Evaluating the Potential Use of River Kaduna for the Production of Hydro-Power Using QSWAT

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Abstract
*This paper applied geo-spatial technology and the Soil and Water Assessment Tool(SWAT) modeling tool for the assessment of hydropower potential in the River Kaduna, Kaduna State, daily precipitation, minimum and maximum temperature data, discharge records, land use, and soil data were used for the SWAT model setup and simulation. The model was calibrated using river runoff data (1997-2002) with a model performance of R^2 of 0.71,*Nash–Sutcliffe Efficiency (NSE) *of 0.859, Percentage Bias (PBAIS) of 10.39 and validated using river runoffdata (2003-2008) with a model performance of R^2 of 0.75, NSE of 0.96 and PBAIS of 12.59, which shows a good correlation. The validated SWAT model was used to simulate the river flow discharge at the potential hydropower points. One potential hydropower location was identified that fulfilled the criteria of sufficient head determined from digital elevation model (DEM) processing.*
Keywords: *Hydropower, Qgis, Calibration, Validation, River Kaduna 4*

1.0 INTRODUCTION

Energy is crucial for improving people's quality of life and growing economies (Liming, 2009). Renewable energy sources are crucial to supplying the world's energy needs while minimizing their adverse environmental effects. The world needs as much power as possible, especially from renewable resources like the sun, wind, hydropower, and ocean waves and currents. Without a doubt, hydropower is part of the answer and provides the best balance between efficiency, environmental concerns, and energy use. Water is the source of this reliable, sustainable, and clean energy source (Kusre*et al.*, 2010). Their durability and long-term dependability also offer other benefits. Typical hydro projects rarely last more than 20 to 30 years, but other power projects, including wind generation, may not. However, even after 30 years, a typical hydro project only reaches the middle of its life. Numerous advantages of hydropower include its cost-effectiveness, environmental friendliness, and independence from global trade, unlike oil and other commodities. The importance of small-scale hydropower and the use of geospatial approaches for potential evaluation cannot be overemphasized. Geographical Information System(GIS) based tools and remote sensing are powerful tools that enable the recording, storage, and analysis of various types of spatial and geographic data in different types of the coordinate system, which can be use to select suitable locations for small hydroelectric power plants, taking into account engineering, economic and environmental criteria (Liu *et al.*, 2017).
There is no universally accepted definition of small-scale hydropower. In the United State for instance "small" can indicate up to 30 Mega Watts (MW), however in Canada, it can refer to top limit capacities of 20 to 25 MW. Nonetheless, a definition of up to 10 MW total capabilities is gaining traction (www.small-hydro.com).Depending on the power output, small-scale hydropower is further divided into small, mini, micro, and Pico hydropower (Singh *et al.,* 2009). Small-scale hydropower systems of 10 MW or less was referred to in this research using the classifications in

Table 2.2.The hydroelectric schemes that fall within the lower range of the "small-scale hydro" concept-mini, micro, and pico hydropower are the most appropriate for our evaluation.

Table 1: Classification of hydropower

Type	Capacity	Required Head (m)
Large hydro	>100 MW	>50
Medium hydro	10-100 MW	20-50
Small / Low hydro	1-10 MW	10 - 20
Mini hydro	100kW-1MW	2 - 10
Micro hydro	5 – 100 kW	1 - 5
Pico hydro	<5kw	<5

Source: Singh *et al.,* 2009

Nigeria can generate up to 3,500 MW of energy, which is more than sufficient to meet its needs for rural electrification, and it has a lot of potential for small hydropower. Only 30 MW of Nigeria's more than 277 small hydro sites, which can generate 734.2 MWh of power, were utilized (Kela*et al.,* 2012). Approximately 145 GWh were generated and supplied by the private sector operator National Electricity Supply Company (NESCO) from the mid-1940s to the 1980s using hydropower from the Kurra Falls on the N'Gell River (River Kaduna). Small hydropower (SHP) has been in Nigeria since 1923, 45 years before the country's first major hydropower plant was placed into operation in Kainji, according to Olayinka*et al.* (2010). The list of Nigeria's current minor hydro projects is presented in Table 2.

Table 2: Existing Small Hydro Schemes in Nigeria

S/N	RIVER	STATE	INSTALLED CAPACITY (MW)
1	Bagel (I) (II)	Plateau	1.0 2.0
2	Kurra	Plateau	8.0
3	Lere(I) (II)	Plateau	4.0 4.0
4	Bakalor (I)	Sokoto	3.0
5	*Tiga	Kano	6.0
6	*Oyan	Ogun	9.0

Source: Adejumobi*et al.,* 2011

This aim of this research is to evaluate the potential use of streams for the production of Hydropower using river Kaduna as a case study. To achieve this, we estimate the river flow in several points along the river network within the study Area, calibrate and validate the observed river flow, to determine the drop head, along the river channel and calculate the available power potential.

1.1 Study Area

1.1.1 Study area

The study area, which spans through Chikun local government, is roughly 70,200 square kilometres in size over a 550-kilometer main river course that covers Kaduna, Niger, FCT, portions of the Plateau, Nasarawa, and Kano States, the river finally flows south through the wide, level Niger valley and empties into the Niger River near Wuya in Niger State (Arimoro*et al*., 2018) and is situated between latitudes 10.12º N and 10.36º N and longitudes 6.84º E and 7.20º E, as seen in Figure 1. The Jos Plateau is the source of the Kaduna River, which flows northwest across the Kaduna plains and cuts through a number of gorges in the rocky terrain between Zungeru and Kaduna. After draining roughly of land The Karami, Galma, Tubo, SarkinPawa, and Mariga rivers are the main tributaries that join the Kaduna River along its path, in that order from the source. The only significant dam across the main is Shiroro Hydropower Reservoir, and Kaduna is the only state capital through which the main channel flows.

