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Preliminary Study of Small Hydropower Potential Along River Yedseram, Northeastern Nigeria

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ABSTRACT: Despite abundance strategic of how importance is the river to the nation, utilization of rivers in Nigeria were fairly untapped and is highly needed, especially hydropower. The purpose of this preliminary study is to estimate the potential of small hydropower scheme along river Yedseram, emphasizing on discharge, head and power output available at the catchment area. Viable result was obtained with an estimated annual discharge between 108.82-114.20 m^3/s at 10 m head and 10.74 MW average output power. Authors recommends further studies to worth it consideration.
Keywords: Hydropower, Preliminary, Head, Discharge, Yedseram

I. INTRODUCTION

There have been growing interests in research and development into Small hydropower (SHP) systems in Nigeria. SHP is the most suitable energy resource for providing reliable electricity to rural remote areas especially in mountainous regions, where there are steep, fast-flowing mountain streams and lowland areas with wide rivers. And, it has been strongly advocated in Nigeria that since small-scale hydropower systems possesses obvious advantages over large hydro systems and that problems of topography are not excessive; they can be set up in all parts of the country so that the potential energy in the large network of rivers can be tapped and converted to electrical energy [1]. SHP scheme is cheaper source electricity, as well as helpful in the development of small industries, irrigation, fisheries, tourism, recreational, provision of employment, and drinking water across a wide range of new technologies to reduce gas emissions to meet up renewable energy generation demand. Today approximately 1.9% of the world's total power capacity, 7% of the total renewable energy capacity and 6.5% (< 10 MW) of the total hydropower capacity is covered by SHP [2]. The hydropower potentials of small rivers and swift flowing streams in Nigeria has been estimated to be about 736MW of electrical energy [3].

Nigeria is blessed with hundreds of rivers that could be dammed to serve the dual purposes of township water supply (for domestic and industrial uses) and electricity generation [4]. With an increase of energy demand, with respect to population increase in the Nigeria, most of their rivers are yet to utilized, and would take long leading time before seeing the light. This number keeps increasing despite the rural electrification programmes because they are not sufficient to cope with the population growth or the political will in some of the places is not strong enough or absent [5]; [1]. However, selecting the most promising sites requires detailed and careful study for all the proposed sites before taking the final decision in setting up the hydropower system. Normally a hydropower site begins with a preliminary study of river to find out the best possible configuration. A preliminary study is the first organised step in the hydropower investigation, planning, design and implementation. Preliminary studies of SHP are much concerned with the location, availability of water, head, expected power output, economic and environmental impact, covering the present, past and future needs of people around the catchment area. Preliminary study gives clear indications whether or not to study the project in more detail and may change considerably as a result of meeting up the deficiencies from further investigation.

In practice, sites that are suitable for SHP schemes vary greatly with location. The site where the small hydropower is installed must have sufficient head and enough water flow rate to produce sufficient amount of energy and the site must also be close to the location where the energy is going to be utilized [3]. SHP are generally of three main sources of hydropower schemes are: run of the river, dam based (storage scheme) and pumped storage systems. In Run off River (RoR), hydropower production is driven by the natural flow and elevation drop of a river (Medium and high head sites derive nearly all their head from the natural gradient). Reservoirs hydropower, is driven by the volume of water flow and the amount of hydraulic head available. The RoR is considered as overland flow so long as it does not join the nearest stream. It is better to have more head than more flow, because on its own does not contain sufficient energy for useful power production except on a very largescale, such as offshore marine currents. Based on this, low-head hydropower generation require reservoirs or dams across rivers in order to increase the head, (that is to say the higher the dam, the higher the head for sufficient discharge). That is to say, the power generated is proportional to the product of head and discharge. Head is the vertical distance between the top of the penstock that conveys the water under pressure (upstream level) and the point where the water discharges from the turbine (downstream level). While, discharge refers to the water flow occurring at the horizontal surface rivers and streams, often expressed in volume of water per unit of time (m^3/s). Sometimes, often defined as the rate of flow or the volume of water that passes through a channel cross section in a specific period of time. The cost of constructing SHP plant tend to be lower with natural higher elevated head.

Nigeria has numerous rivers, where most of them are technically viable for hydropower, but certainly they remain untapped. River Yedseram is one of them, chosen based on energy demand, hydrological, geological and environmental conditions of the region to carryout preliminary study to assess whether it worth consideration for SHP potential or not. This study emphasize to estimate the potential of discharge, head and power output available at catchment area.

