HYDROPOWER POTENTIAL ASSESSMENT OF RIVER OSHIN AT BUDO UMORU AND ENVIRONS IN NORTH CENTRAL NIGERIA

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Abstract

Large populations in rural areas of Nigeria lack access to electrical energy despite huge available renewable energy potential in the country. This study was carried out to assess the hydropower potential of river Oshin at Babaloma in Ifelodun, Kwara State, Nigeria. ***A*** *hydrological gauge station was installed along the river section to measure the daily water level for a period of one year (January to December, 2017). The measured water level was converted to discharges using the relationship between the channel geometry and velocity. Water velocity was measured using Flow Probe model FP211. The net head was estimated as 7.62 m while Digital Elevation Model (DEM) embedded in Geographical Information System (GIS) software ArcGIS (ArcMap 10.3) was used to mark proposed locations of intake and powerhouse. The entire river course was delineated into 11 sub-basins. The sub basin with reasonable drop and which is also close to the nearby off-grid rural communities is sub basin 9. This is where the forebay and powerhouse will be located. Design flow was estimated as 4.63m^3/s from the flow duration curve (FDC). The hydropower potential of the river at the sub-basin 9 was estimated as 363.36 kW which is in the range mini hydropower plants (MHP). Annual energy generation from the river is estimated as 2624482.08kWh. Also, the annual capacity factor was found to be 0.83.*

Acknowledgements

The authors wish to acknowledgement 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.

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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 many reasons 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 provide 61%, while hydropower generation is about 31% (OPICL, 2008). According to Zarma (2006), 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; Zarma, 2006: Shobayo *et al*., 2014). From economic perspective, small hydroelectricity generation is marginal since a large dam that usually renders the project economically unattractive is not required (Basnyat, 2006; BHA, 2005; Shobayo *et al*., 2014). Likewise, most small hydropower plants are run of river (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 an energy source which is renewable, 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, who established gauging stations on rivers within their catchment area 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 this study include ASTER Digital Elevation Model (DEM). Streamflow data was acquired 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, 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 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 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. An 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 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 (T_r) 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 (Q_p), lag time (T_l), time of concentration (T_c) and rainfall intensity (I_c). The available flow for power generation, the head of the river was estimated from records provided by the River Basin Development Authority (RBDA) and flow duration analyses were carried out. The results indicated that flows of 50, 75 and 100% return period 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 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 used streamflow estimation methods using the mean annual flows to gauge rivers (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 potential of rivers is very vital to its design and development.

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 electrical energy at any hydro site. Assessment of hydropower potential of river Oshin which is located at Budo Umoru via Babaloma in Ifelodun local government area, Kwara State, North Central, Nigeria is presented. The evaluation is carried out with the intent to generate electricity for the neighbouring communities.

2.0 Characteristics of the 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. The feature of the region is represented in Table 1.

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

Source: Authors field survey

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. 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 km^2 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 m^2

3.0 Methods

3.1 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. The measured water level was converted to discharges using the relationship between the channel geometry and velocity. The flow velocity was measured using Flow Probe model FP211. To harness available hydropower potential, prediction and analysis of flow duration curve (FDC) and uncertainty analysis for regionalized FDC development is required (Dashora, 2015). FDC can be plotted from historical discharge time-series where records of sufficient length are available (Booker and Snelder, 2012). The measured daily discharge of the Oshin river was used to generate the FDC for the river. An estimation of the area of the region under the FDC provided the average yield of the stream, hence the average flow rate (Q) for the multi-year period (Oregon State University, 2005; Rajput, 2008; Shobayo *et al*., 2014). The discharges were arranged from maximum to minimum and ranked from R = 1 to N (Castellarin *et al.,* 2004 Castellarin; 2014).

The discharge can be calculated using Eqn1. The percentage of time *(P)* flow equals or exceeds a given value was estimated using Eqn 2.

$$Q = AV \tag{1}$$

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

$$P = \frac{R}{N+1}100\% \tag{2}$$

Where *P* is percentage of time flow equals or exceeded (%), R is the rank of observed data and N is total observation.