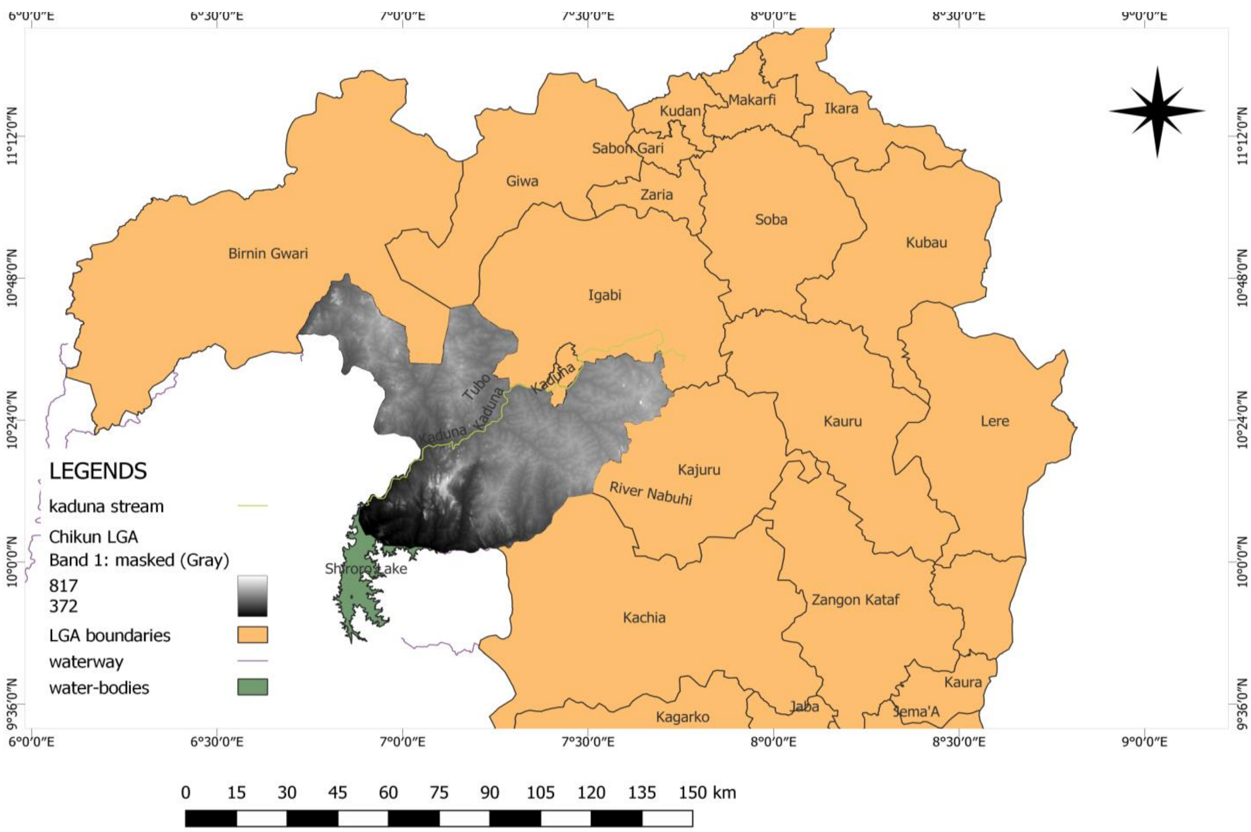

Figure 1: Location Map of Study Area

Chikun is One of Kaduna state's twenty-three local government areas, Chikun is bordered to the south by Kachia, to the east by Kajuru, to the north east by Kaduna South, to the northeast by Igabi, to the northwest by BirninGwari, to the south by Munya, to the west by Shiroro, and to the west by the entirety of Niger state. The water flows from the North which is Rigachikun and emptied into Lake Shiroro which is at the West of map, Figure 2 shows the flow regime of the study area.

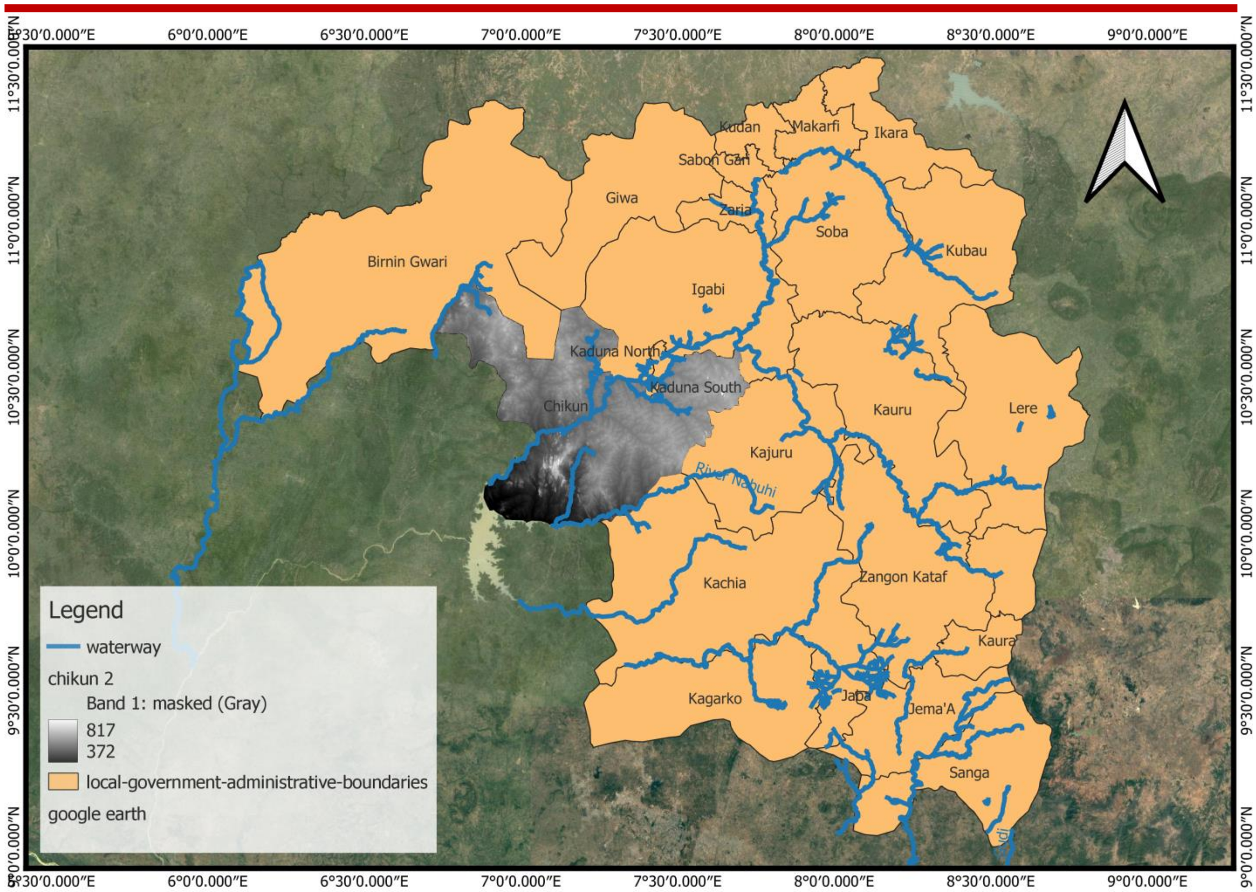

Figure 2: Hydro geological Map showing water way of the Study area

2.0 MATERIALS AND METHODS

2.1 Data Acquisition

Monthly River discharge flow data were obtained from Kaduna state water board from year 2006 to 2012 as the target variable. Digital elevation model of the projected area showing where the elevation was obtained, in particular the 50 × 50 m DEM was used to delineate the stream network by calculate the length of the river channels, evaluate the river bed slope, identify the sub-basin areas, and, finally, assess the elevation of a great number of points along the river network byintersecting the DEM raster with the points layer. The 50 meter Shuttle Radar Topography Mission(SRTM) DEM of the river basin was taken from National Aeronautics and Space Administration (NASA) Earth Data Survey (OS) terrain.

