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SWAT analysis of Ikere Gorge basin for hydrokinetic power estimation in selected rural settlements of Oke Ogun, Nigeria

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Abstract. The issue of power generation is the bane of rural development. Power availability will not only raise standard of living but will also enhance people livelihood. This work examines the application of soil and water Assessment Tool (SWAT) in hydrological analysis of upper catchment of Ikere Gorge Basin for hydrokinetic energy estimation. The operation of hydrokinetic turbines depends on river flow and pressure head (ΔH). SWATGIS system was used to determine the hydrological parameters of the sub-basins. SWAT is a version of ArcGIS Software. The result of the analysis was used to estimate the theoretical hydrokinetic power potential of the selected basins. The total theoretical hydrokinetic energy potential of the 10 basin selected was estimated as 36.4 MW. Potential hydrokinetic energy was computed using a theoretical procedure, assuming a head of 0.3 meters and a constant weight of water at 9800 n/m³. The hydrokinetic energy potential was highest in Oshe at Onikankan (9.542 MW) and lowest in Kojuoba at Olonje (0 MW). The SWAT software was later used to create Geo-database for each catchment of Hydrologic Response Unit (HURs) of the basin under study. A spatial structured query language (SSQL) was used to perform query analysis on the potential of the sites selected for hydrokinetic energy estimation.

Keywords. SWAT GIS, hydrokinetics, hydraulic head, Ikere Gorge, HRUs.

1 Introduction

Hydrokinetics is the process of generating energy from the flow of moving water. This source of clean energy could very possibly produce as much as 23

Giga Watts (GW) by 2025 and 100 GW by the year 2050, and this will just barely scratches the surface of its technically achievable potential (Energy Information Administration, 2014).Water Current Hydrokinetic Turbines [WCT] are system that convert hydrokinetic energy from flowing water into electricity (Verdant Power Canada ULC 2006 in Botto *et al.* 2010). Although, the biggest obstacles facing almost all renewable energy sources, including solar and wind power is their inconsistent output because of its weather dependent sources which produce fluctuating amounts of energy and are tough to accurately predict. Water and wave energy technologies extract energy directly from surface wave (Ocean energy 2008).

However, hydrokinetics poses a strong alternative to hydropower as it does not present any of hydropower's environmental problems, such as encroaching upon nature due to damming and or lowering the water level, impacting water flow, and the health of fish stocks. It does not require massive infrastructure as hydropower does (Hydrovolts 2012). Hydrokinetic energy works similarly to wind power in that a turbine uses the flow of water to drive a rotor, which is connected to a generator. Hydrokinetic energy's key difference to wind power is that water is over 800 times denser than air, making it a highly concentrated, reliable, and largely untapped resource. Lack of stable supply of energy has been a major problem faced by many cities, towns and rural settlements in Nigeria. In order to increase energy supply to the nation, there is need to harness all the energy potential available in our rivers. Kusakana (2013) viewed that Hydrokinetic power production is the best supply option compared to the wind, Photovoltaic (PV) and diesel generator where adequate water resources is available. It is clear that many villages and settlements around the catchment of Ikere gorge basin are not connected to the national grid. Hydrokinetic energy has several distinct advantages over other clean energy sources. Perhaps most notable is hydrokinetic energy's ability to adapt to existing infrastructure, rendering expensive, long term construction projects unnecessary. Hydrokinetics has several advantages over other clean energy technologies such as wind or solar, given that the start-up costs for small-scale hydrokinetic projects are much lower and power production begins much sooner than it other counterparts. For most clean energy source, large plots of land are required, while many potential locations already in place are ready to produce hydrokinetic power (Evan 2012). This research therefore examine the potentiality of using an hydrological model to model the selected watershed and the purpose is to use the model result to evaluate hydrokinetic energy potential of the major river along the basin. The total theoretical hydrokinetic energy potential of the 10 basin selected was estimated as 36.4 MW. Potential hydrokinetic energy was computed using a theoretical procedure, assuming a head of 0.3 meters and a constant weight of water at 9800 n/m³. The hydrokinetic energy potential was highest in Oshe at Onikankan (9.542 MW) and lowest in Kojuoba at Olonje (0 MW).

2 Methodology

2.1 Study area

The study area is the upper catchment of Ikere Gorge, Nigeria. The Ikere gorge drainage basin is located in the Southwestern part of Nigeria. It is within Latitude 6º 26´ N and 9º 10´ N and Longitude 2º 28´E and4º 8´E (Figure 1 and 2).

