between water level and discharge measured shown in Table 5. It was observed from the ANOVA results that increase in water level results in corresponding increase in discharge. At 5% significant level, p-value was 0.00, this implies that variation is significantly difference. This means that increasing in the water level statistically result in much increase in discharge.

Table 5. ANOVA result for comparison between water level and discharge.

	Sum of Squares	Df	Mean Square	F	p-value
Between Groups	134.86536	105	1.28443	3.8E+32	0.00
Within Groups	8.7236E-31	259	3.4E-33		
Total	134.86536	364			

Scattered plot of discharge against water level shown in Figure 5 revealed that there is a perfect linear relationship between them with the determination coefficient (R2) of 0.98. Therefore, the generated linear equation for the variables can be used to predict the future discharge for the river. Relationship between discharge and water level in Figure 5 revealed that at lower value of water level there is corresponding lower value of discharge. This is depicted in the linear equation presented in the Figure 5 with higher gradient value and low intercept. This is similar to the results presented in (Sefe, 1996).

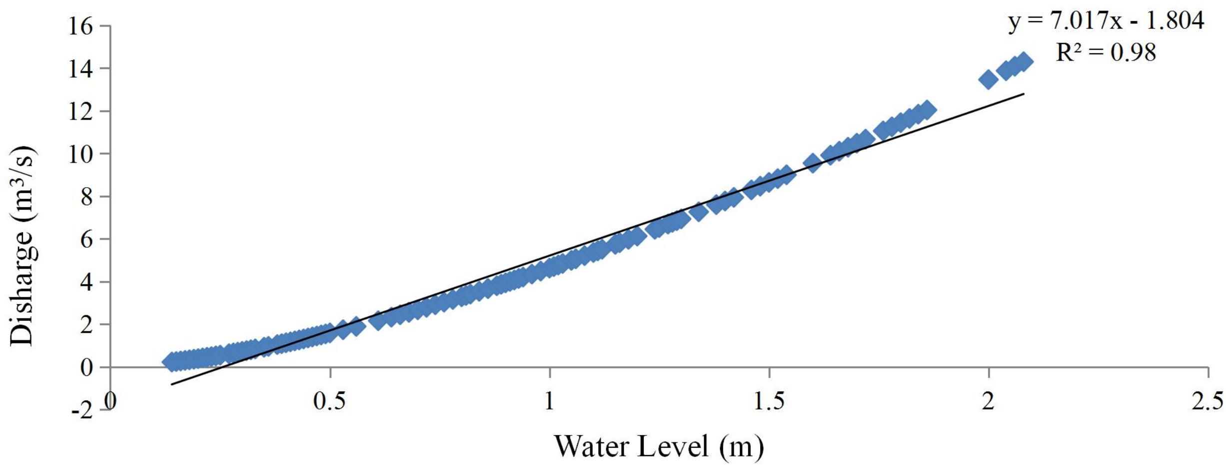

Figure 5. Scattered plot of discharge against water level

Rating curve generated for the river presented in Figure 6 also indicated that there is perfect relationship between the water level and discharge with R^2 value of 0.99. Daily flow duration curve for the Oshin river at Budo Umoru Kwara State shown in Figure 7 revealed that discharge of 0.224 m^3/s will be available throughout the year. Also discharge of 3.670 m^3/s will be available for 50 % of time. This implies that discharge of 3.670 m^3/s will be available in the river for a period of a year (Bilewu et al., 2011).

