Hydropower Potentials Estimation of Biliran Islands Based on Synthetic Aperture Radar Spatial Data Using Soil and Water Assessment Tool Simulation

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ABSTRACT

Synthetic Aperture Radar (SAR) spatial data simulation using Soil and Water Assessment Tool (SWAT) was conducted to determine the hydropower generation potentials of three (3) major islands of Biliran Province in the Philippines. Results indicate that the dominant hydropower potentials of Biliran are of microhydro class with a total of 2,900 sites and an estimated power output of 35.37 megawatts. Minihydro and picohydro power potentials contributed only 2.8% and 20.5%, respectively, to the total of 46.15 megawatts hydropower potential in the main island of the Province. The second and third biggest islands, Maripipi and Higatangan, were found, through simulation, to have no significant river formation and, hence, no hydropower potential.

Keywords: hydropower, Biliran, renewable energy, SAR simulation

INTRODUCTION

Significance of the Study

Electrical energy from flowing water in sloping lands is one of the dependable forms of renewable energy contributing to the Philippine energy mix (DOE 2015). The province of Biliran, being predominantly mountainous, has high river density and frequent rainfall. With this frequent rainfall and steep land slopes, it is believed that the province has many hydropower potential sites.

Hydropower, one of the environment-friendly and promising sources of renewable energy in the country, has successfully contributed to the rise of industries in the rural areas (*ibid.*). Assessment of hydropower potentials is time consuming and requires considerable work force. Using SWAT, however, the assessment process is done fast with minimal expense and at a generally high level of accuracy.

To help accelerate the local economies and generate more livelihood in the rural areas, this study has investigated hydropower potentials.

The three major islands of the province of Biliran were chosen as the sites of

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the study in an effort to support the local government's plans to electrify all parts of the province, bring small to medium scale industries to its countryside, and boost ecotourism in its scenic water formations and other natural resources.

Figures 1, 2 and 3 show few of the many water formations of Biliran.

Figure 1. Caraycaray River, Naval, Biliran (*Photograph by Rolando Borrinaga*)

Figure 2. Drone-taken photograph of Tinago Falls, Caibiran, Biliran (*Photograph by Project LUPAD*)

Figure 3. Ulan-ulan Falls, Almeria, Biliran (Source: *Biliran Tourism*)

The results of this study may serve as a reference or benchmark for hydropower development projects in the province of Biliran to bring electricity to all residents and attract investments on small and medium industries to boost its localeconomy.

The study aimed to (1) determine the existence of hydropower generation potentials in Biliran Province using SWAT simulation, (2) if potential exists, classify the potentials into large, medium, small, mini, micro, and pico hydro, and (3) quantify the potential power generation in megawatts per hydropower class.

MATERIALS AND METHODS

The Study Site

The study covers the entire province of Biliran. The province consists of three (3) inhabited islands, six (6) major rivers, and eight (8) municipalities.

Biliran is geographically located above the northern part of Leyte and southwest of Samar provinces in Eastern Visayas region of the Philippines. The region is in the central part of the country.

The central part of Biliran Province can be found at 11° 35' north latitude and 124° 27' east longitude. The location map of Biliran is shown in Figure 4.

The municipalities of Biliran Province are Almeria, Biliran, Cabucgayan, Caibiran, Culaba, Kawayan, Maripipi, and the capital town Naval.

The province has 6 major river channels namely: Anas River in Kawayan, Amambahag River in Culaba, Mapula River in Caibiran, Caraycaray River in Naval, Santol River in Biliran Municipality, and Bagongbong River in Almeria.

The Synthetic Aperture Radar (SAR) spatial data for the province of Biliran that were used in this study were provided by Phil-LiDAR II project of the University of the Philippines, Diliman, Quezon City. These data were gathered prior to this study

using spatial technology.

Weather data for Biliran used in the simulation covered the period from January 1, 2003 to December 31, 2015. Data were provided by the head office of Philippine Atmospheric Geophysical Astronomical Services Administration (PAGASA) at the Science Garden, Agham Road, Diliman, Quezon City, Philippines.