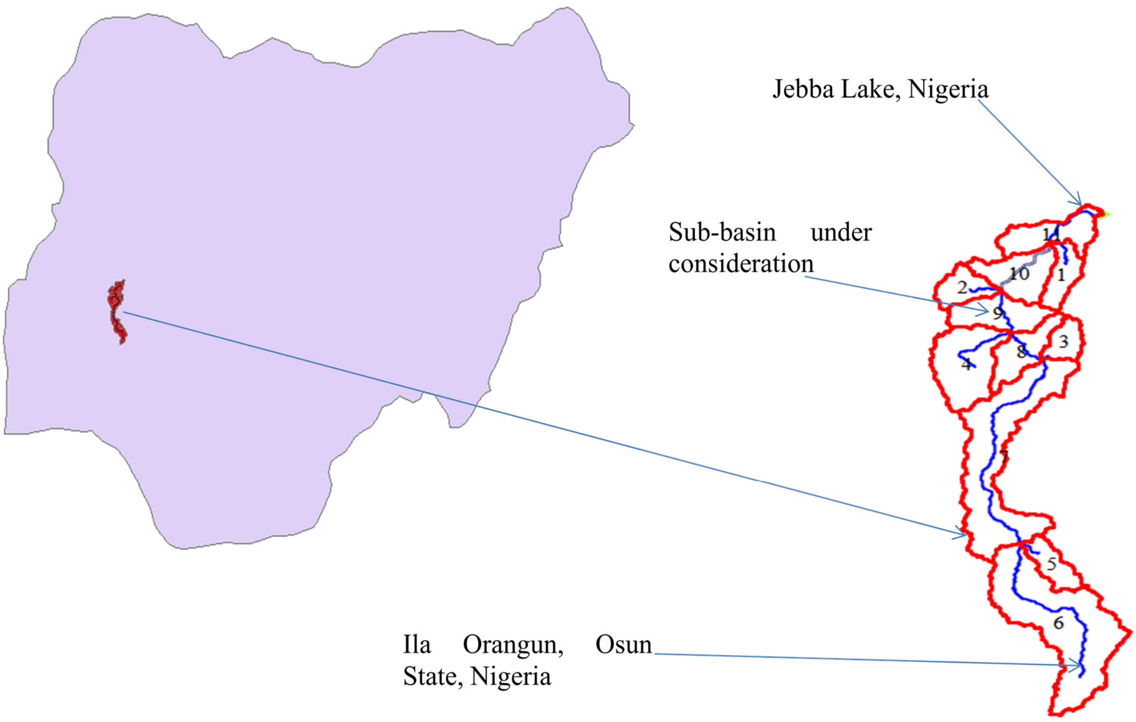

Figure 1: Map of Nigeria Showing the Case Study River Catchment

3.2 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 will be returned (ESHA, 2004; BHA 2005; Shobayo *et al*., 2014). The gross head can be estimated using topographical map of the study site. The actual head available for the turning of the turbine is called net head. The net head is always not as much as the gross head as a result of losses suffered when moving the water into and away from the turbine through water carriage arrangements.

Contours were generated from the DEM of the case study area. The DEM is of resolution 30 m x 30 m and was obtained from United State Geological Survey (USGS) online database (www.srtm.org). The contours were used to determine the possible location of turbine and forebay. The information was used to determine the net head which is the vertical distance between the turbine and the forebay. The input parameters used in computing the head losses are presented in Table 2. Net head was designed by applying Eqn 3. The expression for estimating frictional losses (h_f) is presented in Eqn 4.

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

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 losses due to bend (m) and h_o is outlet losses (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 can be estimated using Eqn 5.

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

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 Eqn 6. The expressions for estimating h_b, h_o, velocity in tube (v) and entrance velocity (v_o) are presented in Eqns 7 to 10.