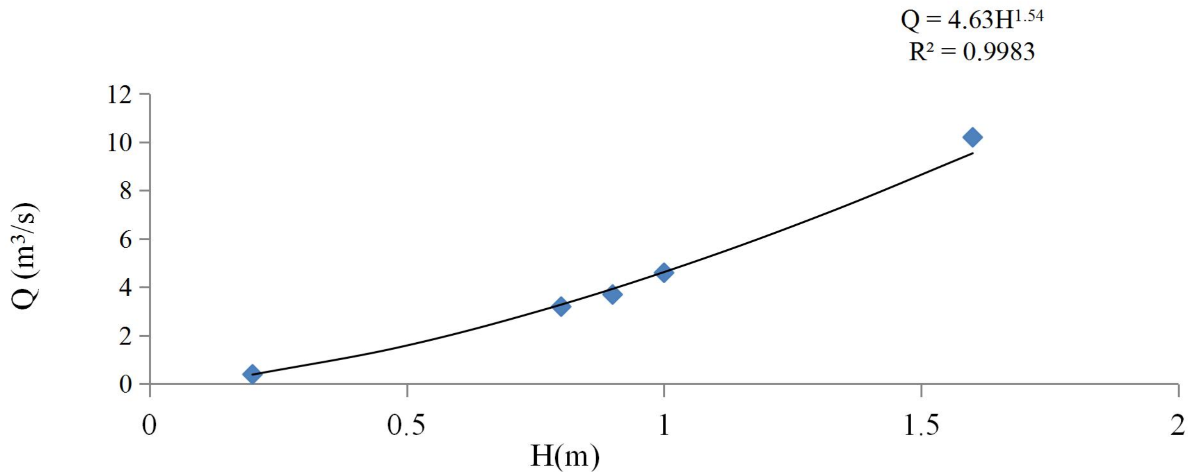

Figure 6. Rating curve generated for the river

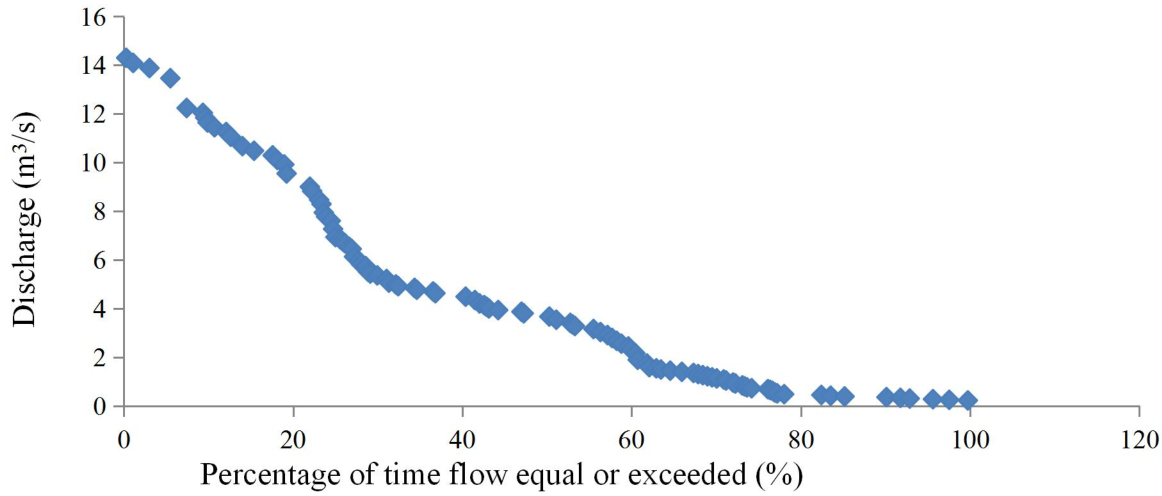

Figure 7. Daily flow duration curve for river Oshin at Budo Umoru Kwara state

3.2 Estimation of Energy Potential of the River

Hourly energy variation for the river for one year (January to December, 2017) shown in Figure 8 revealed that change in the river discharge has a corresponding effect on the quantity of energy generated from the river. Annual energy generation from the river is estimated as 2,624,482.08kWh. Also, the annual capacity factor was estimated as 0.83. This is typically due to variation in water level and discharge (availability of water). Since, the discharge is not constant throughout the year, the capacity factor will always be less than 1 (100%). High energy generation were observed in the months of May through November while lower values noticed in January through April as shown in Figure 8, this is in with (Salami et al., 2011).