The following weather and land parameters were used in the simulation: rainfall, temperature, evaporation, watershed area, subsidiary watershed area, slope, soil type, soil texture, and landuse.

Figure 4. Location map of Biliran relative to Eastern Visayas Region

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Soil and Water Assessment Tool

In determining the hydropower generation potentials of the province, the following state-of-the-art technologies were applied: spatial analysis and GIS-based computer simulation using the Soil and Water Assessment Tool (SWAT). To carry out simulation, the ArcSWAT and ArcGIS computer programs were used. The ArcSWAT was used as an extension program of ArcGIS.

The ArcSWAT software was selected for application in this study due to its high accuracy based on published past studies. Three of those studies were conducted by Serur and Sarma (2016), Tarife et al (2017) and Thair (2016).

A. Simulation Procedure

The commonly used ArcSWAT-GIS modelling and simulation process as shown in Figure 5, was followed in the study. The process uses SAR and meteorological data as basic inputs. The SAR data are made as inputs to the GIS software while the meteorological data in combination with the watershed characteristics are made as inputs to the SWAT software. The GIS software generate the Digital Elevation Model (DEM) which serves as input to the SWAT software. As a result, potential sites and their corresponding power estimates are generated.

Figure 5. The process followed in the modelling and simulation (Source: Anonymous)

In the generation of hydropower sites within the SWAT software, the simulation procedure shown in Figure 6 was used. The simulated river discharge values were combined with the simulated hydraulic heads from the DEM to identify the hydropower potential sites. Finally, from the potential sites, the theoretical power estimates were generated.

Figure 6. Procedure used in generating hydropower potentials sites

B. Data Encoding

Before the start of simulation, the basic characteristics of each river subbasin of the project area were encoded.

For the GIS software, the Synthetic Aperture Radar (SAR) spatial data for the province of Biliran was used as input.

For the ArcSWAT software, watershed characteristics and climatological data were encoded. The watershed characteristics data for the islands include longitude, latitude, soil characteristics, land use/land cover, soil type, terrain slope, subbasin outlets, monitoring points, river and watershed boundaries. The climatological data for the islands include rainfall, air temperature, relative humidity, simulated solar, and wind data.

C. Generation of Digital Elevation Model

The Digital Elevation Model (DEM) of the entire province of Biliran was generated using the ArcGIS software and Synthetic Aperture Radar (SAR) spatial data.

D. Hydraulic Head Generation

Hydraulic heads were generated using the head algorithm developed by the Phil-LiDAR 2 Project at the University of the Philippines, Diliman, Quezon City using

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Python programming language. In the simulation, the SWAT software was set to find only the hydraulic heads that are 20 meters or higher, which were considered sites with economical value.

E. Horizontal Distance Setting

The SWAT simulation model was also set such that it would only determine the hydraulic head if it found two points at 100-meter horizontal distance from each other. One point was at any section of the river and the other was at any lower location along the same river. This is the normal setting for picohydro to minihydro. It is roughly the horizontal length of an assumed penstock path.

F. Theoretical Power Generation

Using the values of hydraulic head and river discharge which were both simulated, the theoretical power output for each site in the river was computed using the waterpower formula:

$$P = \gamma Q H E$$

where P is the power generation potential in kilowatts, γ is the specific gravity of water in kN/m^3 , Q is the river discharge in cubic meters per second, H is the hydraulic head in meters and E is the power generation efficiency of the power plant in ratio. Value of E was set to 0.80 based from the average rating of 65-85% turbine efficiency for small turbines.

The above waterpower formula has been used by the Renewable Energy Management Division (now a bureau) of the Department of Energy in the Philippines (DOE 2015).

Sit Visitation

Biliran was visited to verify the existence of a sample from its 6 major rivers subjected to simulation. The site visitation was done on October 11-13, 2016.