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

Where K is the factor describing the shape of the rakes, 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/s^2), 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	(°)	60	
H_g	m	8	Using topography map of the area
t	mm	12	
b	mm	70	
S	m^2	5	
K		0.8	Assuming an automatic cleaner is used for the trash rack

3.3 Determination of hydropower and energy potential

The outcomes of the FDC and net head were used to estimate the hydropower potential of the river. If discharge and net head are known for a given stream, the hydropower potential of the stream can be easily determined. Relationship between the water level and discharge at the location was evaluated using the correlation coefficient (r). One way analysis of variance (ANOVA) in Statistical Package for Social Sciences (SPSS) version 16.0 was also used to examine statistical significant difference at 0.05 level between discharge and water level.
The mathematical expression used for estimating the hydropower potential of the river is presented in Eqn 11 (Raghunath, 2008; Cyr *et al.,* 2011 Raghunath, 2008) while, the annual energy output of the river (E_{ANH}) can be calculated using Eqn 12.

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

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

3.4 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 can be calculated using Eqn 13. The expression for estimating highest energy (E_{RN}) is shown in Eqn 14.

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

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

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 operating period which is equal to 8760 hours.

3.5 Relationship between the water level and discharge

The relationship between the water level and discharge at the location was evaluated using the correlation coefficient (r) presented in Eqn 15 (Giri and Singh, 2014).

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

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

4.0 Analysis of data and results

4.1 Analysis of data

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 m^3/s while water levels ranging between 0.79 to 1.84 m. The least water level and discharge of 0.14 m and 0.22 m^3/s respectively were observed in April, 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 m^3/s respectively were noticed in September, this is as a result of high intensity of rainfall in the month.

Table 3: Statistics of monthly water level (m) in the river.

	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: Statistics of monthly discharge (m^3/s) in the river.

	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 correlation coefficient of 0.99. 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 seasonal variations of water levels and discharges for the river presented in Figures 2 and 3 revealed that discharge varies with water level. High water level and discharge were observed in the months of May through November while lower values noticed in January through April. This indicated that the river actually flow throughout the year, which is a plus to the ability of the river being 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. Likewise, high electrical energy generation was observed in the months of May through November while lower values noticed in January through April. This was also due to rainfall.

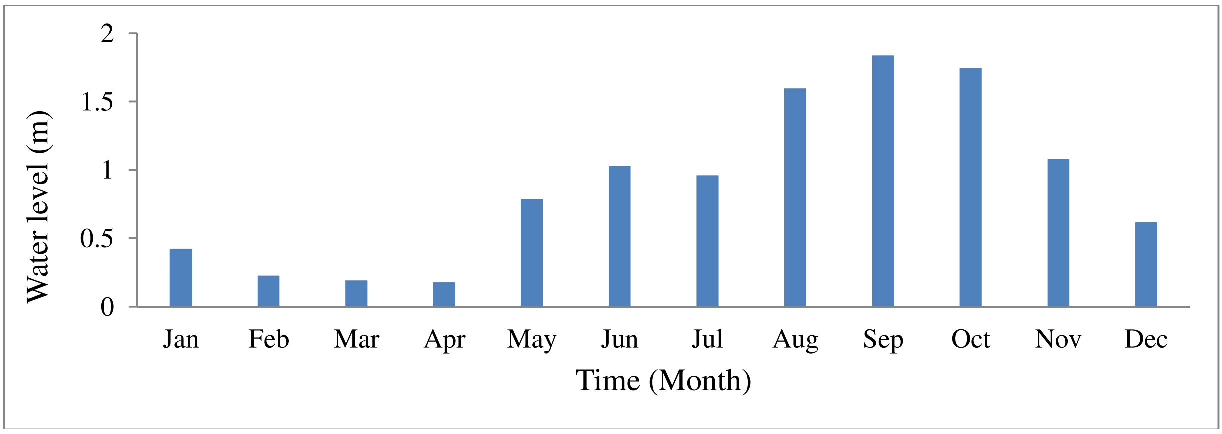

Figure 2: Seasonal variation of water level in the river.

