Changes of the Mekong Hydropower Generation under the Future Climate Projections

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1. Introduction

In the last decades, population growth, urbanization, and economic development have led to an increase in energy consumption in the Mekong region, by up to 10% annually. The average electricity consumption for one person was about 950 kWh, with Thailand having the highest consumption of over 2,000 kWh. Interest in hydroelectric dams has been significantly increased in the Mekong region to maintain energy security while reducing carbon emissions. Hydropower could potentially reduce greenhouse gas (GHG) emissions by up to 13% from the atmosphere, with significant reductions in Sulphur Dioxide (SO_2) and Nitrous Oxide (N_2O). The Mekong River Basin (MRB) could provide the greatest potential for hydropower development given its abundant water resources and location. However, future hydropower generation not only relies on the current river flow variations but also on the future water availability induced by climate change. This study aims to assess the impact of climate change on hydropower production in the MRB using the most recent climate projections CMIP6.

2. Study Area

The Mekong River Basin is generally known as the largest basin in Southeast Asia. Originating from the Tibetan highlands, it is shared by six countries of China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. It covers a drainage area of 795,000 km^2, with an average annual discharge of 14,500 m^3/s. The climate is driven by the Asian Southwest monsoons, giving two seasons: wet season (May–Oct) and dry season (Nov–Apr). In a normal year, it has an average precipitation of 1,500 mm/year.

3. Methodology

3.1 Hydrologic Model Simulation

The study used the two-dimensional distributed Rainfall-Runoff-Inundation (RRI) model coupled with a reservoir model to simulate the discharge and hydropower generation. The model was calibrated and validated using the global optimization algorithm of the Shuffled Complex Evolution (SCE-UA) for the entire MRB by Try et al. (2020).

Given the inflow to the turbines, the hydropower generation can be expressed as follows:

$$E = \eta \times \rho \times g \times H \times Q_{turb}$$

3.2 Dataset

For the hydrologic modeling, precipitation was taken from Global Precipitation Climatology Center (GPCC), topographic data was obtained from the Multi-Error-Remove-Improve-Terrain (MERIT-DEM), land use was extracted from MODIS, evapotranspiration was taken from the Japanese 55-year Reanalysis (JRA-55).

Hydropower information was provided by the MRC’s database. It contained existing and planned hydropower projects in the Lower Mekong Region as well as projects in China. In this study, two hydropower scenarios were prepared: the present scenario (98 projects) and the future scenario (126 projects).

Outputs of eight GCMs from CMIP6 projections with two SSPs (SSP2-4.5 and SSP5-8.5) were adopted in this study. All selected GCMs were bias-corrected with GPCC precipitation using the linear scaling method before applying to the hydrologic model.

3.3 Data Analysis

Characteristics of the hydropower in the MRB were analyzed to determine their potential in generating energy under future climate projections. Several types of analysis were performed:

- Hydropower classification based on turbine flow capacity
- Future flow increase classification based on the flow duration curve

4. Results and Discussions

4.1 Impact of Climate Change on River Discharge

Total inflow to the turbines of present hydropower and future hydropower were evaluated to better understand the potential flow changes in the MRB. Under the present hydropower scenario, the total inflow increased from 974 MCM (present climate) to 1,121 MCM in the SSP2-4.5, and to 1,206 MCM in the SSP5-8.5. Under the future hydropower scenario, the total inflow increased from 2,753 MCM (present climate) to 3,147 MCM and 3,368 MCM in the SSP2-4.5 and SSP5-8.5, respectively.

4.2 Impact of Climate Change on Energy Generation

Climate change is expected to change the total inflow through turbines, thus, affecting hydropower generation. Although the total inflow was estimated to increase in all climate scenarios, hydropower generation will decrease in some GCMs. Under the present hydropower (98 dams), the total inflow will increase on average by 15% in the SSP2-4.5, and 24% in the SSP5-8.5. On the other hand, the total inflow of future hydropower (126 dams) will increase on average

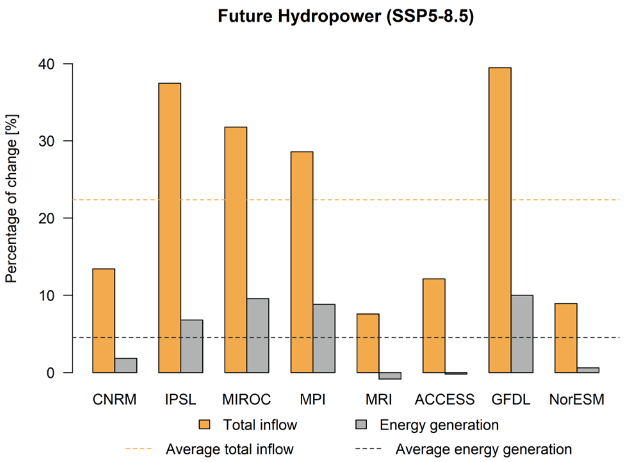

Fig. 1 Relative changes in total inflow and energy generation of the future hydropower development

by 14% and 22% in SSP2-4.5 and SSP5-8.5, respectively. In contrast, the energy generation was expected to increase on average by only 2% (3%) under the SSP2-4.5 (SSP5-8.5) for the present hydropower, and only 3% (5%) under the SSP2-4.5 (SSP5-8.5) for the future hydropower **(Fig. 1)**. The small increase rate in energy production compared to the increase rate in total inflow was due to the limited turbine flow capacity of the hydropower. Restricted by the turbine capacity, excessive inflow will be abandoned through the spillway without generating additional energy.

4.3 Characterization of Hydropower in the Mekong River Basin

The future hydropower scenario in the MRB was classified based on the characteristics of turbine flow capacity and the flow duration curves to identify its future potential in energy generation. According to data analysis based on turbine flow capacity, Type-A hydropower accounted for 67% of all future hydropower adopted in this study, followed by Type-B (20%) and Type-C (13%).

In addition, the majority of the river discharge will increase in high flow in the future, based on the flow duration curve analysis. Results from data analysis indicated that most of the hydropower in the Mekong region was Type-A with a future high-flow increase, accounting for more than half of the total hydropower projects. Dam Type-A and Type-B are primarily found in the Lower Mekong Basin, particularly in the Mekong's tributaries and 3S region (Sekong, Sensan, and Srepok). On the other hand, Dam Type-C is mainly located in the Upper Mekong Basin of China (so-called Lancang Jiang). Hydropower with a future high-flow increase and large turbine flow capacity has greater hydropower potential since most of the inflow could go through the turbine for additional energy generation. Hydropower with a small turbine flow capacity, on the other hand, cannot benefit from increased inflows induced by climate change because the excessive inflow will go to the spillway instead of the turbines.