II. METHODOLOGY

A. Study Area

The Catchment area of interest span to a very large area, which cuts across North-Eastern part of Nigeria and Far North part of Cameroon boundary. It is located within 12.30908 North latitude and 14.13963 East longitude. From a geological point of view, river Yedseram is situated in mountainous region, with hilly, steppy, and cliffs terrains, with an average elevation of 540m high above the sea level.The major towns around the river are Gella, Mubi, Uba, Bazza, Michika, Lassa, and Gulak. River Yedseram is one of the main sources of Chad basin. River Yedseram experiences three seasons a year: from October to March, it is the dry cool season, with the temperature between 19-26℃, most crops harvested by then; from April to June, it is the dry, hot season, with the temperature between 26-33℃; from June to September, it is the warm, wet season, which has a relatively higher temperature than the dry cool.

The people of the area are predominantly Gude, Fali, Margi, Kilba, Higgi and Fufulde by tribes, farmers and they highly depend on local businesses. They mostly plant maizes, beans, groundnut, and sorghum. There major source of energy are; dry cell for touch light, firewood, crop residual, animal dung for cooking and heating.

Figure 1: Location of proposed site along river Yedseram

B. Discharge and Head Estimation

The salt gulp, bucket, kirpich, giandotti, float, Propeller devices and Stage/control are methods mostly adopted for discharge measurements. But, for the purposes of this study, non of them were adopted. Determination of discharge,symbolized as Q usually requires three measurements: time, amount of rainfall and the catchment area. A simple mapping and GIS tools called UTM Geo Map, version 2.8.4, an Android app, developed by Geodesy Engineers was used to estimate the size of the catchment area (as shown in figure 2) to determine the quantity of water available for discharge. Such an estimation can be made simply using nearby historical rainfall data. Monthly rainfall data on the catchment area for 2014, 2015, 2016 and 2018 obtained from Adamawa State University, Mubi, meteorological station was used. Therefore, to calculate discharge, total amount of rainfall on a catchment area in an average months or years (V) were used, given as:

$$V = A.R_f \quad (1)$$

Where, V=Volume of water, A=Catchment area (m^2) and R_f=Average annual rainfall (mm)
Therefore, discharge can be estimated using equation 2 as;

$$Q = \frac{V}{365 \times 86400} \quad (2)$$

Figure 2: Major tributaries of river Yedseram

Figure3: Map of the catchment area

It is important to recognize that the discharge varies with head. Different methods are using for head measurements including: Water-filled tube (with rods or person), Water-filled tube and pressure gauge, Spirit level and plank (or string), Altimeter, Sighting meters, builder's levels and Map. But this study uses an Android app called My Elevation, version 1.61, developed by RDH software, to measure head. The application is reliable and effective for elevation measurements. The altitudes at the propose water intake and at the discharge outlet was taken, and the difference is recognized as the head. Thehead was estimated using the following expression:

$$H_n = h_2 - h_1 \quad (3)$$

where, h_2 is the height of the river at upstream (m) and h_1 is the height at the top of downstream (m).

C. Estimating Power Output

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Turbines is used to convert the energy stored in the falling water into the rotating shaft power. By knowing the discharge and elevation (head) with respect to rainfall data one can estimate the power of water generated on the catchment area. The power calculation is a function of the head, the flow rate, and the acceleration due to gravity [6].

$$P_{out} = Q.H_n.g \quad (4)$$

Also, the output power generation from the hydro turbine (P_{out}), can be estimated by the following expression [7]:

$$P_{out} = \rho.g.H_n.\eta_t.\eta_g.Q \quad (5)$$

where are: P_{out} (W) is the power output, ρ (kg/m3) is the water density, g (m/s^2) is gravity acceleration constant, H_n (m) is the net downward water height, η_t (%) is the maximum efficiency of hydro turbine (η_t = 0.93), η_g (%) is the generator efficiency (η_g = 0.97), Q is discharge.

III. RESULT AND DISCUSSION

A. Estimated Discharge and Head of the Catchment Area

A preliminary selection of appropriate installation site was dedicated between Izge Rana and Kobchi villages, at 10°55'23"N and 13°19'39"E with an average of 400m above the sea level. The site(sometimes called Gambole river) was selected based on the suitability of head and the large collection river tributaries. The terrain were highly complex (steppy head), at different sizes within the location (as shown cutted in red color in Fig.1). Approximately measured 10m head for this study. On the basis of available head, the SHPP are of three type; high head (>50m), medium head (10-50m) and low head (<10m) [8]. This shows how importance the head is for installation of SHP. The tributaries collection area (catchment) to the river was estimated to be 3734Km^2 for estimation water capacity and discharge and the power output using equation (1)-(5).