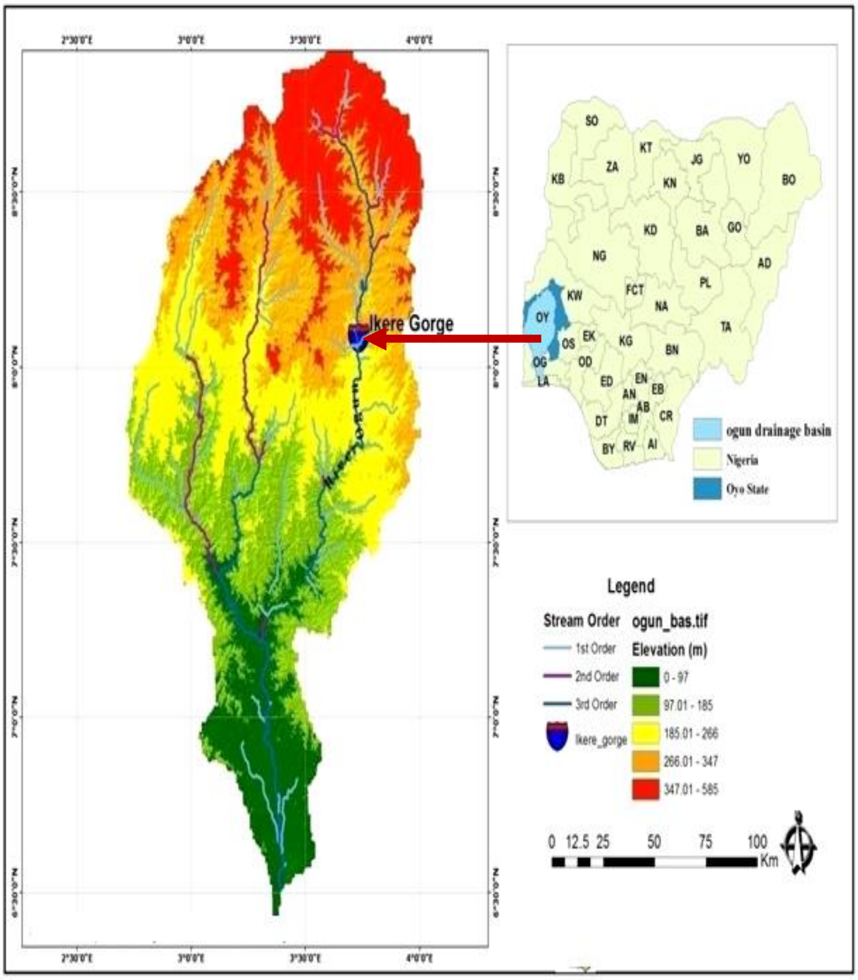


Fig. 1. Ogun River Basin in Nigeria (Inset; Nigeria Showing Ogun River Basin)

The Reservoir capacity of Ikere gorge basin is about 690 million m³ and the water level is about 38 m deep. The land area is about 23,000 km². The relief is generally low, with the gradient in the north-east direction. The Ogun River basin at the upper catchment of Ikere basin takes its source from the Igaran hills with elevation of about 530 m above sea level and flows directly southwards over a distance of about 480 km before it discharge into the Lagos lagoon. Its main tributaries are the Ofiki and Opeki Rivers. Two seasons are distinguishable in the Ogun river basin, a dry season from November to March and a wet season between April and October. Mean annual rainfall ranges from 900 mm in the north to 2000 mm towards the south. The total annual potential evapotranspiration is estimated at between 1600 and 1900 mm (Bhattacharya *et al*. 2012).

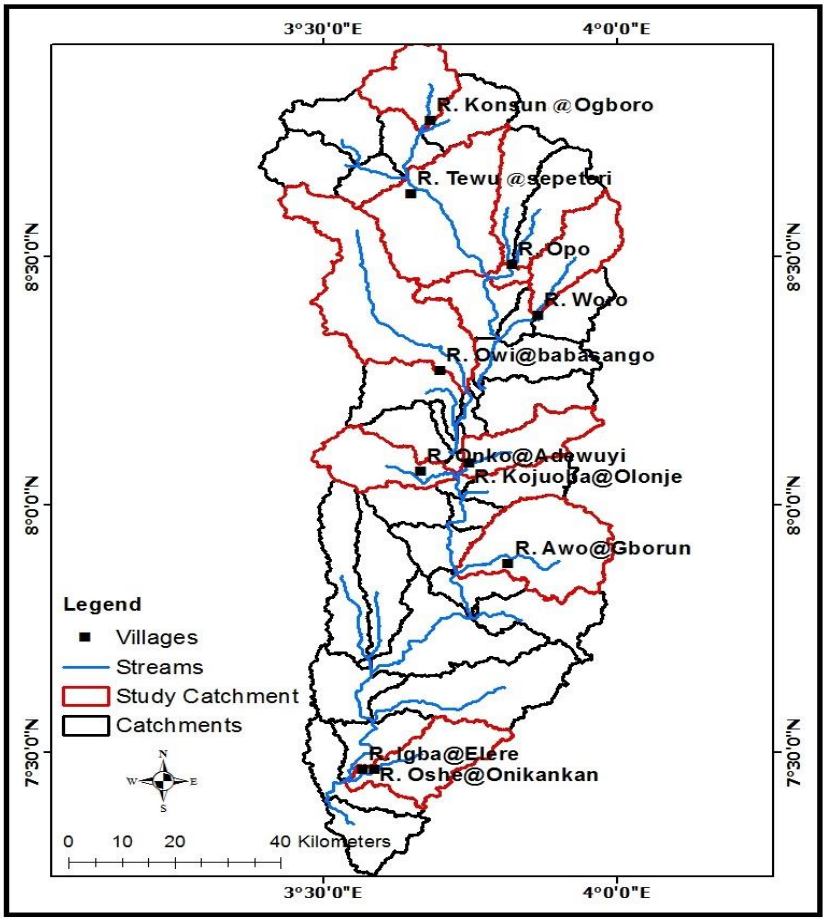


Fig. 2. Drainage network of the upper catchment of Ikere Gorge Basin

2.2 SWAT Model selection and description

According to Arnold *et al.* (1995), SWAT was originally developed by the United States Department of Agriculture (USDA) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large un-gauged basins. The SWAT (Soil-Water Assessment Tool) is a catchment-scale continuous time model that operates on a daily time step with up to monthly/annual output frequency. The major components of the model include studying Soil, Water, weather, hydrology, erosion, soil temperature, nutrients, land management, channel and reservoir routing etc. The Soil-Water Assessment Tool was used to divides the basin into sub-catchments. Hence, each sub-catchment is connected through a stream channel and further divided into Hydrologic Response Units (HRUs). The HRUs is a unique combination of a soil and vegetation types within the sub-catchment. The model calculation was performed on the basis of HRUs. The flow and water quality variables were routed from HRUs to sub-basin and subsequently to the watershed outlet. Neitsch *et al.* (2009) reported that SWAT is a catchment-scale continuous time model that operates on a daily time step with up to monthly/annual output frequency.

2.3 Model input requirements

The SWAT model simulates hydrology as a two-component system which comprised land hydrology and channel hydrology. The model has been developed to predict the impact of land management practices on soil-water in large ungauged basins.

Land use map

The land use map used to run the SWAT (Soil-Water Assessment Tool) model was sourced from Global land cover database. This is done in order to estimate vegetation and other parameters in the watershed area. Also, a recce was done on the watershed to obtain information on the land use and land cover of the study area. The information obtained was used to compliment Global land cover Classification as shown in Figure 3.

