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Impacts of Proposed Hydropower Dams and Climate Change on Streamflow and Flood Inundation in the Mekong River Basin

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1. Introduction

The water resources are the key players in economic growth, food security, flood pulse and ecosystem dynamics in the Mekong River Basin (MRB). In the last few decades, this river basin has been facing two major changes, hydropower construction and climate change. Parts of the river flow are controlled by the reservoir operations, changing from its natural state. On top of that, climate change is putting more pressure on water resources of the basin. Hydropower development is regarded as a potential step toward renewable energy and low carbon emission established by the Mekong River Commission (MRC)'s Strategic Plan and Basin Development. Riparian countries would benefit from foreign investment, energy production, business exchange and agricultural product increase. However, it comes with the costs of changes in flow regime, flood characteristics as well as affecting the whole ecosystem of the basin. In addition, climate change is expected to change rainfall patterns and frequency of extreme events. Clearly, the hydrology of the MRB is affected by these two major drivers while the study on the combined impacts remains limited to some extent. This study aims to assess the cumulative impacts of reservoir operations and climate change till the end of the century using the latest CMIP6 projections.

2. Study Area

The Mekong is the 12th longest river and the largest basin in Southeast Asia (Fig.1). Originated 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 Southeast Asian monsoons, with an average precipitation of 1,500 mm/year[2].

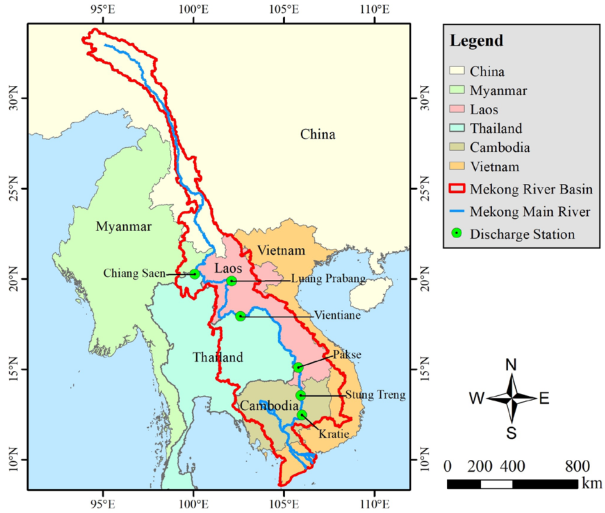

Fig.1 Map of the Mekong River Basin

3. Methodology

3.1 Rainfall-Runoff-Inundation (RRI) Model

RRI model is a two-dimensional model that can simulate rainfall-runoff and flood inundation at the same time. The runoff on slope grid cells is calculated by the 2D diffusive wave model, while the channel runoff is calculated by the 1D diffusive wave model. The model was calibrated and validated using the SCE-UA algorithm for the entire MRB by Try et al. (2018).

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 LMB as well as the projects in China. In this study, two hydropower scenarios were prepared for the hydrological analysis, present scenario (98 projects) and future scenario (126 projects).

Outputs of eight GCMs from CMIP6 projections with two SSPs 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.

4. Results and Discussions

4.1 Cumulative Impacts on River Discharge

This study assessed the cumulative impacts of reservoir operations and climate change on river discharge at seasonal timescales. Two hydrological stations along the main river were chosen: Chiang Saen (located at the most upstream of the LMB) and Kratie (located at the most downstream of the LMB). Fig.2 shows the simulated seasonal discharge under reservoir operations and climate change (SSP5-8.5). The future period was subdivided into near-future, mid-future and far-future period. Results suggested that reservoir operations and climate change would increase the discharge in the same direction during the dry season. While there was some trade-off between the two drivers during the wet season. The climate change would substantially increase the discharge from time to time till the end of the century. While, the reservoir operations tended to reduce the discharge to some degree, especially the future dam scenario. Despite the trade-off, the impact from climate change was so strong that reservoir operations could not fully diminish.

4.2 Cumulative Impacts on Flood Extent

To further understand the impacts on flood inundation, the study re-run the simulations at a finer resolution of 3km instead of 10km, previously applied for flow analysis. The threshold was selected at 0.5m of water depth to classify the inundated and non-inundated areas. Based on the simulation results, flood magnitudes were increased for all future scenarios, but at different degrees ranging from 2% to 37%. Fig.3 presents the simulated inundated area under climate change only (high emission) and combined drivers of climate change and future dams at different timeframes. The largest impact was detected under sole climate change in the far-future, up to +37% in area compared to the historical period. Noticeable, hydropower operations play an important role in reducing the climate change effect as seen in the combined scenario of climate change and future dams. It could potentially reduce the effect of climate change by about 10% on average throughout the future periods.

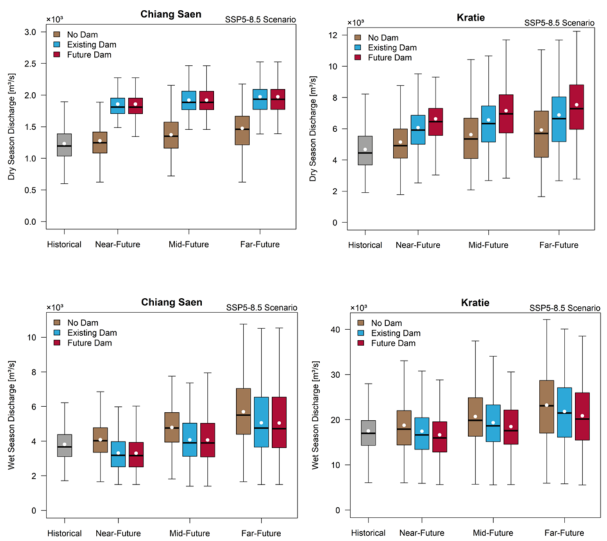

Fig.2 Simulated dry and wet seasonal flow under cumulative impacts

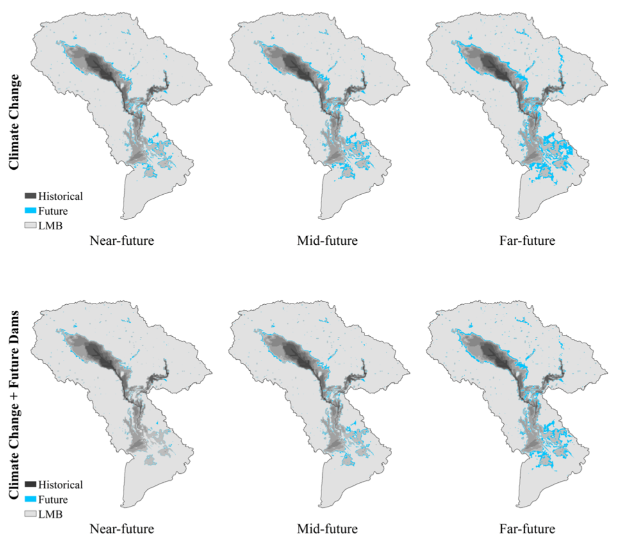

Fig.3 Simulated inundated area under cumulative impacts (SSP5-8.5)