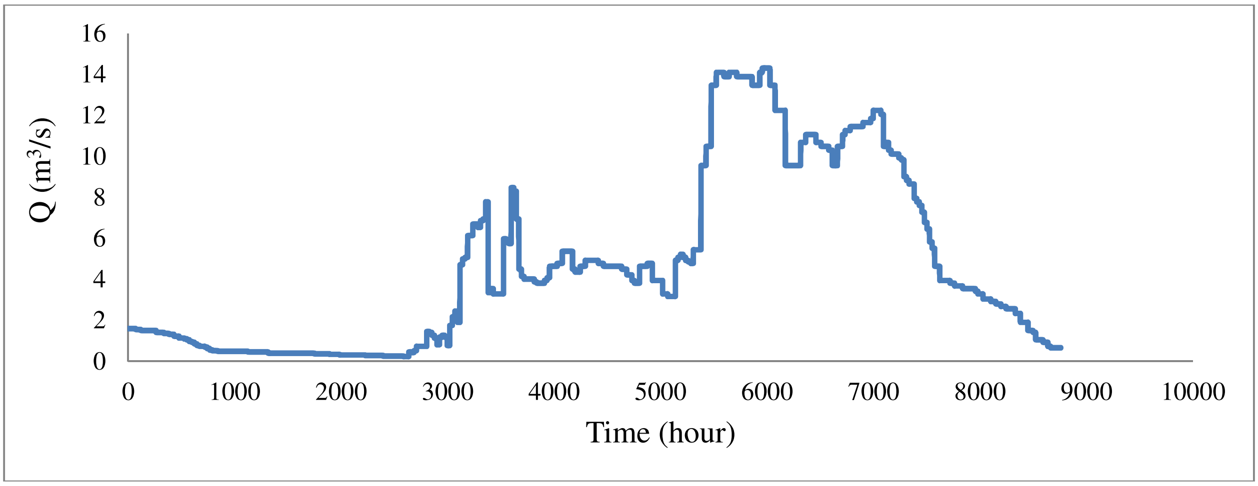

Figure 3: Hourly variation of discharge in the river for one year (January to December, 2017)

ANOVA result for comparison between water level and discharge measured shown in Table 5 at 0.05 level of significant revealed that there is no significant difference in the two hydrological variables since the p-value 0.00 is less than 0.05. This implies that two the variables are closely related and can be used interchangeably.

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 (R^2) of 0.98. Therefore, the generated linear equation for the variables can be used to predict the future discharge for the river.