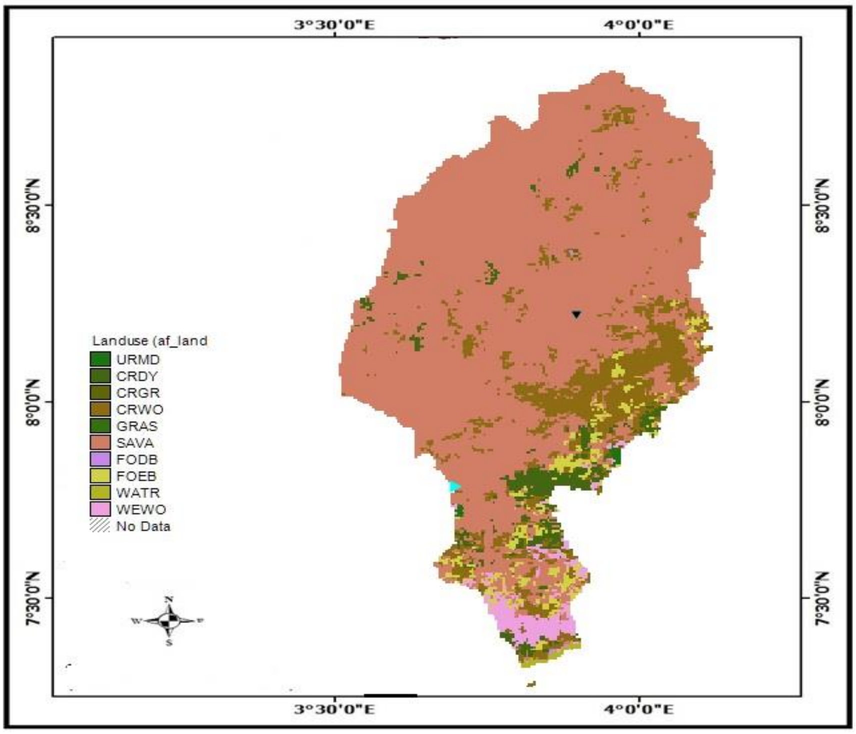


Fig. 3. Land use map of Ikere Gorge Basin.

Table 1 shows the approximate percentage area covered by each of the land use of Ikere Gorge Basin land cover types of the study area.

Table 1. Information on land use of the study Area.

S/N	SWAT Code	Description	Area (Ha)	% of watershed
1	URMD	Urban and Built-Up Land	1234678.44	0.19
2	CRDY	Dry land Cropland and Pasture	16253.97	1.61
3	CRGR	Cropland/Grassland Mosaic	584.07	0.06
4	CRWO	Cropland/Woodland Mosaic	128055.89	12.66
5	GRAS	Grassland	344444.5	0.00
6	SHRB	Shrub land	7777.4	0.00
7	SAVA	Savannah	857133.88	0.00
8	FOEB	Evergreen Broadleaf Forest	7515.37	0.74
9	WATB	Water bodies	4444.4	84.74
10	BSVG	Barren or Sparsely Vegetated	4267.9	0.00

Digital Elevation Model (DEM)

The 90 m resolution extracted from Shuttle Radar Topographical Mission (SRTM) was used to acquire elevation of the selected locations within the watershed area and analyse the drainage pattern of the land surface terrain. With the use of SRTM data, terrain slope, straight length and channel slope were derived from Digital Elevation Model (DEM) (Figure 4).

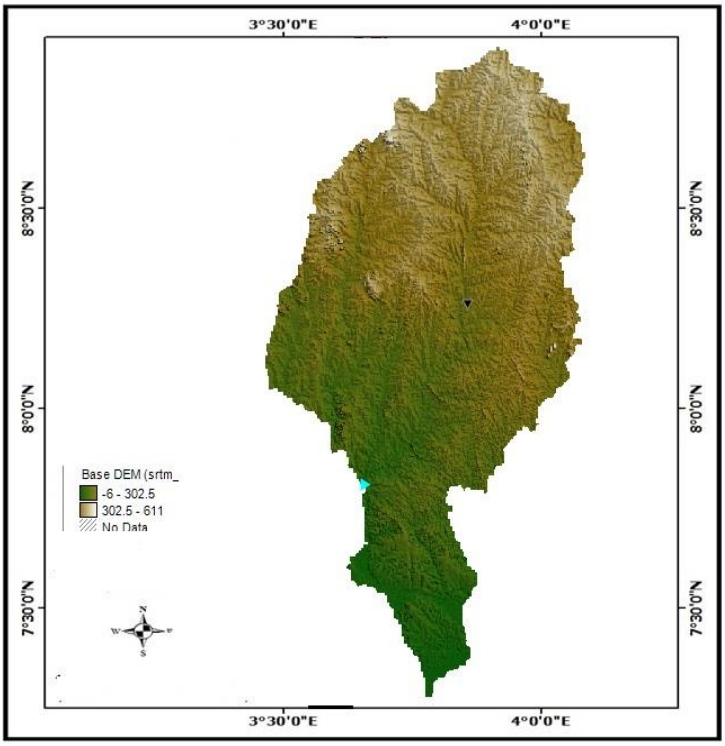


Fig. 4. Digital Elevation Model (DEM) of Ogun River catchment.

Weather data

Weather data such as records of relative humidity, maximum and minimum temperature, rainfall, and solar radiation data were acquired from the Headquarters office of the Ogun-Osun River Basin Development Authority at Abeokuta in Ogun state, Nigeria and from the World Meteorological Organization (WMO) database.

2.4 Model set up and run

In order to run SWAT successively, there is need to configure spatial datasets to the same projection of Universal Traverse Mercator zone 31 North of the Northern Hemisphere of the basin area under study.

2.5 Estimation of energy potentials

The method used to derive energy potential includes hydrological engineering equation. The equation is used to relate theoretical hydraulic power (P*th*, watts) to discharge (Q, m^3/s) and hydraulic head or change in elevation ΔH (m) over the length of the segment. According to Alaska Center for Energy and Power (ACEP 2011) reported that minimum velocity of water current that is required for hydrokinetic generation is between 1.03 m/s and 2.06 m/s; while a range of 2.57 m/s and 3.6 m/s is required for optimum power generation.

