CLIMATE CHANGE IMPACT ON JATIGEDE RESERVOIR OPERATION

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ABSTRACT

The hydrological system is affected by climate change. Reservoir inflow characteristics in the future will change substantially. Dry season with decreasing low flow will be in a longer duration. Jatigede Reservoir in Cimanuk River, West Java is the second-largest reservoir in Indonesia with a capacity of almost one billion cubic meters of water. Jatigede Reservoir has the main function for supplying an irrigation area of 90,000 hectares, public water supply of 3.5 cubic meters per second, hydroelectric power plants with the capacity of 110 MW, providing freshwater aquaculture facility, water sports, and recreational facility, as well as flood control for the area of 14,000 hectares. This paper analyzes the impact of climate change on the lower reservoir operation rule curve to cope with the climate change effect. Climate change impact on rainfall in the future is projected using the worst scenario RCP 8.5, and the monthly rainfall is projected until the year of 2045 using an ensemble of seven models commonly used by the Indonesian Agency for Meteorology, Climatology, and Geo-physics. It is concluded that climate change impact on reservoir inflow generally having a decreasing trend and longer dry season. No significant impact identified for wet and normal year scenarios, while simulation with the dry year scenario shows a shortage in irrigation and lowering reservoir level which means a decrease in energy generation.

1. INTRODUCTION

1.1 Background

Jatigede Reservoir in Cimanuk River, West Jawa, Indonesia is the second-largest reservoir in Indonesia with a capacity of almost one billion cubic meters of water. Jatigede Reservoir has the main function for supplying an irrigation area of 90,000 hectares, public water supply of 3.5 cubic meters per second, hydro-electric power plants with the capacity of 110 MW, providing freshwater aquaculture facility, water sports, and recreational facility, as well as flood control for the area of 14,000 hectares.

Figure 1 : Location of Jatigede Reservoir in West Java, Indonesia

It is important to find out the climate change impact on the inflow to Jatigede Reservoir, and consequently its impact to the operation performance of Jatigede Reservoir in the future.

1.2 Objective

This paper analyzes the impact of climate change on Jatigede Reservoir to cope with the climate change effect.

2. METHODOLOGY

2.1 Climate Change Projection

Climate change impact on rainfall until the year of 2045 is projected using an ensemble of seven models of General Circulation Model (GCM), which are CNRM CM5, CNRM RCA, CNRM v2 RegCM, CSIRO MK3,6, EC EARTH, GFDL ESM, and IPSL. The climate change scenario of the Representative Concentration Pathways (RCP) 8.5 is applied, assuming high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and greenhouse gas emissions in the absence of climate change policies, as mentioned in the latest IPCC The 5th Assesment Report. This scenario is a reflection of the political reality of climate change that is currently happening, where the growth of greenhouse gas emissions is increasing and is accompanied by a limited political will to take drastic greenhouse gas mitigation actions in the near future (Intergovernmental Panel on Climate Change, 2013).

The original model's interval is daily, then accumulated into 15 days to match the reservoir operation time interval. Data were divided into two groups consists of baseline periods (1981-2005) and projection period (2006-2045). Projected rainfall data is bias-corrected by using statistical bias-corrected methods, quantile mapping. CHIRPS dataset is applied as observation rainfall data. CHIRPS data is having high resolution and long data sequences, enable to cover blank areas, disconnected data, and data inconsistencies in the Indonesia area (Fadholi & Adzani, 2018).

The corrected rainfall projection is applied to project river discharge using the empirical projection method. The empirical methods assumed that changes in discharge for each month are caused by changes in monthly rainfall and potential evaporation. Potential evaporation was obtained from the Potential Evaporation Climatic Research Unit Time Series (CRU TS) version 4.01 (University of East Anglia, n.d.). Empirical method steps are following the procedure described by Risbey & Entekhabi (1996) and Fu, Charles, & Chiew (2007).

Flow Duration Curves (FDC) is used to validate the results of discharge projection in the control period in the year of 2006-2015. Westerberg et al. (2011) proved that FDC is suitable for calibration to the regional location by taking uncertainties in the hydrological model and data into account. FDC address problems that traditional performance measures like the Nash-Sutcliffe model efficiency faced, such as (1) uncertain discharge data, (2) variable sensitivity of different performance measures to different flow magnitudes, (3) influence of unknown input/output errors and (4) inability to evaluate model performance when observation time periods for discharge and model input data do not overlap.

Frequency analysis on the ensemble of the seven projection models resulting in the wet, normal, and dry year inflow to the reservoir for the present period and future period (2036-2045). The percentage of the difference between flow in the future compared with at present will be applied to change the reservoir inflow after the impact of climate change.