B. Estimated Power Output

Table 1: Annual distributions of rainfall, discharge and power output on the catchment area.

S/No.	Years	Annual rainfall (mm)	Volumes of water on catchment area (m^3)	Discharge (m^3/s)	Annual Power Output (MW)
1	2014	964.4	3.6×10^9	114.20	10.27
2	2015	1004.6	3.7×10^9	118.59	10.66
3	2016	1150.4	4.2×10^9	136.22	12.25
4	2018	919.0	3.4×10^9	108.82	9.78

Table 2: Monthly Distributions of Discharge and Power Outputs

Parameters	Discharge (m^3/s)				Power Output (MW)			
Months/ Years	2014	2015	2016	2018	2014	2015	2016	2018
Jan	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0
Mar	4.19	0	23.70	71.10	0.38	0	2.13	6.40
Apr	45.81	36.73	87.88	26.08	2.12	3.30	7.91	23.46
May	443.36	221.12	168.14	174.14	39.88	19.89	15.13	15.66
Jun	185.85	155.59	274.88	149.26	16.72	13.99	24.73	13.42
Jul	238.27	510.14	368.21	236.31	21.43	45.89	33.12	21.25
Aug	368.63	312.30	446.57	277.17	33.16	28.09	40.17	24.93
Sep	68.14	165.83	207.89	206.39	6.13	14.91	18.70	18.57
Oct	0	10.46	45.03	150.24	0	0.94	4.05	13.51
Nov	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0