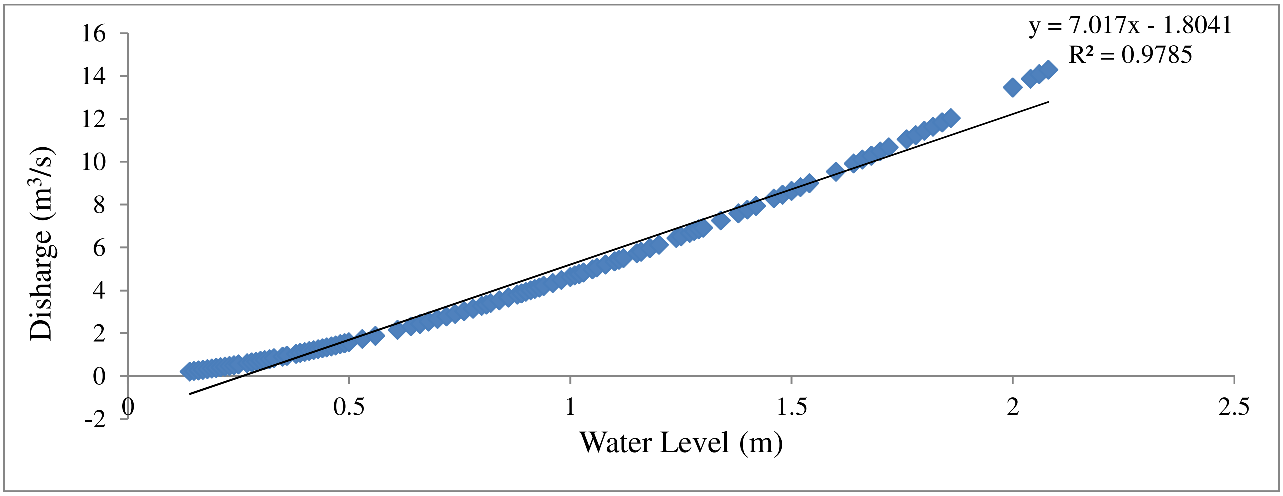

Figure 5: Scattered plot of discharge against water level.

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.

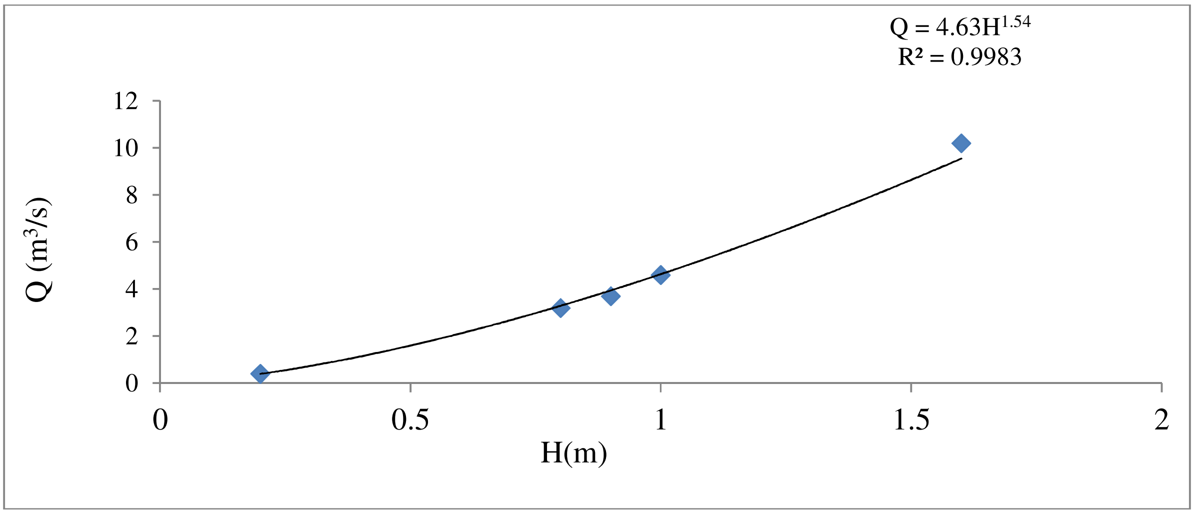

Figure 6: Rating curve generated for the river.

