Preliminary Investigation into Jamaica's Hydropower Potential under Future Climate: The case of Dry Harbour Mountains Basin

Delando Grant, Dr. Tannecia S. Stephenson, Dr. Randy Koon Koon.
(University of the West Indies Mona, Department of Physics)
Contact: delando.grant@mymona.uwi.edu

Abstract

This research investigates model projections of hydropower production in the Dry Harbour Mountains basin of Jamaica. The study aims to provide inputs for plans of action and the development of appropriate strategies for the energy sector development. Future climate data for Jamaica are obtained from the ECHAM5 atmospheric general circulation model (GCM) run at a resolution of 25 km. High emission scenario (A1B), equivalent to RCP 6.0 (Vuuren, 2014) for the period 1961-2100 is used to project future climate and as an input to a hydrological model in order to estimate the impact of future climate on streamflow. Further, qualitative impacts on hydropower plant (HPP) production capacity at three future time horizons: 2030's (2030-2039), 2050's (2050-2059), and end of the century (EOC) (2080-2098) are developed. Rainfall projections for Jamaica reflect the onset of a drying trend from the mid-2030s through to 2100; ECHAM5 GCM suggest high increases in mean temperature for the grid boxes 21-23 –up to 4 °C by end of century. As a result, the hydrological model indicates that the local hydrology of the study basin will be significantly influenced by perturbations in temperature and rainfall; which will lead to a decrease in nominal HPP installed capacity of up to 32% by 2100.