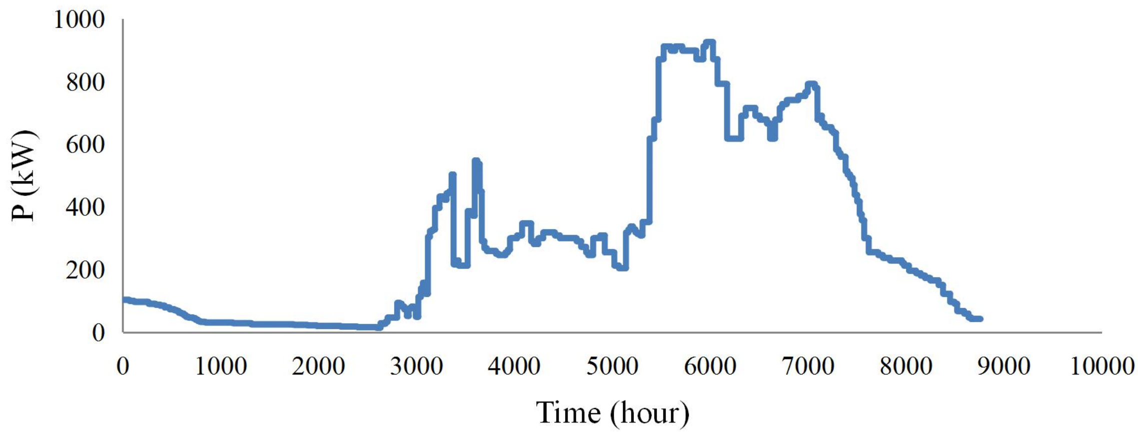

Figure 8. Hourly variation of energy in the river for one year (January to December,2017)

The net head was estimated as 7.62 m. Design flow was estimated as 4.63 m^3/s from the FDC. The hydropower potential of the river at the sub-basin 9 is estimated as 363.36 kW which falls in the range of mini hydropower plants (MHP) (Emeribe et al., 2016). The estimated power can be deployed to satisfy the present and future electricity needs of the nearby rural dwellers.

4. Conclusion

This paper presented the assessment of hydropower potential of River Oshin via Budo Umoru and Environs in North Central Nigeria. The results of this work have shown that there is reasonable small hydropower potential of 363.36 kW at the selected sub-basin along the river. The estimated hydropower potential of the river at the selected sub-basin is in the range of mini hydropower plants (MHP). Annual energy generation from the river is estimated as 2624482.08kWh and the annual capacity factor was found to be 0.83. The potential at this location can satisfy the present and future electricity demand of the inhabitants the cluster of the three rural communities if it is properly and economically harnessed.

Acknowledgements

The authors wish to thank the management of the National Centre for Hydropower Research and Development (NACHRED), University of Ilorin, Ilorin Nigeria for providing funding and enabling environment in the course of this study. We also appreciate the cooperation of the Budo Umoru community for giving necessary supports while the hydrological gauge was installed at the location.

References

Abebe, N. 2014. Feasibility study of small hydropower schemes in Giba and Worie subbasins of Tekeze river. Ethiopia Journal of Energy Technologies and Policy, 4(8): 8-17.

Adedokun, G., Oladosu, JA. and Ajiboye. TK 2013. Small hydropower potential capacity estimation for provision of rural electricity in Nigeria. ACTA Technica Corviniensis, Bulletin of Engineering, Hunedoara Romania, 4(2): 117-120.

Adejumobi, IA. and Shobayo. DI. 2015. Optimal selection of hydraulic turbines for small hydro electric power generation: A case study of Opeki river, south western Nigeria. Nigerian Journal of Technology, 34(3): 530-537.