2.2 Reservoir Operation Simulation

Jatigede Reservoir operation is simulated using the River Basin Simulation Model (Ribasim) which is widely available and used to be applied as tools in the development of strategic planning studies in Indonesia (Gany et al., 2001).

3. RESULTS AND DISCUSSIONS

3.1 Climate Change Projection

Averaging the climate change projections model is a common practice for showing the tendency of each model, such in Diallo, Sylla, Giorgi, Gaye, & Camara (2012) and Kamworapan & Surussavadee (2019) Figure 2 shows the FDC of flow discharge from the seven projection model together with ground station observation data, which shows a fairly good result. At the probability of exceedance 60%, 80%, 90%, and 95% the ensemble average is very close to the observation data, which only deviates of about 2 m3/s, 7 m3/s, 2 m3/s, and 2 m3/s consecutively with the observation curve. For the next analysis, the ensembles average is used to represent the discharge condition at present in 2016 to in the future year 2045.

The seasonal patterns of the ensembles average are compared per decade as shown in Figure 3a. The dry season tends to arrive sooner and stay longer than in the current period. In the current period 2006-2015, the dry season lasted from June-I to October Week-I with the average discharge valued about 66 m^3/s, while in the near future period of 2026-2035 models project the dry season will begin in June Week-I until October Week-I with an average flow of about 82.7 m^3/s. In the far future period of 2036-2045 model projects a much longer dry season starting from May Week-II to October Week-I, with an average discharge of 69.3 m^3/s. The wet season also tends to experience a significant increase in discharges, especially in September II to November II causing the probability event of floods also increased.

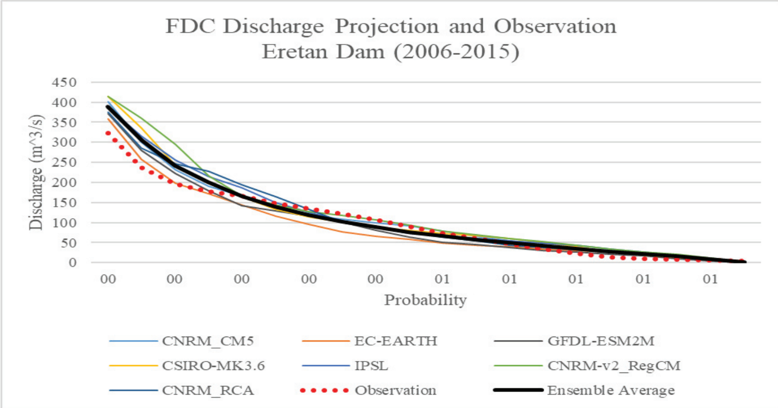
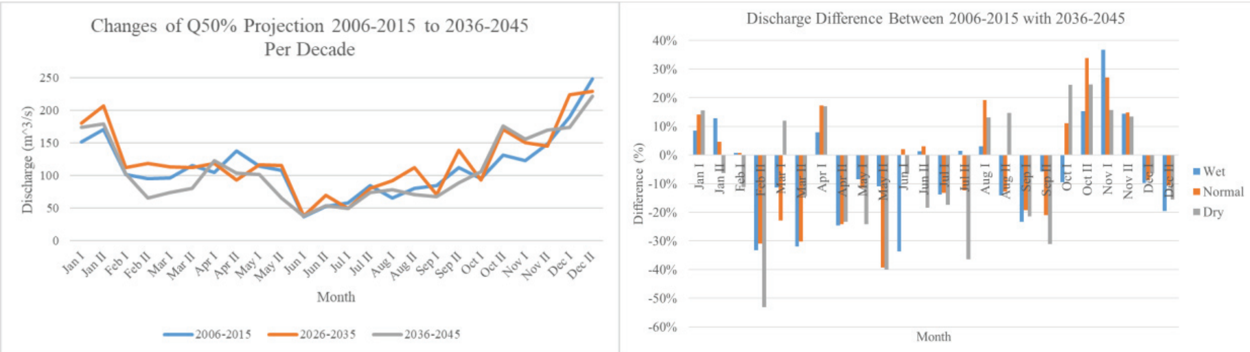


Figure 2 : Comparison of Projection and Observation Discharge's FDC in 2006-2015



(a) Changes of Q50% between 2006-2015, 2026-2035, 2036-2045

(b) Percent of discharge Change between 2006-2015 with 2036-2045

Figure 3 : Discharge difference between 2006-2015 to 2036-2045

Figure 3b shows the discharge differences between the current 2006-2015 period and the projected in the 2036-2045 period. Q33% shown as Wet, Q50% as Normal, and Q67% as Dry. In the first transition season to the dry season (February Week-II to September Week-I), especially in Q33%, model projects a mostly decreased discharge of 8% to -34% while Q67% projections showed a significant decrease of -13% to -40%. With projection showing a decrease in Q33% in the first transition season to the dry season, it could indicate the chance of a water deficit will be more frequent happened in the period 2036-2045.