2.1.1 Production of Soil and Land Cover Maps using ArcMap

ArcGIS (ArcMap) is a Windows-based collection of Geographic Information Systems (GIS) software products designed to produce detailed maps, build spatial models, and manage spatial data. Included are ArcGIS Desktop, ArcGIS Online, ArcMap, &ArcScene.

This was used in the reading of an already made soil maps data which was downloaded from Food and agricultural organization (FAO), as seen in Figure 3.

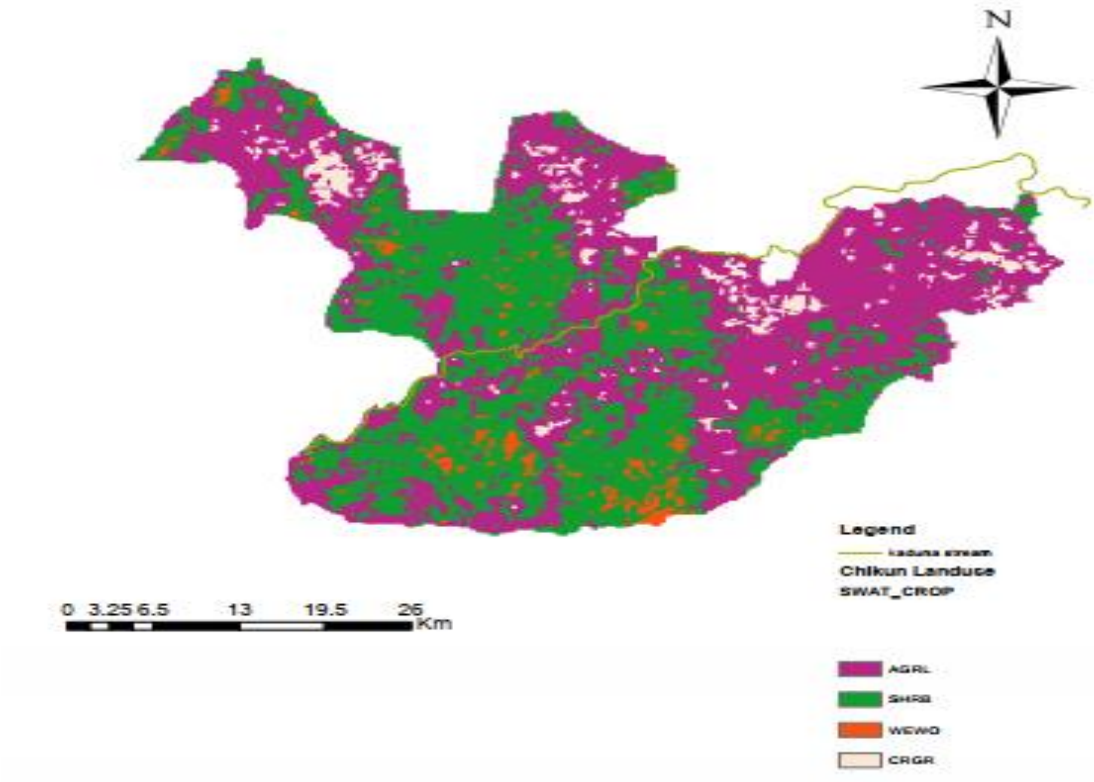

Figure 3: Created Soil Map from ArcGIS for the Study Area

2.1.2 Digital Elevation Data Processing

In particular, the 50 × 50 m DEM was used to delineate the stream network, calculate the length of the river channels, evaluate the river bed slope, identify the sub-basin areas, and, finally, assess the elevation of a great number of points along the river network (intersecting the DEM raster with the points layer). The 50 meter SRTM DEM of the river basin was taken from NASA Earth Data Survey OS terrain. The contours was interpolated to create a continuous surface, was used to calculate river height differences and identify possible locations for small hydro power plants. Figure 4 shows the created DEM for the study area (Figure 4).