Agiralioglu, NE., Andic, G., Cigizoglu, HK., Coskun, HG., Yilmaz, L., Alganci, U. and Toprak, ZF. 2017. Practical methods for the estimation of hydroelectric power potential of poorly gauged basins. Sigma Journal of Engineering and Natural Science, 35(2): 347-358.

Basnyat, D. 2006. Fundamentals of small hydro power technologies, financing cogeneration and small-hydro projects in the sugar and tea industry in east and southern Africa Training, Nairobi, Kenya. ADB FINESSE Training Course on Renewable Energy and Energy Efficiency for Poverty Reduction, pp. 5-36.

BHA, 2005. British Hydropower Association, "A guide to United Kingdom Mini–hydro developments", Version 1.2, London, United Kingdom. Available on line at: http://www.british-hydro.org/Useful20%Information/A20% . Accessed online on 23rd January, 2018

Bilewu, SO., Salami, AW., Sule, BF., Adeleke, OO., Usman, A. and Jimoh, MO. 2011. Retrofitting Asa water supply dam for hydroelectric power generation. A technical report number 6, submitted to National Centre for Hydropower Research and Development, University of Ilorin, Ilorin, Nigeria. pp. 1-75

Booker, DJ. and Snelder, TH. 2012. Comparing methods for estimating flow duration curves at ungauged sites. Journal of Hydrology, 4(3): 78-94.

Castellarin, A. 2014. Regional prediction of flow-duration curves using a three-dimensional Kriging. Journal of Hydrology, 513: 179-191.

Castellarin, A., Galeati, G., Brandimarte, L., Montanari, A. and Brath. A. 2004. Regional flow-duration curves: reliability for ungauged basins. Advances in Water Resources, 27: 953-965.

Cyr, JF., Landry, M. and Gagnon. Y. 2011. On the large scale assessment of small hydroelectric potential: application to the province of New Brunswick (Canada). World Renewable Energy Congress, 8th -13th May, 2011, Linoping, Sweden, 55: pp. 1472-1479.

Dashora, I. 2015. Hydrological Investigations and Analysis for Hydropower Projects. Ph.D. Thesis, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, India. pp. 1-250.

Emeribe, CN., Ogbomida, ET., Fasipe, OA., Biose, O., Aganmwonyi, I., Isiekwe, M. and Fasipe, IP. 2016. Hydrological assessments of some rivers in Edo State, Nigeria for small-scale hydropower development. Nigerian Journal of Technology, 35(3): 656-668.

ESHA2004.European small hydropower association, "Guide on How to develop a small hydropower plant", ESHA, Brussels, Belgium,. available on line at: http://www.esha.be/fileadmin/esha_files/documents/publications/GUIDES/GUIDE_SHP/GUIDE_SHP_EN. pdf. Accessed online on 23rd June, 2018.

Giri, A. and Singh. NB. 2014. Comparison of artificial neural network algorithm for water quality prediction of river Ganga. Environmental Research Journal, 8(2): 55-63.

Gumindoga, W., Makurira, H., Phiri, M. and Nhapi. I. 2016. Estimating runoff from ungauged catchments for reservoir water balance in the lower middle Zambezi basin. Water and Sanitation Association, 42(4): 641-649.

Haas, R., Panzer, C., Resch, G., Ragwitz, M., Reece, G. and Held, A. 2011. A historical review of promotion strategies for electricity from renewable energy sources in EU countries. Renewable and Sustainable Energy Reviews, 15:1003-1034.

Jaramillo, OA., Borja, MA. and Huacuz, JM. 2004. Using hydropower to complement wind energy: A Hybrid system to provide firm power. Renewable Energy, 29: 1887-1909.

Kasamba, C., Ndomba, PM., Kucel, SB. and Uamusse, MM. 2015. Analysis of flow estimation methods for small hydropower schemes in Bua River. Energy and Power Engineering, 7: 55-62.

Khan, M. and Zaidi, AZ. 2015. Run-of-river hydropower potential of Kunhar river, Pakistan. Pakistan Journal of Meteorology, 12(23): 25-32.