Measurement of the Recent Discharges of Selected Rivers

Having been identified in the SWAT simulation as the two rivers with the highest hydropower potentials, Caraycaray River in Naval and Bagongbong River in Almeria were visited to measure their discharges. The discharge measurements were done on March 15, 2017.

The current meter (2-dimensional flow electro-magnetic current meter, model *Infinity-EM-AEM-USB*) used in the velocity measurement and photographs during the discharge measurements are shown in Figure 7.

Figure 7. Two-dimensional flow electro-magnetic current meter used in velocity measurement (a), velocity measurement at Caraycaray River (b) and discharge measurement at Bagongbong River ©

RESULTS AND DISCUSSION

Generated Digital Elevation Model (DEM)

The DEM shows high elevation differences. This elevation differences were found to be co-existent with rivers formations. It is this co-existence of elevation differences and rivers that is contributory to the formation of waterfalls. The waterfalls in turn provide the hydropower potentials. High elevation differences were observed in the municipalities of Almeria, Culaba, Kawayan, Naval, Caibiran, Biliran and Cabucgayan. These municipalities have many waterfalls (Biliran Provincial Government 2016).

The DEM of the main island of the province of Biliran is shown in Figure 8. In the figure, the white color denotes the highest elevation (approximately 1.3 km) while brown color denotes the next to the highest elevation. On the other hand, yellow color denotes steep slopes while dark green denotes the next to the lowest elevation. Finally, light green color denotes the elevation close to the shoreline or sea level.

Hydrologic Simulation Geographical Results

Computer simulation results showed that out of the eight (8) municipalities of Biliran, seven (7) have significant river formations. The discharge values vary at different sections of each river due to the presence of tributaries. River discharges were only found constant in sections of the river without tributaries. The only municipality without a river formation is Maripipi, a smaller island. The major river in Naval has 10 potential sites for minihydro power plant development located in Barangay Villa Caneja. All the six (6) major rivers in Almeria, Biliran, Cabucgayan, Caibiran, Culaba, Kawayan, and Naval have potentials for both microhydro and picohydro power generations. In the simulation, no significant river formation was also found in the island of Higatangan. Hence, this island has also no hydropower potential like Maripipi Island.

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Figure 8. Digital Elevation Model (DEM) of Biliran Island

Hydropower Potential Sites

The simulation results for the three (3) Biliran islands indicating river density and hydropower potential sites are shown in Figure 9. The map shows that there is no simulation-detected river formation in the smaller islands of Maripipi and Higatangan, while there are six (6) major rivers detected in the main island of Biliran.

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Figure 10. Magnified map of Naval capital town in Biliran Province showing river density and hydropower potential sites

Magnified View of Minihydro Potential Sites

Figure 11 shows the magnified view of the 10 minihydro potential sites. This view corresponds to the vicinity of the circled part in Figure 10. The minihydro potential sites are located along Caraycaray River at Barangay Villa Caneja in the Municipality of Naval.

Figure 11. Magnified view of the minihydro potential sites

Simulated Hydropower Potentials

In the simulation, the whole Biliran Province was found to have significant hydropower potential with a total power generation of 46.15 megawatts (MW). Table 1 shows the summary of hydropower potentials. The hydropower potential comes principally from microhydro (76.6%), followed by picohydro (20.5%), and minihydro (2.8%). Figure 12 shows the contribution of each hydro class. This study uses the hydro classification used by Renewables First (2018) in the United Kingdom.

Table 1. Summary of Biliran hydropower potentials

Class	Power Range	Potential Sites	Average Head (m)	Average Flow (m ³ /s)	Average Power (kW)	Total Power (MW)
Large Hydro	>100 MW	0	N/A	N/A	0.00	0.00
Medium Hydro	>10 MW- 100 MW	0	N/A	N/A	0.00	0.00
Small Hydro	>1 MW- 10 MW	0	N/A	N/A	0.00	0.00
Minihydro	>100 kW- 1 MW	10	22.34	0.742	130.14	1.30
Microhydro	>5 kW- 100 kW	2,900	30.20	0.055	12.20	35.37
Picohydro	>0 kW- 5 kW	3,012	27.58	0.015	3.15	9.48
Total		5,922				46.15