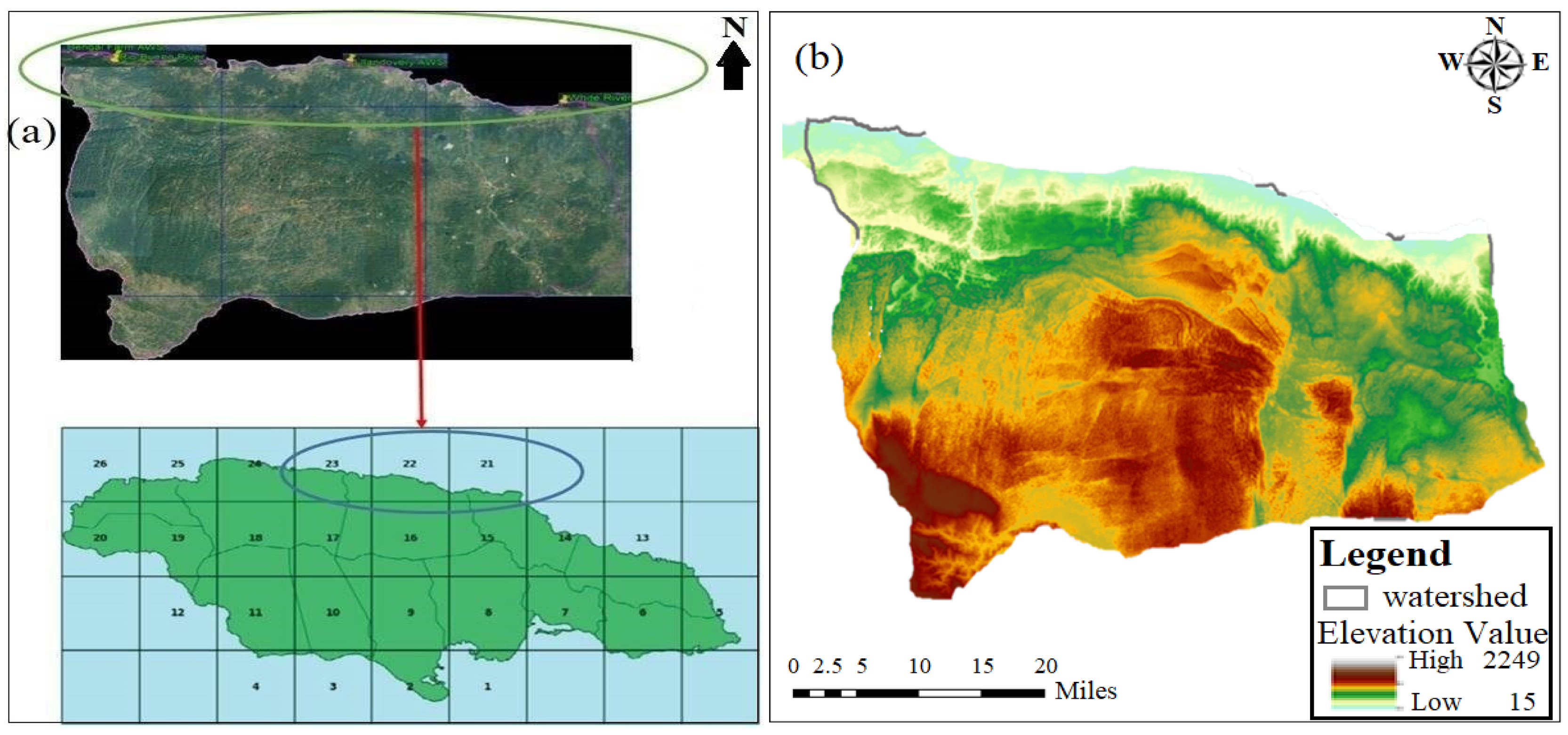


Figure 1. (a) Future streamflow and Hydropower capacity were simulated for Grid box 21-23. (b) DEM of the Dry Harbour Mountains basin

Introduction

- The Caribbean region faces a challenging situation with respect to energy for sustainable development. Globally there is a thrust to increase clean energy production using renewable sources such as Solar Photo-Voltaic (PV), Wind Power and Hydro-Power systems. Flowing water creates energy that can be harnessed and converted into electricity; this is called hydropower
- Hydropower is a renewable, efficient, and reliable source of energy that does not directly emit greenhouse gases or other air pollutants, and can be scheduled to produce power on demand. However, the capacity of hydro units in Jamaica depends largely on the availability of water and the quality of the stream flow (JPS 2017).
- The impacts of climate change and variability on hydro electricity production sector in Jamaica is a cause for concern.
- What will the magnitude of change in future HPP capacity as a result of precipitation and streamflow changes in the Dry Harbour Mountains Basin, Jamaica?

Methodology

- A continuous conceptual hydrological model was developed in HEC-HMS which is calibrated and validated based on the observed daily streamflow (2013 – 2017) at Rio Bueno.
- The hydrological model was subsequently forced with the projected 2020s, 2050s and EOC climate data (Rainfall and Evaporation) extracted from the ECHAM5 GCM (A1B scenario) for grid box 23 seen in Figure 1(a).
- The probability of exceedance (20%, 40%, 50%, 80% & 90%) for projected low, median and high flows were compared to 1986-2003 baseline obtained from WRA's database.
- An energy generation model was used to estimate projected Hydropower generation changes for a design head and HPP efficiency of 80 meters and 80% respectively.