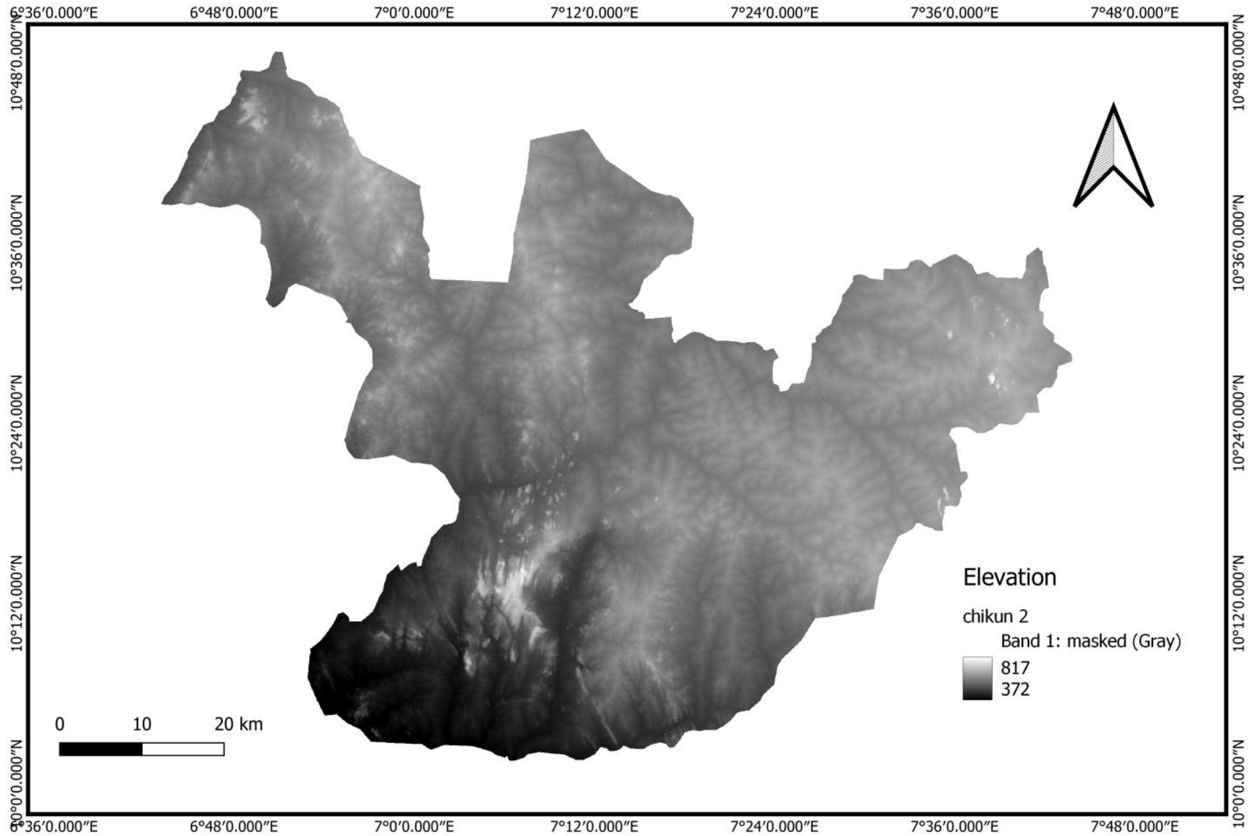

Figure 4: Created DEM map for the study area

2.1.3 River Discharge Flow data

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, stream flow 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 stream flow data, can be obtained from them. However, in the past fifteen years it was reported that there have not been stream flow measurements along major rivers in Nigeria due to lack of funding (Adedokun*et al.,* 2013).. Table 3 shows the monthly inflow data for Kaduna River in cubic meter per second that was used for calibration and validation (1997-2008).

Table 3: Monthly inflow data for Kaduna River in cubic meter per second (m^3/s)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Peak flow(m^3/s)
1997	59.69	53.57	39.96	55.66	66.34	121.97	284.83	617.86	657.07	375.58	168.15	92.61	657.07
1998	55.55	53.67	55.89	58.45	68.99	145.77	299.66	772.63	681.90	370.99	195.52	107.31	772.63
1999	59.83	50.98	44.55	37.94	56.66	125.84	302.05	730.20	637.58	368.32	169.57	92.43	730.20
2000	65.90	52.70	44.85	40.65	62.25	120.01	282.71	693.08	625.52	345.85	179.49	87.87	693.08
2001	59.82	51.39	53.94	57.66	68.06	122.36	284.25	648.16	645.12	388.04	197.91	92.80	648.16
2002	63.06	58.31	40.56	36.85	57.96	114.79	277.82	762.98	758.30	427.34	212.82	110.69	762.98
2003	66.50	59.40	47.66	56.88	76.53	126.92	305.97	725.66	669.37	377.98	171.55	90.07	725.66
2004	63.43	53.29	48.48	41.86	59.21	140.50	302.60	788.35	780.46	441.63	189.92	90.75	788.35
2005	63.08	57.34	40.14	52.12	68.06	127.22	316.44	709.55	709.53	391.16	195.94	111.30	709.55
2006	57.74	52.17	50.10	46.77	73.83	155.98	329.30	801.18	661.83	377.75	173.91	88.84	801.18
2007	57.45	46.14	45.67	58.22	77.86	125.47	247.86	649.48	706.30	421.21	180.61	109.84	706.30
2008	65.81	55.56	42.02	50.34	76.96	141.32	307.67	659.95	626.59	380.81	176.21	94.43	659.95

2.1.4 RIVER HEAD MEASUREMENT

In potential micro-hydropower site, the available head is the vertical distance that water falls (U.S.A Department of Energy, 2001). When evaluating a potential site, head is usually measured in feet, meters, or units of pressure. Head also is a function of the characteristics of the channel or pipe through which it flows. It is generally better to have more head than more volumetric flow; because less water will be needed to produce a given amount of power with smaller, less expensive equipment River profile for the catchment area was generated using civil 3D and the most suitable elevation was gotten.

2.1.5 Soil and Water Assessment tool (SWAT) Modelling

SWAT needs the topography, land cover, and soil map for the study area as well as historical measurements of weather data (precipitation, temperature, solar radiation, relative humidity, and wind speed) as input. The basin is divided by SWAT into numerous sub-basins, which are further subdivided into geographical units known as Hydrological Response Units (HRUs), which have uniform slope, land use, and soil characteristics. Each HRU's response to changes in water quantity and quality is simulated by the model, and the findings are then combined at the sub-basin level and sent via the channel network to the watershed outlet. Equation 2.1 shows that hydrological model is based on the following water balance equation for soil water content:

$SW_t = SW_{t-1} + P_t - - Q_t - - ET_t - - SP_t - - QR_t (1)$

Where $SW_t$is the soil water content for the current time step, SWt-1 is the soil water content for the previous time step, $P_t$is the precipitation, $Q_t$is the surface runoff, $ET_t$is the evapotranspiration, $SP_t$is the percolation or the seepage, and $QR_t$is the return flow.

2.2 Methods

In this study, the QGIS interface of the model, called QSWAT (Dile., 2016) was used. This interface is provided with tools for stream network and watershed delineation, sub-basins definition, and the identification of the HRUs. For the area of study, SWAT has been calibrated while using the software package SWAT-CUP (Abbaspour.,2008). For simulation the river flow series recorded at the Kaduna River's mouth was used to calibrate the model. Two datasets one for calibration and the other for validation have been created from the available observed data. The SWAT model was used to estimate river flow at various locations along the river network after it has been calibrated and verified. The SWAT execution chart used to achieve the desired outcome is displayed in Figure 5.