In the second transition season (October Week-I to November Week-II), the projections showed consistent results with an increase in the amount of 11% to 34% at Q50% and 13% to -20% at Q67% with the highest peak of discharge decrease in October. It also happened in January Q50% increased 5% to 14% and in January Week I Q67% increased by 16%. This indicates the extremely heavy rainfall would occur leading to flooding in this time span.

3.2 Inflow Projection

The resulting climate change impact on river discharges in terms of percentage from its original flow is applied to the three scenarios of the wet year, normal year, and dry year inflow to Jatigede Reservoir. Figures 4, 5, and 6 show that the dry season is lengthened, usually begin in July is becoming starting in May. This fact would affect the operation of Jatigede Reservoir to maintain the power generation and at the same time satisfy the downstream water demand.

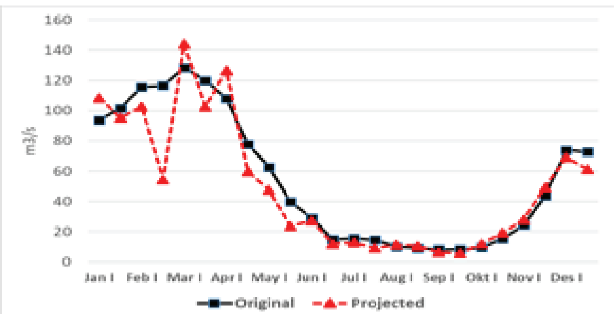


Figure 4 : The projected reservoir inflow for the dry year

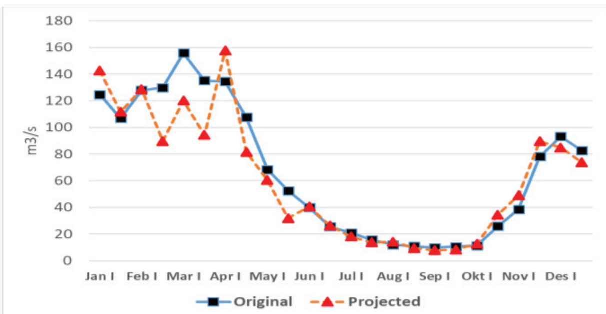


Figure 5 : The projected reservoir inflow for the normal year

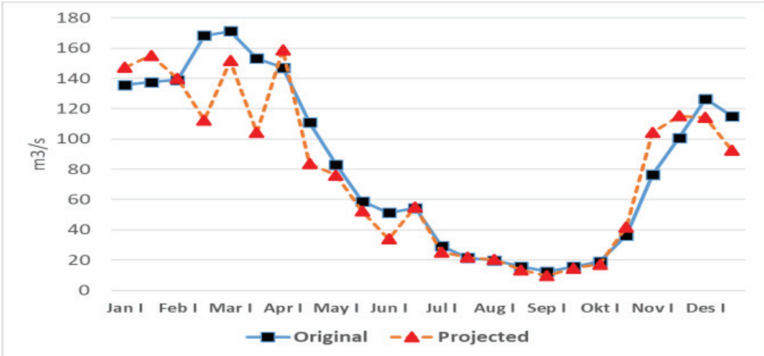


Figure 6 : The projected reservoir inflow for the wet year

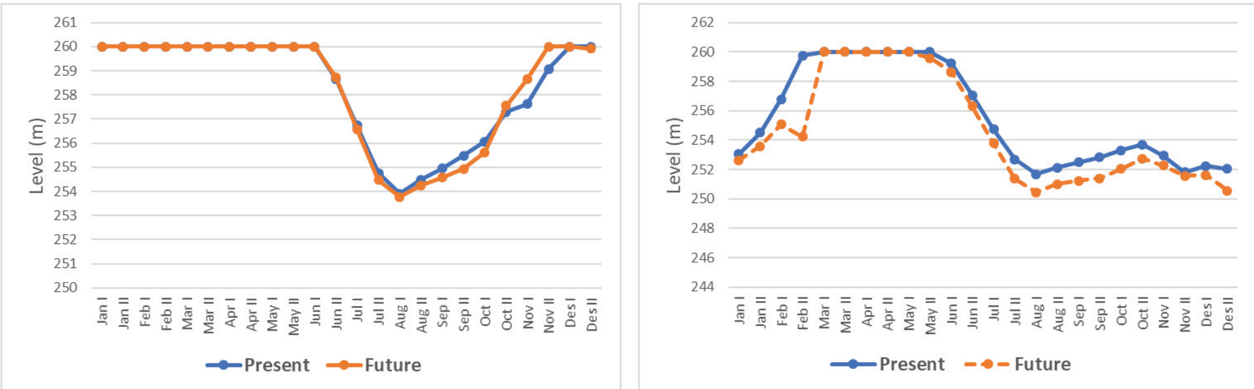
3.3 Reservoir Simulation

The simulation result of reservoir operation using three inflow scenarios of wet, normal, and dry year is tabulated in the following table.