Thus, the available power depends primarily on the speed of the current (Sandra 2010). Hence, a multiplication of discharge values with the measured elevation and constant mass density gives the segment specific theoretical hydrokinetic power resource of the location. In this regards, the theoretical hydraulic power potential can also be derived with used of simple hydrologic equation using the formula,

$$P_{th} = \gamma \, Q \, \Delta H \quad \textbf{(1)}$$

where, P*th* (watts) = theoretical hydraulic power, γ= Specific weight of water (9800 n/m^3), ΔH (M) = Change in Hydraulic head between the beginning and end of the river segment or change in elevation over the length of the segment, Q= Flow rate (m^3/s).

However, River orders, slope, name of the rivers, x and y coordinates and other properties of the basins were input into SWAT Software in order to estimate the Hydrokinetic energy potentials besides the use of hydrologic equation. Besides, this hydrologic equation was used by the Electric Power Research Institute (EPRI) to determine the theoretical riverine hydrokinetic resource for continental USA with the use of assumed river slope of 0.3 m (EPRI 2012 in Ladokun *et al*. 2013).

2.6 GIS Database Design for selected basin in the catchment

The coordinate points of some river catchment within the basins are captured with GPS and were converted to shape file with the use of SWAT Software. The Table 2 shows the coordinates of some locations of the catchments.

Table 2. Geographic coordinate locations of the upper catchment of Ikere Gorge basin

	Location	Basins	Coordinates	
			Easting	Northing
1	Ogbooro	Konsun	3.683	8.774
2	Sepeteri	Tewu	3.651	8.627
3	Opo	Opo	3.822	8.483
4	Woro	Woro	3.866	8.382
5	Adewuyi	Onko	3.667	8.067
6	Gborun	Awo	3.816	7.880
7	Onikankan	Oshe	3.587	7.565
8	Babasango	Owi	3.700	8.269
9	Olonje	Kojuoba	3.749	8.083
10	Elere	Igba	3.567	7.466

Therefore, the coordinate points were used to geo-reference the drainage basin map of the study area for accuracy. However, SWAT which is an extension of GIS software was used to input configured shape file in order to run the software automatically. Geospatial database for each of the basin has been computed through the creation of Shape files with the use of SWAT Software. Also, spatial query is done for each of the rivers and their respective Hydrokinetic power potential is generated as it has been shown in Figure 5 and 6.

The attributes of the catchment displayed in Figure 5 depicted the entire sub-basins area. These basins area is imported into GIS environment in order to determine the Hydrokinetic potential of each basin in the catchment. The software was used to run the morphometric properties of the basin to generate the desirable result.

Figure 6 is the spatial information of the basins in the drainage basin of Ogun River catchment. Some of the data generated are the location of the basins, HydroID, GridID, river orders, shape of the length of the basins, shape of the basins area etc. The attribute features of the basin area represented the morphometric properties of the river basin in Figure 6. Ten out of 57 sub-basins in the entire river basin were considered for hydrokinetic power potential. All the basins categorized under upper catchment of Ikere-Gorge dam. The river selected falls under 1st, 2nd and 3rd order rivers. The x, y coordinates of the basin area is depicted in the attributes table accordingly. Though, the query language is used to retrieve hydrokinetic potential of each catchment accordingly. The decision to exploit SQL as the backbone for a spatial query language was driven by the recognition of the efforts to standardized SQL as the database query language (ANSI, 1986).

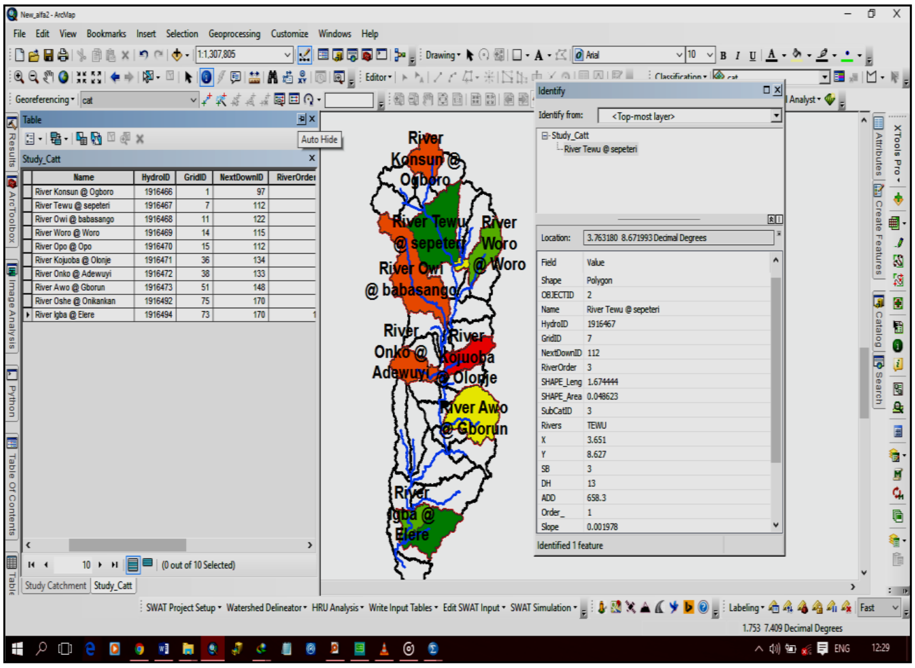
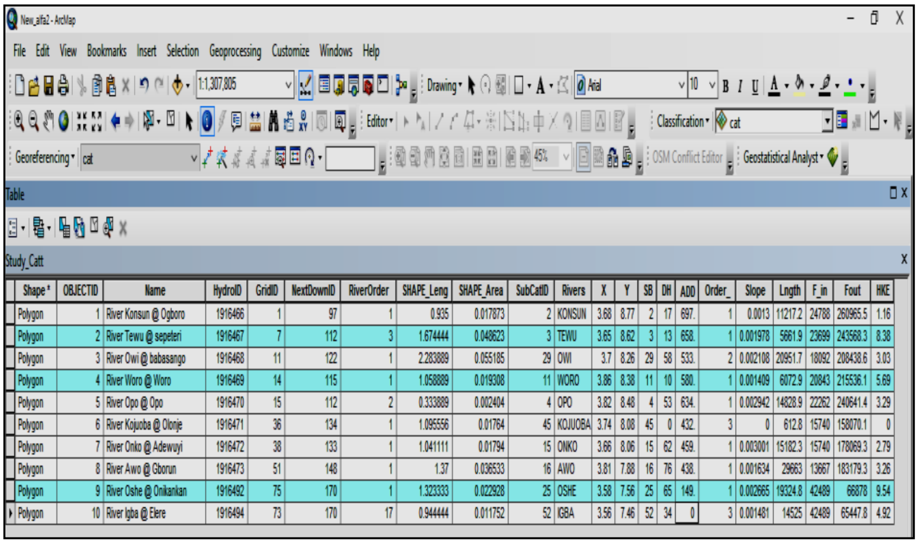


Fig. 5. Database design parameters of all the rivers in the catchment.