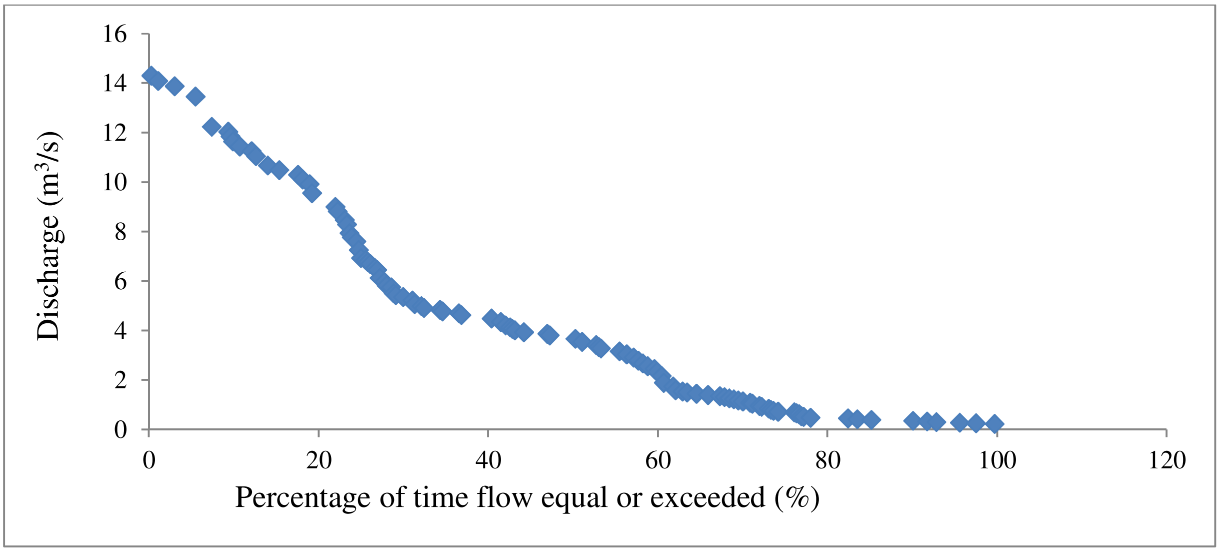

Figure 7: Daily flow duration curve for river Oshin at Budo Umoru Kwara state.

4.2 Results

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 2,624,482.08 kWh. 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.

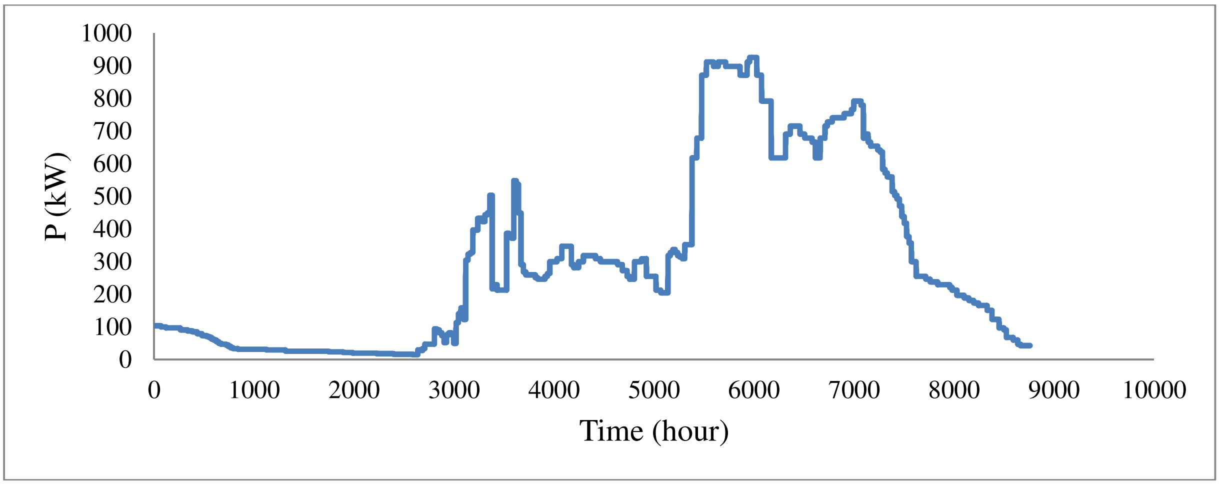

Figure 8: Hourly variation of energy in the river for one year (January to December, 2017)

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). The estimated power can be deployed to satisfy the present and future electricity needs of the nearby rural dwellers.

Conclusion

This paper presented the hydropower potential assessment of River Oshin at Budo Umoru and Environs in North Central Nigeria. The results of this work have shown that there is reasonable small hydropower potential at the selected sub basin along the river Oshin in Kwara State. The potential at this location can meet up with the present and future electricity demand of the nearby rural communities if it is properly and economically harnessed. The hydropower potential of the river at the selected sub-basin 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 and the annual capacity factor was found to be 0.83.

Acknowledgements

The authors wish to acknowledgement 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.

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