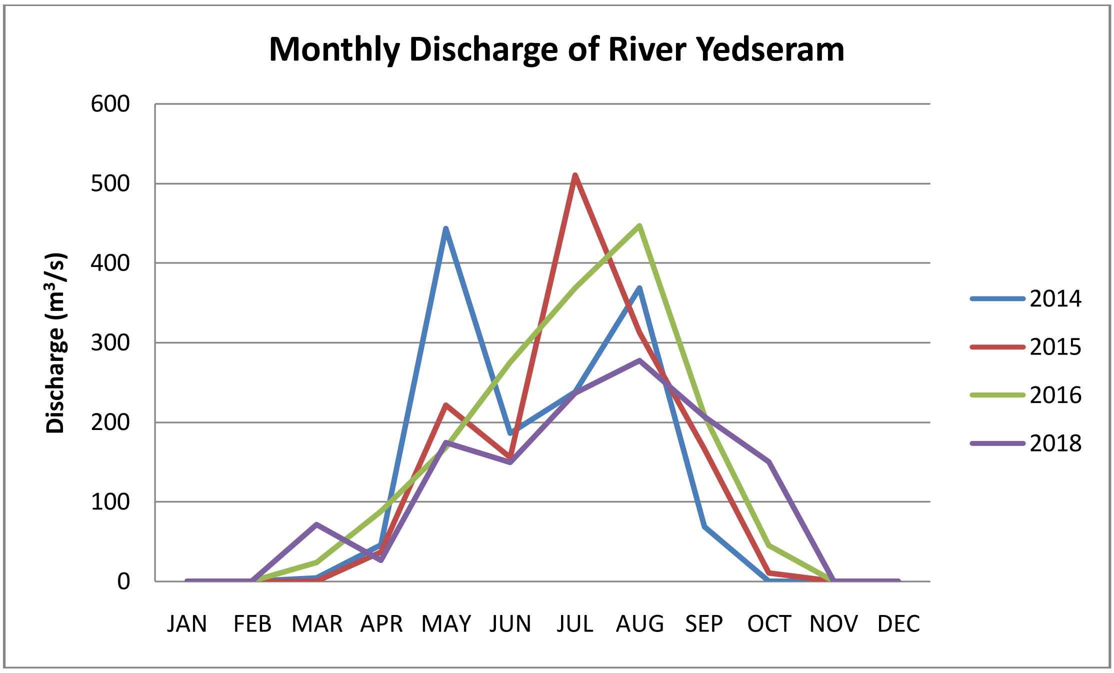

Figure 4: Monthly discharge of river Yedseram

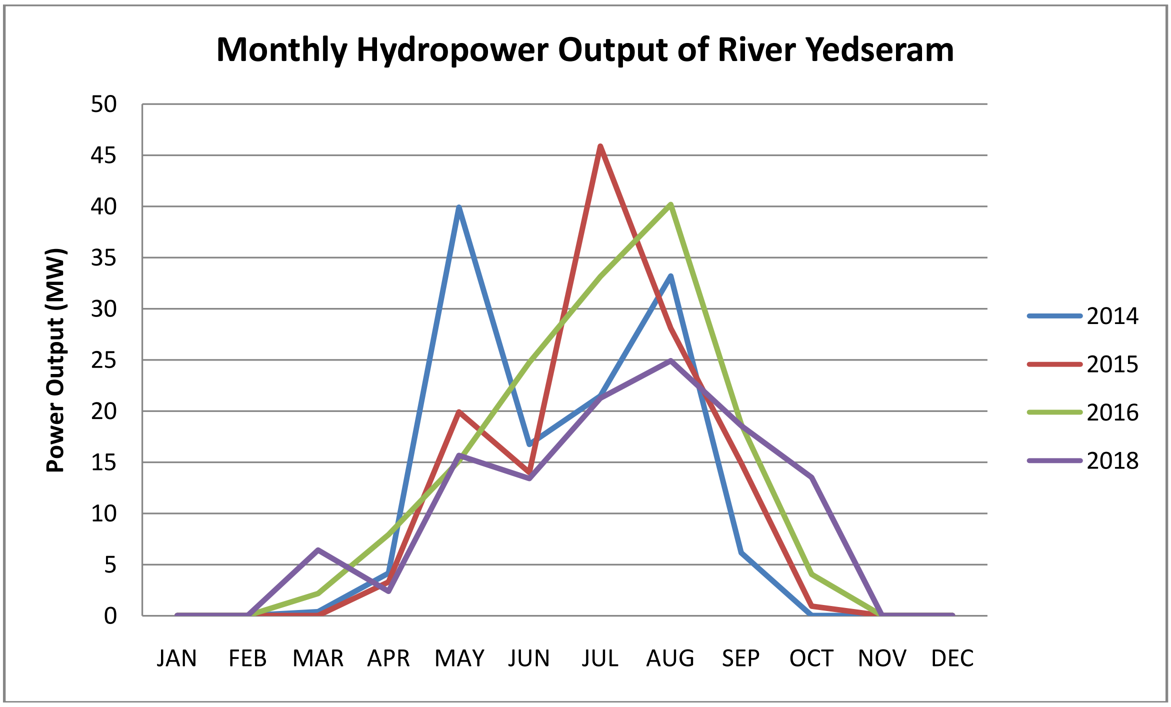

Figure 5: Monthly hydropower output of river Yedseram

From Table 1, the total volume of water feeding on the catchment area in a year is between 3.4×10^9 (2018) to 4.2×10^9 m^3 (2016), corresponding to the discharge between 108.82 to 114.20 m^3/s, while the power output range between 9.78 to 12.25 MW. The power output is much more concerned for hydropower scheme. For this study the power output was approximately 10.74 MW.

There is no unique consensus on the definition of small hydropower but can be classified into large, medium, and small hydro power. However, within the small hydro range, a distinction can be made between mini hydro (maximum 1 MW installed capacity), micro hydro (below 300 or 100kW installed capacity) and pico hydro (below 20, 10 or 5 kW installed capacity) [9]. Sizes for small

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hydropower plants in various capacities such as small (1- 10 MW), mini-hydro (0.5 - 1MW), micro-hydro (50 to 500 kW) and pico-hydro (0- 50 kW), are found across Nigeria [10]. With this, we can say river Yedseram is eligible for SHP potential based on this preliminary study.

Figure4 and 5 plotted from Table 2, also respectively described the monthly distributions of discharge and power outputs, revelling that the raining season span from March to October. It was observed from Figure 4 that the discharge with highest value (510.14m^3/s) at month of July, 2015 corresponding to Figure5were suitable to provide a maximum power output of 45.89MW during raining season. While, lowest discharge of 4.19 m^3/s and power output of 0.38 MW were observed. This shows that during dry season (from the months November to February), river Yedseram experience less discharge/power outputs (taking place by the collection of seepage from tributaries).