Shape *	OBJECTID	Name	HydroID	GridID	NextDownID	RiverOrder	SHAPE_Leng	SHAPE_Area	SubCatID	Rivers	X	Y	SB	DH	ADD	Order_	Slope	Lngth	F_in	Fout	HKE
Polygon	1	River Konsun @ Ogboro	1916466	1	97	1	0.935	0.017873	2	KONSUN	3.68	8.77	2	17	697.	1	0.0013	11217.2	24788	260965.5	1.16
Polygon	2	River Tewu @ sepeteri	1916467	7	112	3	1.674444	0.048623	3	TEWU	3.65	8.62	3	13	658.	1	0.001978	5661.9	23699	243568.3	8.38
Polygon	3	River Owi @ babasango	1916468	11	122	1	2.283889	0.055185	29	OWI	3.7	8.26	29	58	533.	2	0.002108	20951.7	18092	208438.6	3.03
Polygon	4	River Woro @ Woro	1916469	14	115	1	1.058889	0.019308	11	WORO	3.86	8.38	11	10	580.	1	0.001409	6072.9	20843	215536.1	5.69
Polygon	5	River Opo @ Opo	1916470	15	112	2	0.333889	0.002404	4	OPO	3.82	8.48	4	53	634.	1	0.002942	14828.9	22262	240641.4	3.29
Polygon	6	River Kojuoba @ Olonje	1916471	36	134	1	1.095556	0.01764	45	KOJUOBA	3.74	8.08	45	0	432.	3	0	612.8	15740	158070.1	0
Polygon	7	River Onko @ Adewuyi	1916472	38	133	1	1.041111	0.01794	15	ONKO	3.66	8.06	15	62	459.	1	0.003001	15182.3	15740	178069.3	2.79
Polygon	8	River Awo @ Gborun	1916473	51	148	1	1.37	0.036533	16	AWO	3.81	7.88	16	76	438.	1	0.001634	29663	13667	183179.3	3.26
Polygon	9	River Oshe @ Onikankan	1916492	75	170	1	1.323333	0.022928	25	OSHE	3.58	7.56	25	65	149.	1	0.002665	19324.8	42489	66878	9.54
Polygon	10	River Igba @ Elere	1916494	73	170	17	0.944444	0.011752	52	IGBA	3.56	7.46	52	34	0	3	0.001481	14525	42489	65447.8	4.92

Fig. 6. HKE Geo-database of all the selected rivers in the catchment.

3 Results, Analysis and Discussion

The weather data obtained from Ogun River Development Authority and World Meteorological database was used with Soil-water Assessment Tool (SWAT) Software to estimate various parameters such as nature of the terrain, river order, river discharge, shape, etc. The results of the analysis were shown in Table 3.

3.1 Stream ordering and classification

The ordering and classification of streams in the Ogun River catchment was derived with the use of MWSWAT model. The parameters of the catchment such as sub-basin, order, straight – length, slope, and hydraulic head (ΔH) was derived to compute the mean annual discharge along each sub basin of the catchment. Table of basins parameters is presented in the Table 3.

Table 3. Basin hydrologic parameters of Ogun River catchment.

River basin	River order	Head, Δh(m)	Slope (m)	Straight length (m)	Flow-in (m^3/s)	Flow-out (m^3/s)	Average daily discharge (m^3/s)
Konsun	1	17.00	0.0013	11217.2	247885.0	260965.5	697.1
Tewu	1	13.00	0.0020	5661.9	236996.8	243568.3	658.3
Opo	1	53.00	0.0029	14828.9	222624.4	240641.4	634.6
Woro	1	10.00	0.0014	6072.9	208438.6	215536.1	580.8
Onko	1	62.00	0.0030	15182.3	157408.5	178069.3	459.6
Awo	1	76.00	0.0016	29663.0	136673.3	183179.3	438.2
Oshe	1	65.00	0.0027	19324.8	42488.6	66878.0	149.8
Owi	2	58.00	0.0021	20951.7	180923.1	208438.6	533.4
Kojuoba	3	0.00	0.0000	612.8	157408.5	158070.1	432.2
Igba	3	34.00	0.0015	14525.0	42488.6	65447.8	147.9

The implication of the results of the SWAT shown in Table 3 depicted that there are 7 first order streams, 1 second order steam and 2 third order streams in the selected location. It was therefore imperatives that River Konsun which is one of the first orders River has the highest discharge of 697.1 (m^3/s) while River Igba has the lowest discharge of 147.9 (m^3/s). Also, River Awo recorded highest value for Head while River Kojuoba has the lowest Head. Not only that, all the river has reasonable values of discharge that can be used to project hydrokinetic power production.

3.2 Delineation of watershed into sub-basins and HRUs

The Soil and Water Assessment Tool (SWAT) model is used to analyse and delineate the watershed into sub-basins and delineation of sub-basins into Hydrologic Response Units (HRUs). SWAT model is a watershed scale and continuous-time model scale capable of simulating long-time yields for determining the effects of land management practices (Arnold and Allen 1999). The delineation of watershed into sub-basins is shown in Figure 7.