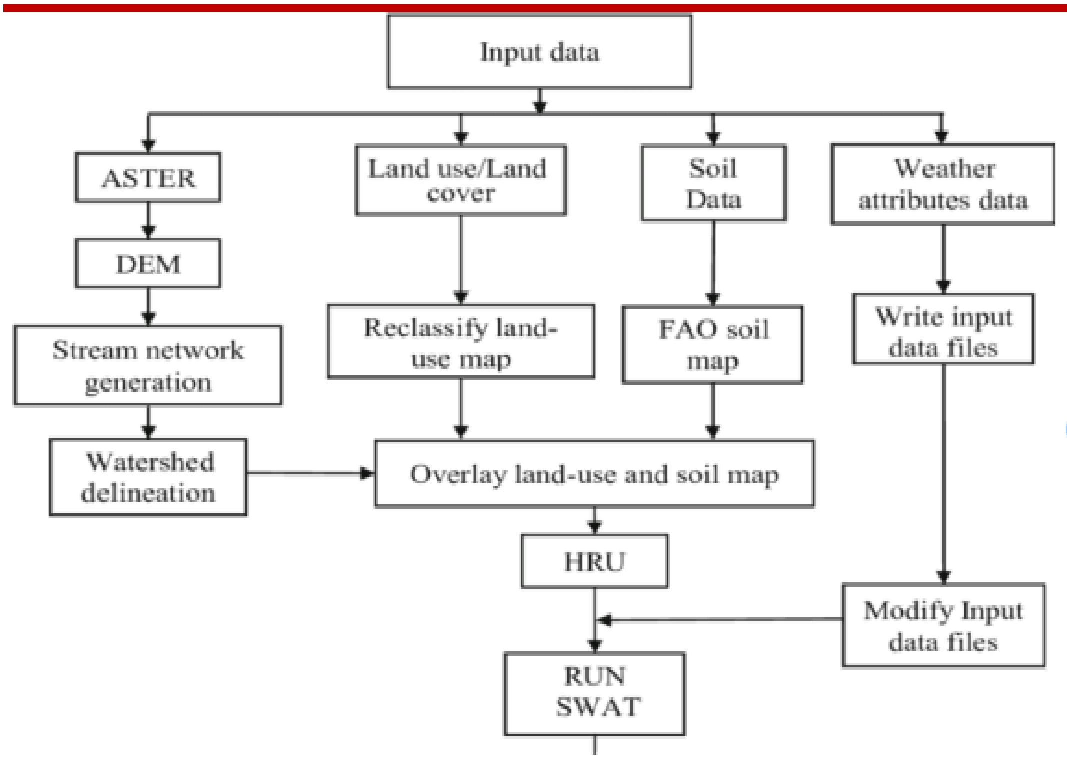

Figure 5: SWAT modelling chart

The workflow, which consists of four major inputs with unique sub-steps for each, is clearly shown above. The required input data such as soil types, climate data include rainfall data, land use, and hydrology data have been prepared in the data collection process. They are inputted into the input data file of Soil and water Assessment Tool (SWAT). The stages of the analysis activities carried out are as follows:

2.2.1 Delineation of Hydrological Response unit using QSWAT+

In order to process the results, the initial stage in the process is to load the digital elevation, soil, and land use maps of the research region. The Watershed Delineation Process uses QSWAT software to process digital elevation model (DEM) data with a 50 meter resolution. The Kaduna River watershed's natural topographic borders served as the basis for defining the observation area. The threshold area technique 100 ha was employed in the delineation procedure; the number of sub-basins generated depends on the magnitude of the threshold value. Watershed boundary maps, river flow network maps, discharge measurement outlet point coordinates, and 50 x 50 m DEM data are used in this delineation stage(Figure 6). After delineation, the Kaduna River is divided into 5 catchments. The pattern of water flow is dependent on the elevation value. The chosen outlet is the discharge measurement post of Chikun LGA; the watershed delineation map is presented in

Figure 6. .

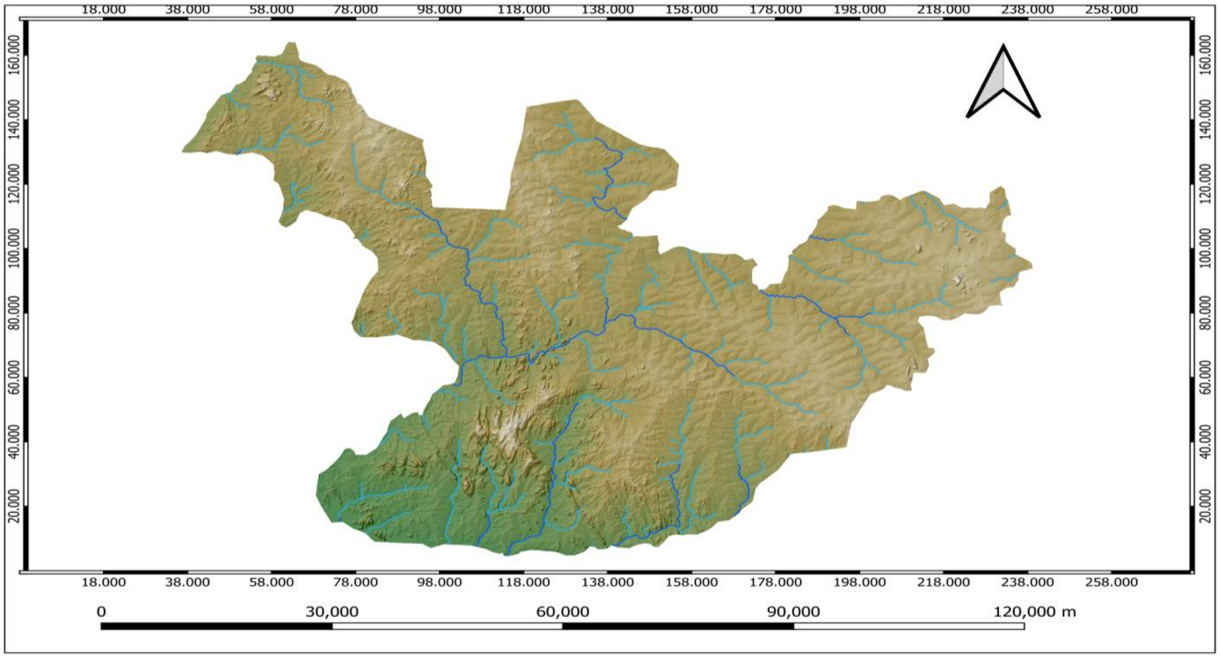

Figure 6: Study Area watershed delineation

The sub-basin's forecast accuracy is improved by the development of HRUs (Williams *et al.,*2012).HRU can explain how a watershed area affects the hydrological factors that exist there, as well as how the region is divided according to land use, slope, and soil properties.
The catchment area is divided into five (5) sub-basins as shown in Figure 7, in the course of initializing the result.