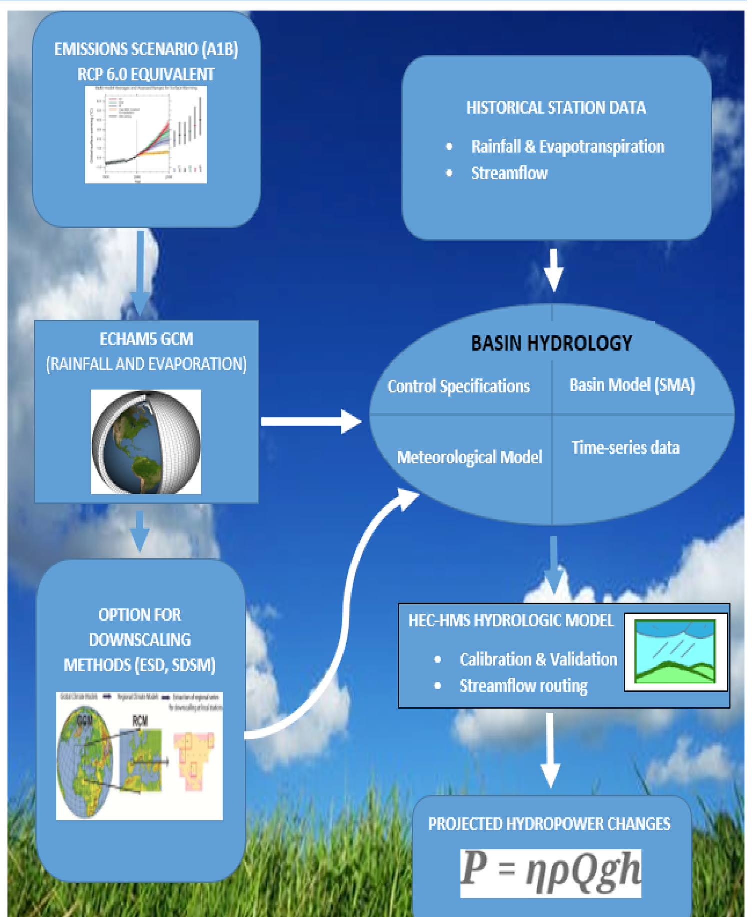


Figure 2. Climate impacts on HPP modelling chain

Results

- **Model performance**

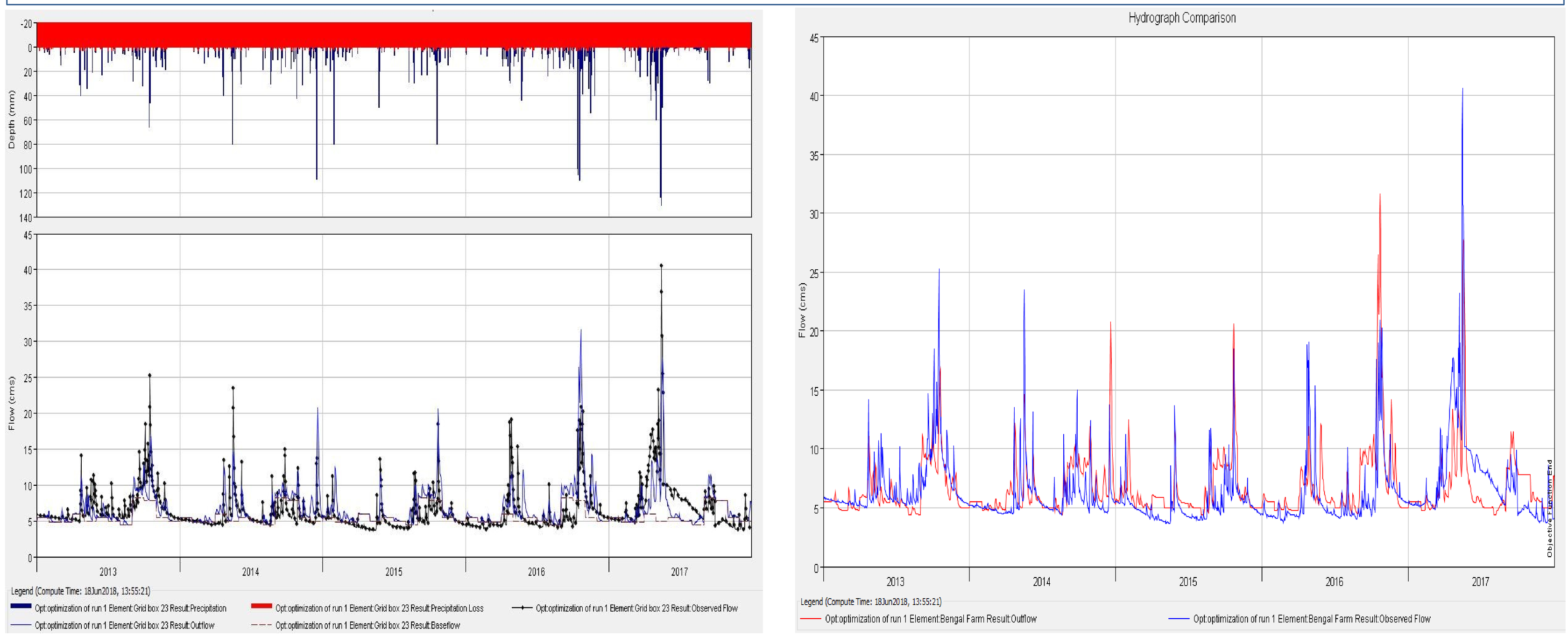
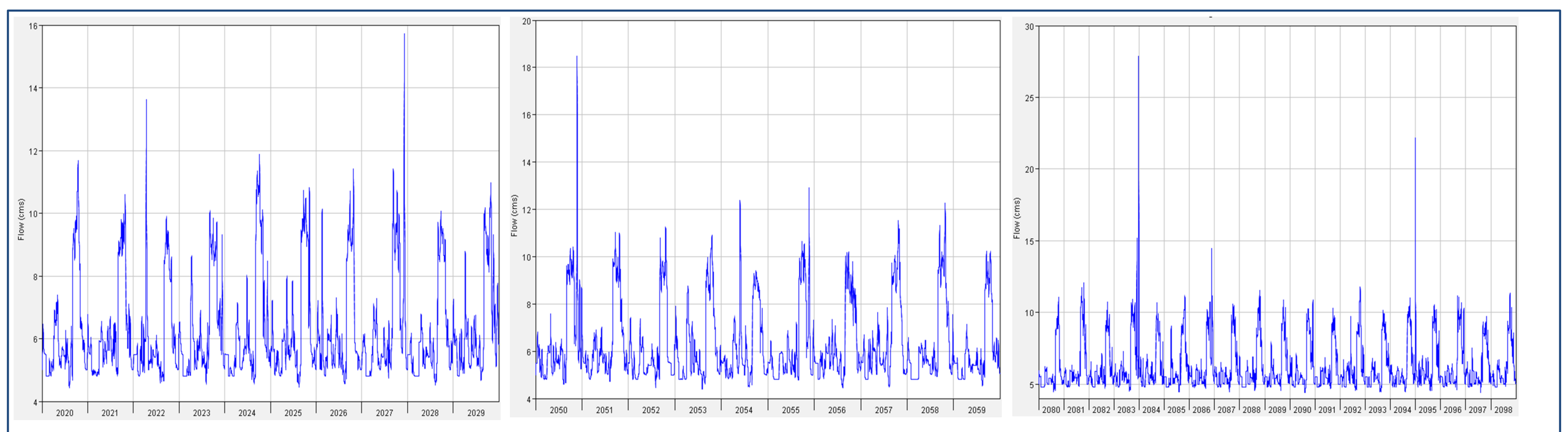