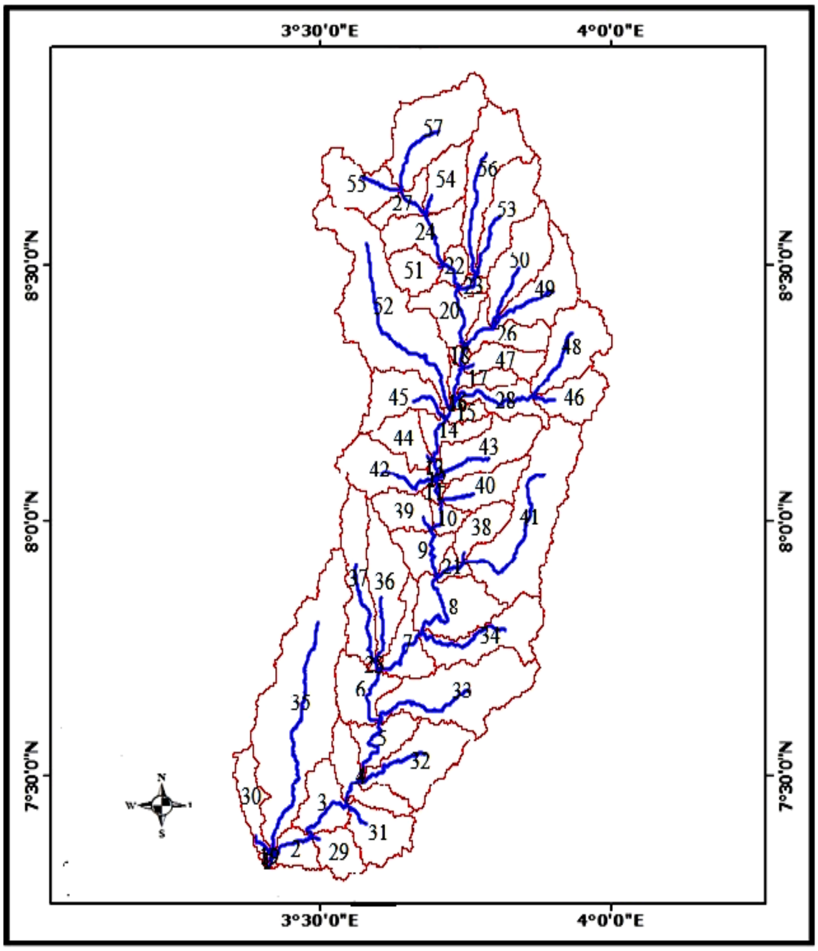


Fig. 7. Network of watershed of sub-basin and HRUs in the catchment.

3.3 Prediction of annual and mean stream flow

The model was used continuously to get the result of maximum flow-in, maximum flow-out, annual mean flow-in, annual means flow-out. The result generated determined hydrokinetic power potential of the river basin under study. The model was used to predict flow rate of rivers within the catchment. Ten major rivers were identified within the catchment.

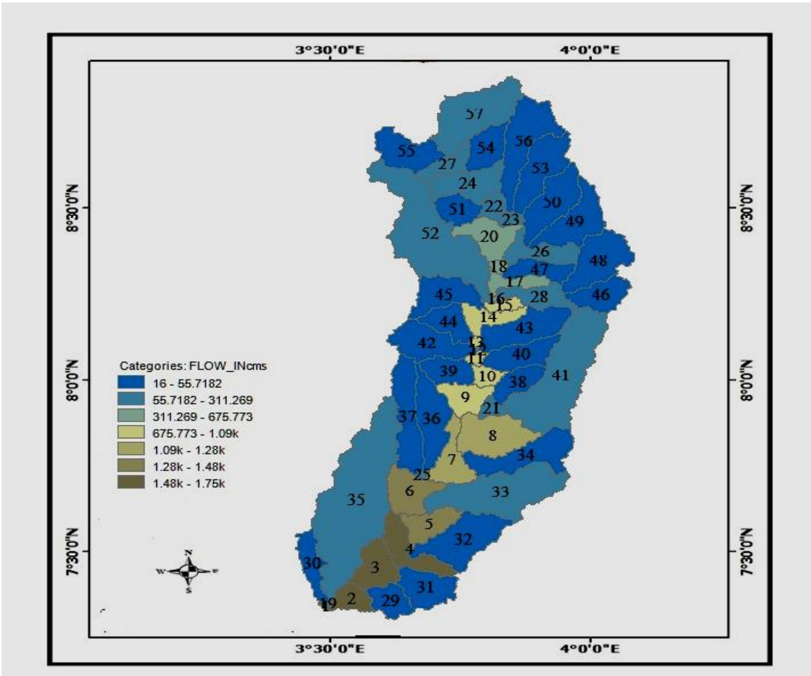


Fig. 8. Annual flow-in entering the Sub-basin.

The minimum annual flow in was estimated as 1410238.4 (m^3/s) and the maximum annual flow out was estimated to be 1820794.4 (m^3/s). Hence, the model generated the output of the sub-basin according to the value of the output in the catchment which represent the result of the maximum discharge entering each sub-basin. The output represent the mean annual discharge of the 10 major rivers across the catchment along each sub-basin. Figure 8 and 9 present annual flow-in and mean annual flow-out of the catchment area respectively.

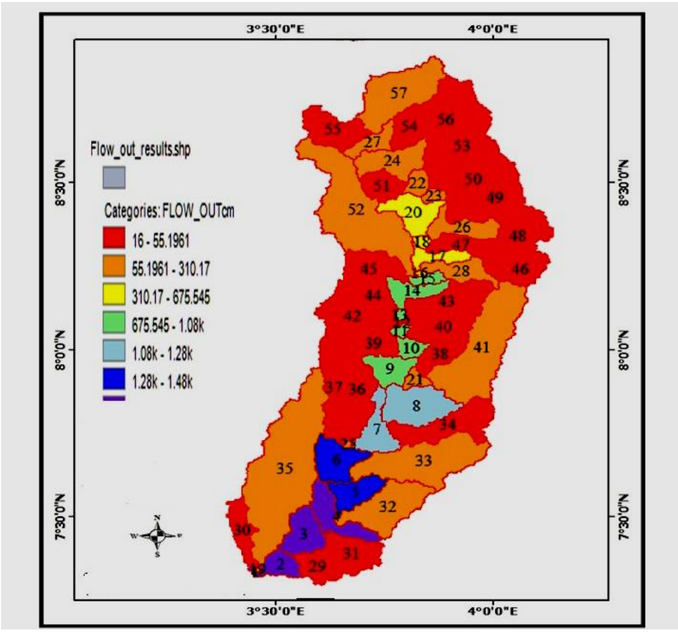


Fig. 9. Mean annual flow-out leaving the sub-basins.