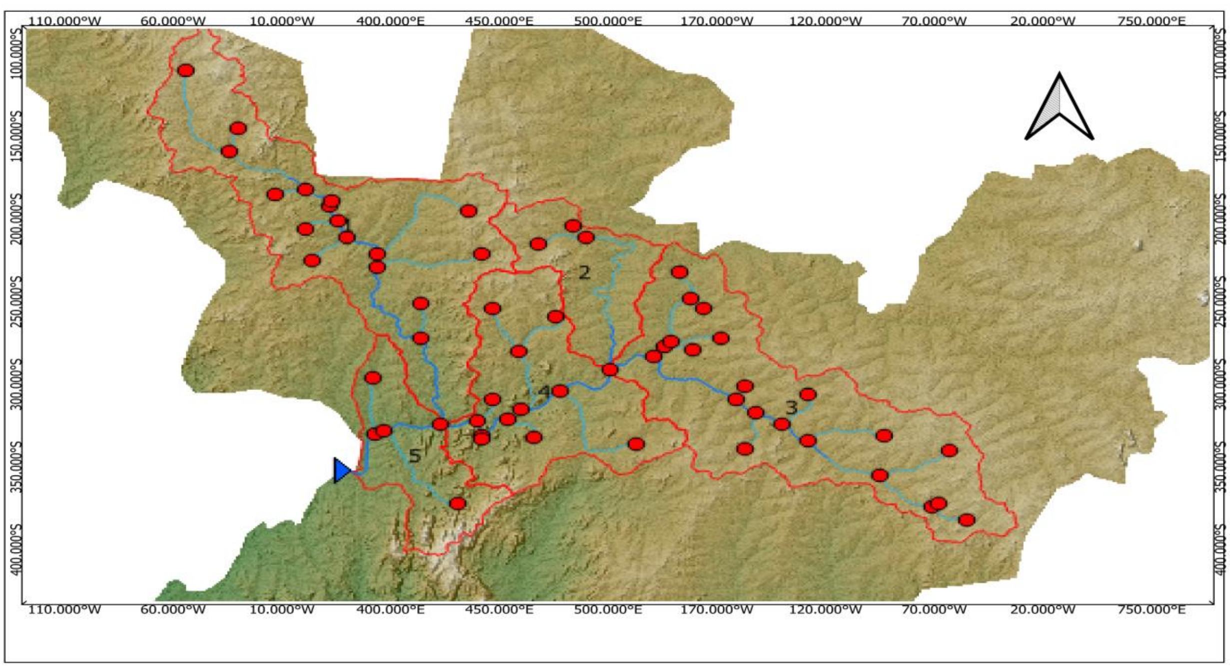

Figure 7: Establishment of Sub-basin

After establishing the HRU and Sub-basins, the climate data for a weather generator (WGN) input were downloaded from SWAT plus. The 2012 SWAT climate data from WGN output to run the SWAT model.

2.3 Evaluation Criteria

The model performance was used to evaluated from a comparison of simulated and observed discharge data in terms of mean, standard deviation, maximum daily discharge and total discharge using commonly-used indices (Krause et al; 2010). Three statistical indices; Coefficient of Percentage Bias (PBAIS) were used to evaluate the model performance by using the expression

$$R^2 = \frac{\sum(Q_{Obs}-\overline{Q_{Obs}})^2-\sum(Q_{sim}-\overline{Q_{sim}})^2}{(Q_{Obs}-\overline{Q_{Obs}})^2} \quad (2)$$

Where Q_{Obs} is Observed discharge and Q_{sim} is the Simulated discharge

If R^2 is close to 1, then there is a pattern of a close relationship between the prediction results of the model and the results of field observations.

The SWAT model uses more than 500 hydrological parameters for calibration (Arnold *et al*., 2012). Not all parameters are used at the calibration stage. Parameter selection is made by conducting a literature study on the often-used parameters in the SWAT model. The value of these parameters is calibrated by trial and error to get the best value seen from the results.

The Nash-Sutcliffe model efficiency coefficient (NSE) as shown in equation 2.3 is used to assess the predictive skill of hydrological models. It is defined as:

$$E_{NS} = 1 - \sum\frac{(Q_{Obs}-Q_{sim})^2}{\sum(Q_{Obs}-Q_{sim})} \times 100 \quad (3)$$

Where:Where Q_{Obs} is Observed discharge and Q_{sim} is theSimulated discharge

The Nash-Sutcliffe efficiency is calculated as one minus the ratio of the error variance of the modelled time-series divided by the variance of the observed time-series. In the situation of a perfect model with an estimation error variance of zero, the resulting Nash-Sutcliffe Efficiency equals 1 (NSE=1). Conversely, a model that produces an estimation error variance equal to the variance of the observed time series results in a Nash-Sutcliffe efficiency of 0.0 (NSE=0). In reality, NSE=0 indicates that the model has the same predictive skill as the mean of the time-series in terms of the sum of the squared error. In the case of a modelled time series with an estimation error variance that is significantly larger than the variance that is significantly larger than the variance of observation, the NSE becomes negative. An efficiency less than zero (NSE <0) occurs when the observed mean is a better predictor than the model. Values of the NSE nearer to 1, suggest a model with more predictive skill. Subjective application of different NSE values as thresholds of sufficiency have been suggested by several authors or smaller than their observed ones. The optimal value of PBIAS is 0.0, with low magnitude values indicating accurate model simulation. Positive values indicate overestimation bias, whereas negative values indicate model underestimation bias and been describe in equation 2.4.

$$PBAIS = \frac{\sum(Q_{Obs}-Q_{sim})}{\sum(Q_{Obs})} \times 100 \quad (4)$$

Where Q_{Obs} is Observed discharge and Q_{sim} is theSimulated discharge

3.0 RESULTS AND DISCUSSION

3.1 Model Performance

The study area has few river gauging sites. For this reason, a well-calibrated model has been required for assessing the river flow in different ungauged sites along the river network. The hard calibration tool of QSWAT enables adjustment of different parameters through user intervention. These parameters can be adjusted manually or automatically, the manual calibration and sensitivity analysis of curve number parameters was done in this study.

3.1.1 Calibration results

The influence of the curve number (CN2) on the calibrated output in the monthly flow analysis from 1997 to 2002 is presented in Table 4 and the gotten graphical relationship for Observed and simulated flows for calibration is shown in Figure 8.

Table 4: NSE, R2 and PBIAS of the observed and simulated series for model calibration

Statistical Evaluation Parameter	Calibration (1997 -2002)
	Monthly Time Step
R^2	0.71
NSE	0.89
PBIAS	10.39

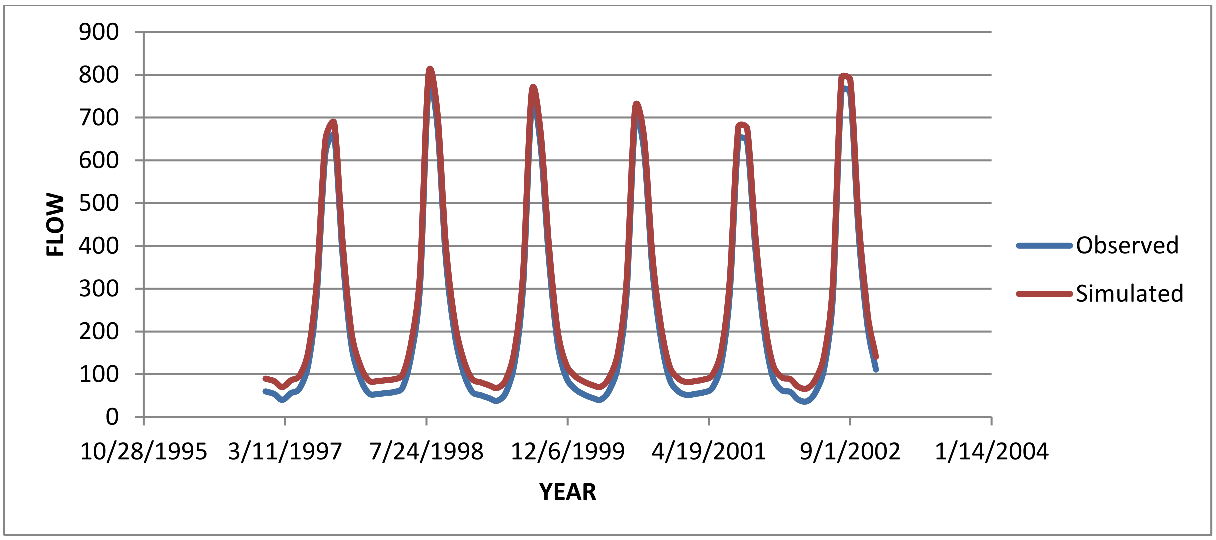

Figure 8: Observed and simulated flows for calibration (1997 – 2002)

3.1.2 Validation results

The influence of the curve number (CN2) variables on the validated output in the monthly flow validation value from 2003 to 2008 is presented in Table 5 and the gotten graphical relationship for Observed and simulated flows for calibration is shown in Figure 9.