Table 1 : Climate change impact on Jatigede Reservoir

Inflow Scenario	Wet Year	Normal Year	Dry Year
Public water supply	100%	100%	100%
Irrigation supply	100%	100%	89% to 100%
Drops of water level	No.	No.	Up to 5 meters

Under the inflow scenario of the wet year and normal year, climate change does not have any significant impact on the Jatigede reservoir performance. Public water supply, as well as irrigation water demand, are still fulfilled as planned. However, during the dry year, irrigation water can not be fulfilled by 100%. Furthermore, there is a drop of water level during the dry year as low as 5 meters from the present water level (Figure 7b). This would affect energy generation significantly.



(a) Reservoir level under normal year inflow (b) Reservoir level under dry year inflow

Figure 7 : Reservoir level at present and in the future with climate change impact

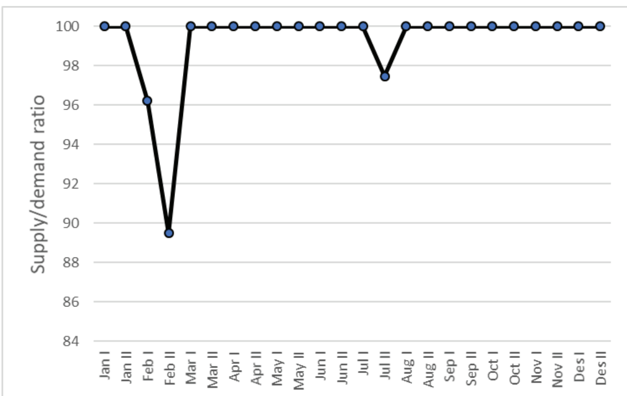


Figure 8 : Supply over demand ratio of irrigation water

4. CONCLUSIONS AND RECOMMENDATIONS

Jatigede reservoir inflow has been projected until the year of 2045 incorporating the climate change impact as the average of the ensemble of the seven climate change models available in Indonesia. Climate change impact on reservoir inflow generally having decreasing tren and longer dry season. However, simulation of reservoir operation reveals that no significant impact identified for wet and normal year scenarios. Simulation with the dry year scenario shows a shortage in irrigation and lowering reservoir level which means a decrease in energy generation.

It should be noted that this analysis is based on the average of an ensemble of the seven climate change models. The worst-case scenarios of the seven model might bring worse results, and could be elaborated in the next research.

REFERENCES

Diallo, I., Sylla, M. B., Giorgi, F., Gaye, A. T., & Camara, M. (2012). Multimodel GCM-RCM Ensemble-Based Projections of Temperature and Precipitation over West Africa for the Early 21st Century. International Journal of Geophysics vol. 212.

Fadholi, A., & Adzani, R. (2018). Analisis Frekuensi Curah Hujan Ekstrem Kepulauan Bangka Belitung Berbasis Data Climate Hazards Group Infra-red Precipitation With Stations (CHIRPS). Gea: Jurnal Pendidikan Geografi Vol. 18 No. 1.

Fu, G., Charles, S., & Chiew, F. (2007). A Two-Parameter Climate Elasticity of Streamflow Index to Assess Climate. Water Resources Research Vol. 43.

Gany AHA, Hatmoko W, Yusuf IA. A General Overview of Decision Support System for Water Resources Planning and Management in Indonesia. J Pengairan. 2001;1–14.

Intergovernmental Panel on Climate Change. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Kamworapan, S., & Surussavadee, C. (2019). Evaluation of CMIP5 Global Climate Models for Simulating Climatological Temperature and Precipitation for Southeast Asia. Advances in Meteorology.

Risbey, J., & Entekhabi, D. (1996). Observed Sacramento Basin streamflow response to precipitation and temperature changes and its relevance to climate impacts studies. J. Hydrol., 184(3–4), 209-223.

University of East Anglia. (n.d.). Retrieved from Climatic Research Unit: https://crudata.uea.ac.uk/cru/data/hrg/.

Westerberg, I. K. et al. 2011. "Calibration of Hydrological Models Using Flow-Duration Curves." Hydrology and Earth System Sciences 15(7): 2205–27.