3.4 Theoretical hydrokinetic power estimation

The Sub-basins along the rivers catchment and their respective theoretical hydrokinetic power potential of upper Ogun River catchment at Ikere gorge dam were computed using theoretical hydrokinetic power equation. The result of the potential of each river in megawatts is computed and displayed in Table 4.

Table 4: Result of theoretical potential energy of Ogun river catchment.

Rivers in the basin	Location of the basin	Head, Δ H (m)	Average daily discharge (m^3/sec.)	Theoretical hydrokinetic resource (Gross Power Estimate x 10^6)
Konsun	Ogbooro	17	697.1	1.161
Tewu	Sepeteri	13	658.3	8.387
Opo	Opo	53	634.6	3.296
Woro	Woro	10	580.8	5.692
Onko	Adewuyi	62	459.6	2.793
Awo	Gborun	76	438.2	3.264
Oshe	Onikankan	65	149.8	9.542
Owi	Babasango	58	533.4	3.032
Kojuoba	Olonje	0	432.2	0
Igba	Elere	34	147.9	4.928

The values of theoretical hydrokinetic resource in Table 4 are functions of changes in water pressure head (ΔH), velocity and specific weight of water (9800 Nm^{-3}). The result in Table 4 showed that river Awo at Gborun has the highest pressure head of 76 m followed by river Oshe at Onikankan with 65 m respectively.

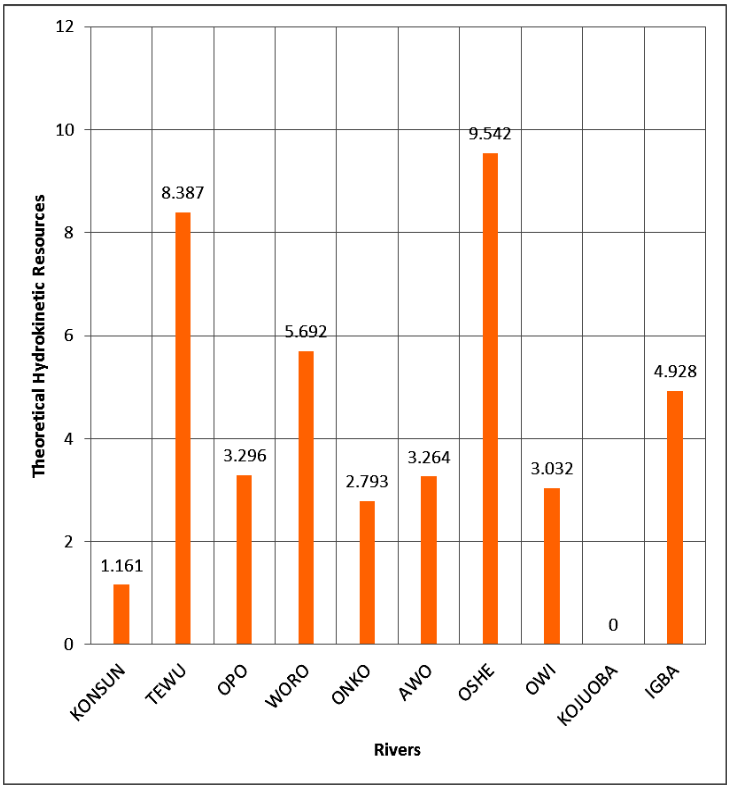


Fig. 10. Pattern of hydrokinetic energy potentials in the Ikere-Gorge basins (x 10^6) (Source: Author's computation, 2015).

All the stations generally have relatively high pressure head. In the analysis of power generation, 3 categories of head exist. These are Low head (< 15m), Medium head (15-60 m) and High head (> 60 m). In this study, three Low head stations exist (river Tewu at Sepeteri, river Woro at Woro, river Kojuoba at Olonje), four Medium head stations are found (river Konsun at Ogboro, river Opo at Opo, river Owi at Babasango and river Igba at Elere) while three High head stations are found (River Onko at Adewuyi, river Awo at Gborun and River Oshe at Onikankan). Hence, with the exception of River Kojuoba at

Olonje where pressure head is 0, all the other 9 stations have higher potential for water energy generation. Hydrokinetic energy generated is highest in river Oshe at Onikankan with 9.542 MW followed by river Tewu at Sepeteri with 8.387 MW. These two stations remained high and medium head. The weight of water for the basins is 9800 Nm^{-3}. Generally, the least value of zero was recorded in river Kojuoba at Olonje where a difference in pressure head is zero. The pattern of energy generated per basins is displayed in Figure 10.

However, the delineation of the watershed was carried out with the use of SWAT model to generate all the files needed through input from digitized map. Also, manual editing of the necessary data was carried out and the weather data of the basins were run accordingly to get average daily discharge for the calculation of potential capacity of each river as it shown in Figure 11 and 12 respectively.

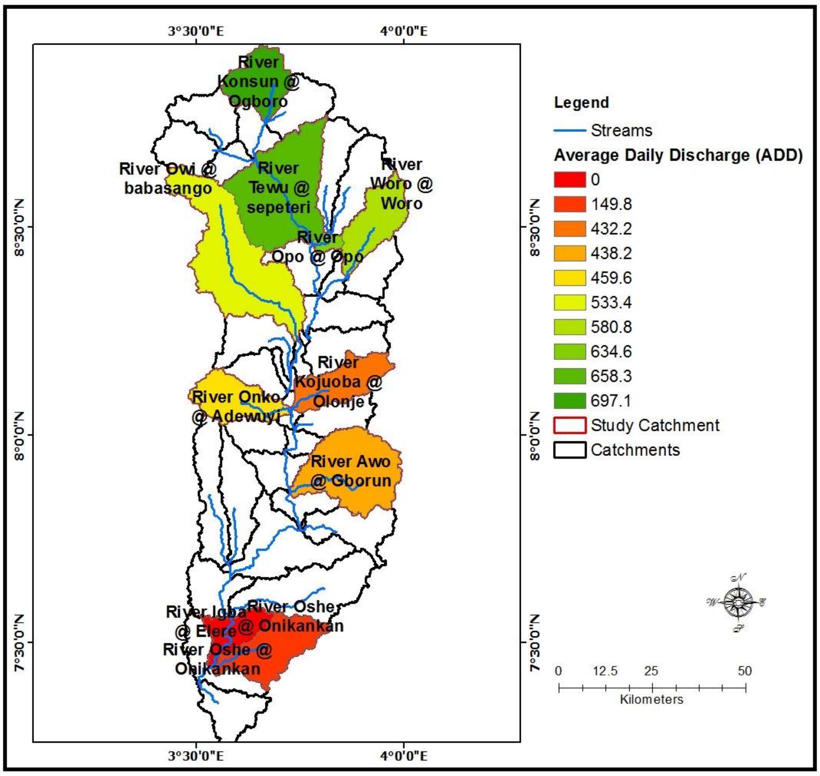


Fig. 11. Average daily discharge of rivers in Ikere Gorge Basin.