Kling, H., Stanzel, P. and Fuchs, M. 2016. Regional assessment of the hydropower potential of rivers in West Africa. Energy Procedia, 97: 286 -293.

Natural Resources, 2004. Small hydro project analysis chapter, RETScreen engineering and cases textbook, Published by Natural Resources Canada. Ottawa, Canada, Catalogue No. M39 – 38/2003E.

Okorafor, OO., Okereke, NAA. and Egwuonwu, CC. 2013. Evaluation of the hydropower potential of Otamiri river for electric power generation. Research Journal of Applied Sciences, Engineering and Technology, 6(24): 4541-4547.

Okpanefe, PE. and Owolabi, S. 2002. Small hydropower in Nigeria. A TCDC training workshop in small hydropower programme. Hangzhou, China, pp. 1-24.

Oregon State University, 2005. "Analysis techniques: flow duration tutorial", in stream flow evaluations for watershed restoration planning and design. Available on line at:http://streamflow.engr.oregonstate.edu/analysis/flow/Flow_Duration_Tutorial.pdf. Springer, London, (accessed on 14th March, 2018). pp. 1-85.

Prajapati, RN. 2015. Delineation of run of river hydropower potential of Karnali basin-Nepal using GIS and HEC-HMS. European Journal of Advances in Engineering and Technology, 2(1): 50-54.

Raghunath, HM. 2008. Hydrology Principle, Analysis and Design, A revised second edition, new age international limited publishers, New Delhi, India. pp. 1-463.

Rajput, RK. 2008. A textbook of Power Plant Engineering. Laxmi Publications Limited, New Delhi, India.

Ratnayake, AS. and Pitawala, A. 2014. Prediction of ungauged river basin for hydropower potential and flood risk mitigation: A case study at Gin River, Sri Lanka. Interdisciplinary Environmental Review, 15(4): 203-214.

Raynal, S., Courret, D., Chatellier, L., Larinier, M. and David, L. 2013. An experimental study on fish friendly trash racks. Journal of Hydraulic Research, 51(1): 56-66.

Rees, G., Gustard, A. and Kansakar, SR. 2004. Development and testing of a flow estimation model for nepal. Journal of Hydrology and Meteorology, 1(1): 16-23.

Reichl, F. and Hack, J. 2017. Derivation of flow duration curves to estimate hydropower generation potential in data-scarce regions. Water, 9(2): 1-15.

Salami, A.W., Mohammed, A.A., Adeyemo, J.A. and Olanlokun O.K. 2015. Modeling of reservoir inflow for hydropower dams using Artificial Neural Network. Nigerian Journal of Technology, 34(1): 28-36.

Sambo, S. A. 2005. Renewable energy for rural development: The Nigerian perspective, ISESCO science and technology vision, Volume 1, ISESCO - Islamic Educational, Scientific and Cultural Organization, Rabat, Kingdom of Morocco, pp. 12-22.

Sefe, FTK. 1996. A Study of the stage-discharge relationship of the Okavaiigo river at Mohembo, Botwana. Hydrological Science, 41(1): 97-116.

Shobayo, DI., Adejumobi, IA., Awokola, OS., and Akinwale, AT. 2014. An assessment of the small hydro potential of Opeki river, southwestern Nigeria. Science Journal of Energy Engineering, 6(3): 25-31.

Tuna, MC. 2013. Feasibility assessment of hydroelectric power plant in ungauged: A case study. Arabian Journal of Science and Engineering, 38: 1359-1367.

Wali, U.G. 2013. Estimating hydropower potential of an ungauged stream. International Journal of Emerging Technology and Advanced Engineering, 3(11): 592-600.

Zhou, Y., Hejazi, M., Smith, S., Edmonds, J., Li. H., Clarke, L., Calvina, K. and Thomson A. 2015. A Comprehensive view of global potential for hydro-generated electricity. Energy Environmental Science, 8: 2622-2633