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Figure 12. Percent share of each hydro class in total potential

Minihydro Potential

Minihydro contributes 1.3 MW equivalent to only 2.8% of the total potential. However, individual minihydro power plants generate power that can support small industries such as handicrafts for tourists, bakeries, farming tool shops and electronic repair shops. Results of the simulation shows 10 potential sites that have maximum, minimum, and average power generations of 144.7 kW, 121.1 kW, and 130.1 kW, respectively. Simulated flow was found to be uniform since microhydro potential sites were found only in one river, Caraycaray, in the capital town of Naval.

The minihydro potential sites were found in the midstream part of the river because the river is small in the upstream side and has generally low slope in the downstream side.

Microhydro Potential

Microhydro was found to have a total generation potential of 35.37 MW. Individual site generation can be generated only in smaller scale, above 5 kW up to 100 kW. Simulation results show that each microhydro in Biliran can support a group of about 5-60 households. Results show that microhydro has 2,900 potential sites found in all six (6) major rivers having maximum, minimum, and average power generations of 63.4 kW, 5.0 kW, and 12.2 kW, respectively.

The microhydro potential sites were found mostly in the downstream portions of the rivers with steep slopes. The river formations can be observed in Figures 9 and 10 while the corresponding land elevations can be observed in Figure 8.

Picohydro Potential

The smallest potential was found in the picohydro class. It was found to have a total generation potential of 9.48 MW. Simulation results show that each picohydro in Biliran can support a group of about 1-5 households. Results show that picohydro has 3,012 potential sites found in all six (6) major rivers having

maximum, minimum, and average power generations of 5.00 kW, 1.00 kW and 3.15 kW, respectively.

In contrast with microhydro potential sites, the picohydro potential sites were found mostly in the upstream portions of the rivers with steep slopes as observed in Figures 9 and 10. This is due to the fact that river discharges are smaller in the upstreams since tributaries into the river, which augment river discharges, are normally found in the midstream and downstream parts of the river.

Recent Discharges of Selected Rivers

The results of the measurement of the discharges in the year 2017 at Caraycaray and Bagongbong Rivers are shown in Table 2. These rivers were identified in the SWAT simulation as the two (2) rivers with the highest hydropower potentials.

Table 2. Discharges at Caraycaray and Bagongbong Rivers (2017)

Name of River	Coordinate of Measurement (Latitude, Longitude)	Discharge (m ³ /s)	Date Measured
Caraycaray	11°34'7.34" N, 124°26'39.9" E	1.96	3/15/2017
Bagongbong	11°37'46.34" N, 124°23'54.57" E	1.57	3/15/2017

Based on the simulation, the maximum discharges of Caracaray and Bagongbong Rivers were 0.74 and 0.37 m³/s, respectively. The recent river discharge is expected to be different from simulation result. This is because the data were taken from a single discharge measurement in 2017 at a single section of the river. In contrast, the simulation result was based on long-term climatic data from January 1, 2003 to December 31, 2015, considering the entire length of the river.

Further Studies

Follow-up studies may be conducted to determine the hydropower potentials of Biliran Province, excluding the small islands, with horizontal distance settings of 200 meters and above. This is to find out if the main island of Biliran has potentials for small, medium, and large hydropower classes.

CONCLUSION

Based on simulated results, the following conclusions are drawn: (1) Biliran Province has hydropower generation potentials; (2) the potential sites found were under the classes of minihydro, microhydro and picohydro; no potential was found for small, medium, and large hydro classes; (3) the potentials were quantified as follows: 1.30 MW for minihydro, 35.37 MW for microhydro, and 9.48 MW for picohydro. All minihydro potential sites were found along Caraycaray River in the capital town of Naval, while the microhydro and picohydro potentials were found in

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all the six (6) major rivers of Biliran Island. No significant river formation was found through simulation in the islands of Maripipi and Higatangan, hence, these islands have no potential for hydropower generation.

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