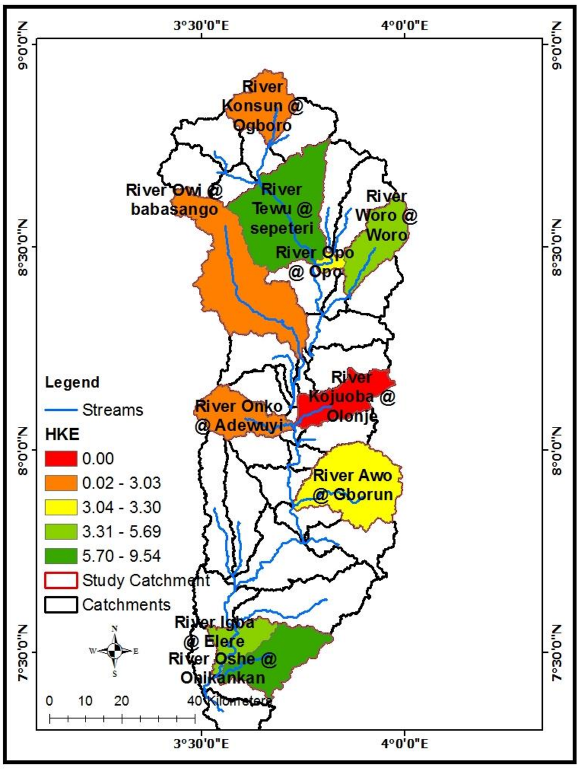


Fig. 12. Hydrokinetic potential energy of rivers in Ikere Gorge Basin.

3.5 Implication of hydrokinetic generation on the environment

The development of hydrokinetic energy for power generation is a step to sustain the ecosystem. The study area, i.e. Ikere Gorge basin has a reasonable potential for generation of hydrokinetic energy for sustainable socio-economic development. The Ikere Gorge basin geographically coincides with the Oke-Ogun area of Oyo State which has a number of rural communities with sparse settlement. There are numbers of rural populations which are largely in scattered settlement. Provision of electricity in scattered settlement is often a challenge in many of our communities today. With the evolution of hydrokinetic energy, this problem is hoped to be resolved. Hydrokinetic power is hoped to develop rural area for small scale industries such as shear butter processing industry, flour mill, Gari processing industry, metal fabrication industry, agro industrial based settlement etc. The selected basins have strong potential for Hydrokinetic development. It will foster socio-economic integration between rural and urban migrants. If hydrokinetic energy is properly harnessed, it will boost local production. The use of standalone power generation like hydrokinetic will help to develop small scale industries and if well-developed it will reduce importation of foreign goods.

The results of the river head, average daily discharge and theoretical Hydrokinetic energy in Figure 10 shows that the selected location can be used as pilot study for the production of hydrokinetic energy in the rural settlements of Oke Ogun, Nigeria. There is an indication that hydrokinetic is thought to be a stable source of standalone power supply. Hence, its sustainability can be predicted for short and long term. Also, the theoretical method used on the energy potential estimation for any flowing water can be successively used to predict hydrokinetic power potential of some rivers in Nigeria. The rate of flow of the water velocity is significant on the part of the hydrokinetic power generation. Constant flow of water is needed to keep the turbine running all the time. Basically, Hydropower depends on rate of flow and head for its efficiency. The basic requirement of hydrokinetic energy is constant water flow. In conclusion, it means that Hydrokinetic power generation is an opportunity for rural industrialization and regional development in Nigeria. Hydrokinetics would help to develop indigenous technology such as gold smith industry, metal fabrication industry, yam and corn flour processing industries through rural electrification project in this country.

4 Conclusion

The use of SWAT Software for the analysis of Ikere Gorge basin for hydrokinetic power estimation of rural settlements in Oke Ogun, Nigeria was carried out with the view to predict its capability for power production. The entire study area fall under 1st, 2nd and 3rd order streams. The total number of 57 streams made up entire Ikere Gorge basin. There are 29 first order streams, 8 second order and 19 third order streams in the entire basin. The drainage pattern of the streams network is dendritic type which indicates the homogeneity of texture of the drainage basin. The result of the SWAT analysis shows that the catchment has the capacity to promote off-grid hydrokinetic power generation. The rivers in the basin has reasonable discharge and required depth. However, the total theoretical hydrokinetic energy potential of the 10 basin selected was estimated to be 36.4 MW with assume head of 0.3 meters and a constant weight of water at 9800 N/m^3. The hydrokinetic energy potential was highest in Oshe at Onikankan (9.542 MW) with lowest in Kojuoba at Olonje (0 MW).

It is therefore become necessary to harness the potential of Ogun River at upper and lower catchment of Ikere Gorge dam for standalone power supply. Attention should be geared towards judicial exploitation of hydrokinetic energy in these sites located. Hydrokinetic conversion system is hoped to be a versatile tool for economic viability, social development and higher power densities of lower cost of electricity. Miller *et al.* (2010) subsumed that Hydro

Kinetic Power (HKP) has a lower cost per unit of energy extracted than Hydro Potential Power (HPP) system, and is economically compared with other distributed system such as solar, wind and others making it a better method for policy support and compliance. Therefore, there must be critical evaluation in setting up this technology because typical hydropower set-ups (dams and small hydropower) have caused serious ecological and environmental damages.

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