Due to the wide discharge fluctuations of the river, the proposed hydropower system required dam or reservoir for maximum and stable generation of energy. Damretain excess water supplies and release them gradually during low discharge, when the need arises to maintain power stability (10.74 MW) throughout the year (as shown in Table 1). Moreover, reservoirs and dams, which are artificial hydropower infrastructure, provide multiple-use benefits such as increasing availability, reliability, and quality of fresh water supplies, as well as reducing risks of flooding [6]. Therefore,it may be possible to preliminary understand how importance is river yazaram by observing the relationship between the quantity discharge, head and power output, which were suitable for SHP potential by this study.

C. Economic, Social and Environment Impacts Overview

The preceding result discussed some technical aspects of power potential of water energy resource, defined by the discharge, head and power output of the river. The following paragraphs will discuss the impact of economic, environmental to the around the river tributaries.

Environmental and social assessment of this resource do also pose technical challenges. This challenges could be generated during and after the implementation of project. Such information might cover water use, water quality, fisheries, river ecology, flood defence, nature conservation, navigation and public recreation issues [11]. This has to be taken before construction started, in particular, the climate change concerned to protect the natural habitats and the likelihood. Although, there are some villages like Mubi, Uba, Lassa, Gulak, Mayo-bani, towns are also benefiting the river. But the impacts that can be associated with site is significantly negligible,because energy demand is highly neededin the region. And small hydropower projects usually have minimal reservoirs and civil construction works so they are considered as having a relatively very low environmental impact compared to large hydropower plants [12].

Actually, the reasons behind this preliminary study were not only for benefits of renewable energy supply, but also to move one step ahead to eradicate insecurity and poor living conditions among rural people, who still lived under poverty line. The availability of energy will highly facilitate the social and economic development of the population, as hydropower has potential for irrigation, fishery and tourism for the nearby settlements. Also harvested energy is expected to meet the communities households, schools, hospitals and markets center demand by less-expensive, more stable, and cleaner energy and water supply. SHP, where a suitable site exists, is often a very cost-effective electric energy generation option [13].

The decision to access hydropower site is usually made on economic grounds, but other factors such as cultural and physical characteristics of the site and the costs and availability of technological and engineering solutions are also important. The cost of developing a small-scale hydropower system is not fixed, as it depends on a number of factors such as: condition of site, role of the water body to the local communities, required system capacity, initial feasibility study of site, and cost of purchase of components, requires great amount of time and money in addition to expertise in various disciplines. The major cost of a scheme is for site preparation and the capital cost of equipment [1].

IV. CONCLUSION

The purpose of this feasibility study is to identify the opportunities for small hydropower scheme along river Yazaram. It was estimated that the river has a head of up to 10m, within the catchment area of 3734Km^2, which was used to estimate annual discharge (obtained between 108.82 to 114.20 m^3/s) and the power output of an average of 10.74 MW. This result shows that the site were eligible for sufficient power production at the scale of 10 MW, in order to generate water and electricity for the benefits of communities around the catchment area.

V. RECOMMENDATIONS

Further studies before the full installation should take place, with emphasize to the following recommendations and which also not consider in this study are:

- This study is preliminary and it is impossible to exactly, accurately and completely study the potential of such schemes in the region, therefore, careful and detailed feasibility study is necessary to be carryout to yield successful, economic and cost-effectiveness of the project. These includes carryout comprehensive hydrological, geological, geomorphic, seismic, environment assessment, system design and costing, and estimating energy output and geotechnical assessment on the study area.
- This study noticed that the catchment area may not produce exact power output due to the accuracy rainfall data, Un-even surface distributions which results in an increase in retention time by distorting rain water to infiltrate for a longer period before runoff can occur; water losses due to evaporation, seepage, soil, land use and others should be consider.
- Negligible factors responsible for evaporation such as: vapour pressure, solar radiation, air temperature, wind velocity, atmospheric pressure, heat storage in water bodies and the quality of water may also be consider.
- Suitable weather condition, local habitat, climatic condition, flow of water, national security, access to distribution and transmission networks are the various factor to be considered in further studies. This is because some sites, for instance, may be located on fishing rivers, inheritance, and therefore consultations are needed to take place.
- A series of MHP could be study along the river Yedseram tributaries for a wide range of feasibility studies. To ensure that the resources are efficiently and sustainably used, economic, environmental and social aspects of this project should be of priority in further studies.
- Power companies who have the legal forces that would go through such complex procedures, because individuals or even rural associations could not afford it should be assign to carryout such studies.

Therefore, accoding to [11] the accuracy of the information may only be plus or minus 25%, however, this should be sufficient for deciding whether to proceed to a more detailed feasibility study.

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