Table 5: NSE, R2 and PBIAS of the observed and simulated series for model validation

Statistical Evaluation Parameter	Validation (2003-2008)
	Monthly Time Step
R^2	0.75
NSE	0.96
PBIAS	12.59

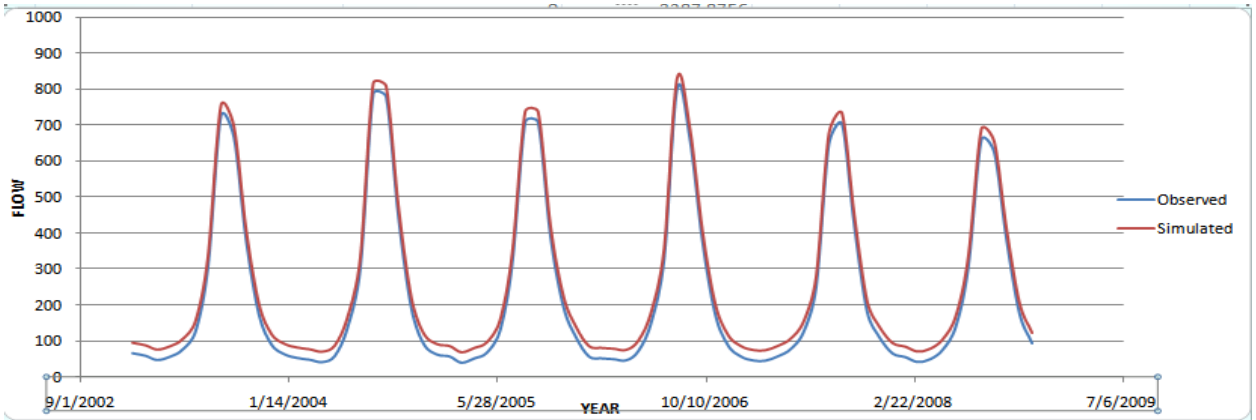

Figure 9: Observed and simulated flows for validation period (2003 – 2008)

The overall performance of the SWAT model was judged by statistical analysis of the discharge data for all the years considering the wet and dry season. High values of R^2 (0.71), NSE (0.89) indicated a close relationship between the observed and modelled discharge, while PBAIS (10.39) indicated that although simulated discharge is under estimated (positive PBAIS), the simulated discharge by the model is well within the acceptable limit.
The performance of the model is considered to be satisfactory if both R^2 and NSE are greater than 0.6 for each observation and simulation (Kwarteng et al., 2020; Franco and Bonuma, 2017., Christine et al., 2005; Santhi et al., 2001) and PBIAS value is less than 15 % (Santhi et al.2001; Vanliew *et al*., 2007).The overall summary of statistical evaluation of model showed a good performance of the model. The comparatively higher PBAIS in validation period than in calibration period was observed because of use of latest DEM, soil data and land use data for model preparation.'

3.1.3 RIVER HEAD

River profile for the catchment area were generated using AutoCAD civil 3D and the most suitable elevation was gotten at a distance of 5+600m from the outlet as shown in Figure 10.

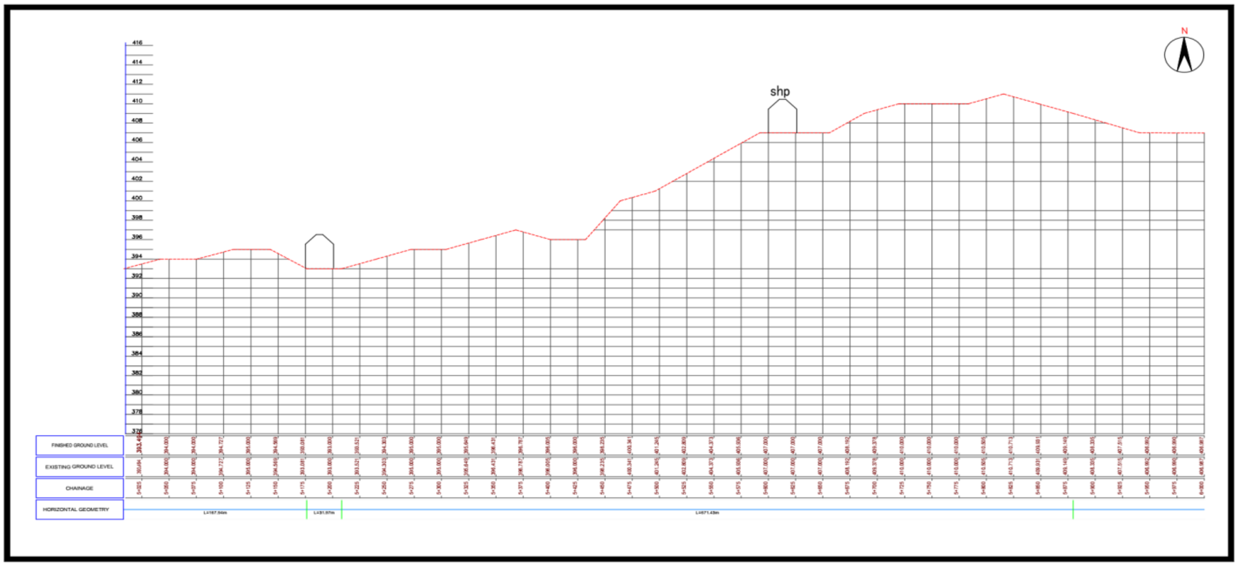

Figure 10: Possible Mini Hydropower sites

The design and analysis of the mini hydropower was done based on the monthly mean discharge gotten from channel 55 and channel 49 Swat channel flow output result, which corresponds tochainage 5+600 , for the year 2006 to 2019.