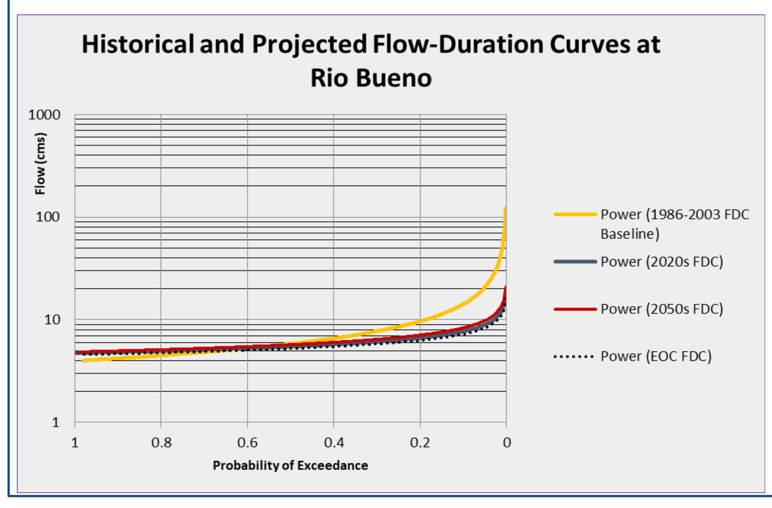


Figure 3. Streamflow calibration Hydrograph in HEC-HMS for years 2013-2017; Blue lines indicate observed flows and Red line indicate model median simulation (Right).





Period	Exceedance probability (%)	Flow (cms)	% change in Flow	Power yield (MW)	% change in power yield
2020s	20	6.4	-26.4	4.0	-26.4
	40	5.7	-8.1	3.6	-8.1
	50	5.4	-3.6	3.4	-3.6
	80	4.9	6.5	3.1	6.5
	90	4.7	6.8	2.9	6.8
2050s	20	6.8	-21.8	4.3	-21.8
	40	5.7	-8.1	3.6	-8.1
	50	5.5	-1.8	3.4	-1.8
	80	4.9	6.5	3.1	6.5
	90	4.8	9.1	3.0	9.1
EOC	20	5.9	-32.2	3.7	-32.2
	40	5.3	-14.5	3.3	-14.5
	50	5.2	-7.1	3.3	-7.1
	80	4.7	2.2	2.9	2.2
	90	4.5	2.3	2.8	2.3

Figure 4. (Top) Hydrograph of projected flow regime for grid box 23 - (Left) 2020s, (Center) 2050s, (Right) EOC (Bottom- left) Flow Duration Curve of Historical and Projected flows at Rio Bueno, located in Grid box 23 (Bottom- Right) Projected percentage changes in power capacity for HPP located in Grid box 23 (Bottom- Left) Estimated changes in projected flow and HPP capacity with respect to 1986-2003 baseline for Grid box 23

Discussion

- The current installed capacity of the Rio Bueno HPP located in grid box 23 is 3.6 MW (JPS 2015).
- The study reveals that at median design flow, the theoretical projected power potential of sub basin represented by Grid Box 23 range between 3.3-3.4 MW. This represents a decrease of approx. 6-8% in power capacity.
- The projected changes in power capacity is greatest by EOC for high flows (20% - 40% exceedance probabilities) and justifies the objective of this study.
- Limitations : The rainfall pattern and distribution were not considered (Only one gauge station used). Areal rainfall methods such as Thiessen polygons would better represent the sub-basin (grid box 23)
- The parameters used in the HEC-HMS SMA loss method were held constant for future simulations- however, future basin conditions (such as canopy storage etc.) may change.

Future Work

- Employ downscaling techniques to existing HPP locations in Dry Harbour Mountains basin, in order delineate future HPP potential.
- Use RCM such as PRECIS or RegCM with RCP scenario.
- Bias correction of projected data (Rainfall and ET).
- Investigate sub-basin specific changes in evaporation (Evap-pan paradox?).
- Seasonal Analysis would better represent seasonal energy yield.

Figure 5. An old abandoned dam built in 1920 for a mini hydropower plant at Serge Island, St. Thomas, Jamaica and is now locally known as Reggae Falls

References

1. Analysis Techniques: Flow Duration Analysis from Stream flow Evaluations for Watershed Restoration Planning and Design, http://water.oregonstate.edu/streamflow/, Oregon State University, 2002-2005.
2. Caribbean Community Climate Change Centre clearing house database http://www.caribbeanclimate.bz/
3. Jamaica Public Service Company (JPS) https://www.jpsco.com/about-jps/how-we-serve-you/power-plants/
4. Van Vuuren, D.P.; Carter, T.R.(2014) Climatic Change, volume 122, issue 3, pp. 415 – 429 (Article)
5. Water Resources Authority, Jamaica http://www.wra.gov.jm/Resource%20Monitoring