M	1	2	3	4	5	6	7	8	9	10	11	12
Discharge (cumec)x100	60.81	41.14	38.02	52.22	69.96	118.47	298.67	639.48	616.59	419.21	169.21	90.43
Percentage of time equalled or exceeded p= $\frac{m}{12} * 100$	8.3	16.7	25.0	33.3	41.7	50.0	58.3	66.7	75.0	83.3	91.7	100

Stream flow data for dependable discharge.

50% dependable discharge = 118.47 m^3/s
75% dependable discharge = 616.59m^3/s
100% dependable discharge = 90.43 m^3/s

a. Net Head for HP 1 (Chainage 5+600 and Chainage 5+175) = 407 – 393
= 14 meter

3.1.4 POWER POTENTIAL AVAILABLE

Conceptually, the equation generally used to determine the power output based on the flow and head is (Sule et al., 2011) as shown in Equation 5.

$$P = Q*H*g*\eta*\rho \quad (5)$$

Where P is Power (watts), η is overall efficiency (%), ρ is the density of water (1000 kg/m^3), g is the acceleration due to gravity (9.81 m/s^2), Q is the water flow rate (m^3/s) and H is the net head (m). Taking efficiency of 0.85 to estimate the power output

1. The power potential (P) available at HP 1 is:

I. At 50% dependable discharge

Power = 118.47 x 13 x 9.81 x 0.85 x 1000 = 12,842,207.2 KW = 12.8 MW

II. At 75% dependable discharge

P = Q*H* g *η*ρ

= 616.59 x 13 x 9.81 x 0.85 x 1000 = 5,141,425.5 kW = 5.1 MW

4.0 CONCLUSION

The study evaluated the use of river runoff in Kaduna River for the production of mini hydropower. The river runoff at suitable elevation along the river bed was simulated and gotten using SWAT. The Calibration and validation of SWAT for the above-mentioned catchment shows that the model is able to provide a reliable and constant estimation of the river flow along river beds. From the analysis made, it can be concluded that SWAT software in hydrological modelling is able to give a real scenario result. Proven statistically, the final model performance proved good with a Nash Sutcliffe Efficiency of (NSE, 0.89), Coefficient of determination of (R^2, 0.71), Percent BIAS of (PBIAS, 10.39) for calibration and a Nash Sutcliffe Efficiency of (NSE, 0.75),Coefficient of determination of (R^2, 0.96), Percent BIAS of (PBIAS, 12.59) for validation. Head for hydropower situation was identified using the river profile, and it was establish to fall within the classification of a Small hydropower project, which ranges within 10 meter and 20 meters.

References

Abbaspour, K.C.SWAT-CUP2:SWAT Calibration and Uncertainty Programs–A User Manual.Department of Systems Analysis, Integrated Assessment and Modelling(SIAM);Eawag,Swiss Federal Institute of Aquatic Science and Technology, CH: Dübendorf, Switzerland, 2008.

Adedokun, G.,Oladosu, JA. and Ajiboye.TK2013.Smallhydropower potential capacity estimation for provision of rural electricity in Nigeria. ACTA Technical Corviniensis, Bulletinof Engineering, Hunedoara Romania, 4(2): 117-120.

Adejumobi I.A, and O.I. Adebisi, "Exploring Small Hydropower Potentials for Domestic and Information Communication Technology Infrastructural Application in Rural Communities in Nigeria". Proceeding of the 12th Biennial International Conference of Botswana Institution of Engineers, Gaborone, Botswana, pp.19-26, 2011

Arimoro, F. O., Olisa, H. E., Keke, U.N.,Ayanwale,A.V.,andChukwuemeka,V. I. (2018). Exploring spatio-temporal patterns of plankton diversity and community structure as correlates of water quality in a tropical stream. ActaEcologicaSinica, 38(3), 216-223.

Arnold, J,G., Moriase, D.N., Gassman, P.W., Abbaspour, K.C., White, M.J.,Srinivasan, R., Santhi, C.,Harmel, R.D., Griensven, A., Liew, M.W.V., Kannan, N., &Jha, M.K. (2012). SWAT: Model use, calibration,and validation. American

Christine J., A.S. and A. H. Douglas, Calibration and validation of soil and water assessment tool on an agricultural watershed in upstate New York, Journal of Hydrologic Engineering,2005.

Franco, A.C.L.,Bonuma, N.B., 2017. Multi-variable SWAT model calibration with remotely sensed evapotranspiration and observed flow.RBRH22.https://doi.org/ 10.1590/2318-0331.01171609

Kela, Rosaline, Kaisan Muhammad Usman, and Ahmad Tijjani. "Potentials of small hydro power in Nigeria: The current status and investment opportunities." *Natural gas* 9.12 (2012): 1703.

Kusre, D. C. Baruah, P. K. Bordoloi and S. C.Patra,Assessment of hydropower potential using GIS and hydrological modelling technique in Kopili River basin in Assam (India), Applied Energy 87.1 (2010):298-309

Krause P., D.P. Boyle, and F.Bäse, Comparison of different efficiency criteria for hydrological model assessment, Advances in Geosciences, 2010

Kwarteng,E.A.,Gyamfi,C.,Anyemedu,F.O.K.,Amaning-Adjei, K., Anornu, G.K., 2020. Coupling SWAT and bathymetric data in modelling reservoir catchment hydrology. Spat.Inf.Res. https://doi.org/10.1007/s41324-020-00337-7.

Liming, H. Financing rural renewable energy.A comparison between China and India. *Renew. Sustain. Able Energy Rev.* 2009, *13*, 1096–1103

Liu,Yang,Wang,Wei,Ghadimi,Noradin,2017.Electricity load forecasting by an improved forecast engine for building level consumers. Energy 139, 18–30.

Olayinka S.,Ohunakin and Sunday J. Ojolo., 2010 /Small Hydro Power (SHP) Development in Nigeria; An assessment and option for sustainable development. Nigerian Society of Engineers, Abuja; 1 – 16

Santhi C.,J.G. Arnold, J. R. Williams,W.A., R. Srinivasan, and L. Hauck, Validation of the SWAT model on a large river basin with point and non point sources, Journal of American Water Resources Association (JAWRA), 2001.

Singh, Dilip, 2009. Micro hydro power: Resources Assessment Handbook, Prepared for APCTT, Asian and Pacific Centre for Transfer of Technology of the United Nations –Economic and Social Commission for Asia and the Pacific (ESCAP), September 2009

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

Vanliew M., T.L. Bosch, D.D, and J. Arnold, Suitability of SWAT for the conservation effects assessment project: A comparison on the USDA-ARS experimental watersheds, Journal of Hydrological Engineering, 2007.

Williams,J.R.,Kannan,N.,Wang,X.,Santhi,C.,Arnold,J.G.,2012.Evolution of the SCS runoff curve number method and its application to continuous runoff simulation. J. Hydrol. Eng. 17(11),1221–1229