

# Increasing flood risks in the Vietnamese Ca river basin: a challenge for reservoir-based flood management

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## INTRODUCTION

As global warming is expected to intensify extreme rainfall over Vietnam, an increase in flooding is also anticipated. To study this issue for the Ca river basin, we conducted an assessment of future flood changes under various global warming levels by integrating extreme rainfall projections from climate models with hydrological and hydraulic modeling. Results show large increases in flood flow over the basin, especially in the main Ca River and Hieu River. Flooding in the downstream area would be more severe, with for instance an increase in the number of inundated communes for a typical flood event from 119 currently to 125 at 3°C of global warming compared to pre-industrial levels. The findings further suggest that the flood regulation capacity of major reservoirs, such as Ban Ve reservoir, would be exceeded.

## CONTEXT & MOTIVATION

Climate change is increasingly recognized as a critical driver of changes in flood dynamics, with increasing flood frequency and magnitude in many regions of the

world, including southeast Asia. Located in the North Central region of Vietnam, the Ca River basin faces large floods almost every year. These events regularly cause great damage to local people and their properties, seriously affecting production and people's lives.

Although several previous studies have investigated flooding in the Ca river basin, the assessment of climate change impacts on floods and reservoir regulation capacities remains limited. To contribute to a better anticipation of future changes, we conducted a modeling study on the impact of increased extreme rainfall on flood flow and flood extent at 1.5°C, 2°C, 3°C and 4°C of global warming.

## METHODS

We have implemented a suite of hydrological and hydraulic models (MIKE package) to simulate the discharge flows in the Ca river and its tributaries, as well as flood extent and water depth downstream. We calibrated and validated the models using meteorological and

hydrological observations for 3 past flood events.

Then we generated future extreme rainfall scenarios by combining:

- the hourly rainfall data observed at station level during the flood event of August 2018;
- the projected changes of the annual maximum precipitation in a single day (Rx1d) and annual maximum precipitation cumulated over 5 days (Rx5d) – in percentages compared to 1986-2005 – as simulated by bias-corrected regional climate models driven by CMIP5 global climate models under 2 RCP scenarios.

Specifically, future rainfall scenarios are built by scaling the hourly rainfall data with the Rx1d/Rx5d changes from the climate ensemble, at different global warming levels. In addition, we tested two operational scenarios for the Ban Ve reservoir: 1) the real-time operation during the 2018 flood; 2) a flood-control optimized operation.

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**Geography** Vietnam, Ca River Basin

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**Key words** heavy rainfall, flooding, global warming, reservoir operation

**Themes** hydrology, climate change, flood

## RESULTS

**Extreme rainfall.** Projected average increases in Rx1d at the station level range from 11–30% and 23–49% at 1.5°C and 4°C of global warming, respectively. Similarly, very large increases are projected for Rx5d, from 19–30% at 1.5°C to 26–49% at 4°C of global warming.

**Discharge flow.** More intense rainfall leads to large increases in river discharge at hydrological stations in upstream areas along the Ca and Hieu Rivers. At Quy Chau station, on the Hieu River, the simulated flood peak rises by 127% to 149% at 1.5°C and 4°C of global warming, respectively, compared to the 2018 flood. Midstream, at Dua station, the increase ranges from 65% to 98%, while a smaller increase of 15% to 30% is projected at Son Diem station on the Ngan Pho branch.

**Flood extent and water depth.** Total flooded area increases by about 36–45% compared to the 2018 reference simulated flood. Looking at the flooded area according to the water depth, it appears that the largest changes are simulated for zones where water depth exceeds 1.5m. Of particular concern are the expansion of areas inundated to depths greater than 2.5 meters – approximately the height of a typical house’s first floor. The number of communes experiencing flood depths exceeding

**Table 1: Number of flooded communes as simulated for the 2018 flood event and for different global warming levels.**

GWs	Reservoir operation scenario	Flooded depth				Total
		0-1.5m	1.5-2.5m	2.5-3m	>3.0m	
Sim. 2018	Real-time	119	74	51	27	119
Sim. 2018	Optimized	116	71	50	23	116
+1.5°C	Optimized	123	79	58	36	123
+2.0°C	Optimized	123	90	63	39	123
+3.0°C	Optimized	125	94	66	39	125
+4.0°C	Optimized	124	85	63	36	124

1.5 meters – roughly equivalent to human height – shows a significant increase (Table 1).

**Impact of reservoir operation.** The peak discharge to Ban Ve and Ban Mong reservoir is projected to increase by approximately 40–80% and 110–130%, respectively depending on the level of global warming. The total flood volume flowing into these reservoirs also shows a substantial increase – exceeding their flood storage capacities. Hence, climate change could have a significant impact on the reservoir operational procedures. For the 2018 flood, optimized operation at the Ban Ve reservoir outperforms the actual operation during the event in term of number of flooded communes (Table). However, under future rainfall scenarios, the effectiveness of the reservoir in reducing downstream flooding diminishes. Under all

scenarios, both the flooded area and the number of affected communes is higher than for 2018.

**Conclusion.** Despite some limitations – notably the uncertainties in extreme rainfall projections from climate models, due to a large inter-model spread, the lack of flood return period and frequency analysis, and possible compound effect with sea level rise – our study<sup>1</sup> shows that climate change is likely to amplify flood hazards and place increasing pressure on existing hydraulic infrastructure in the Ca River basin. Addressing these challenges will require not only technical innovation but also institutional coordination and long-term strategic planning grounded in science.

<sup>1</sup>Luong et al. (2025). Impacts of climate change and land use change on flood flow in the Ca River basin (Viet Nam). AFD Research papers, n°387.

## RECOMMENDATIONS

- ▶ **Strengthen the monitoring and early warning systems**, especially in the upper basin.
- ▶ **Reservoir operation rules should be re-evaluated and updated**, with consideration for climate-induced variability in inflow patterns, and the increasing risk of events exceeding the reservoir flood control capacity.
- ▶ **Strengthen institutional collaboration and data sharing** between hydrometeorological services, dam operators, local governments, and scientific institutions to ensure a unified and effective response to flood risks.
- ▶ **Support research on flood hazards** in the context of climate change, with a focus on high-resolution flood hazard mapping under different climate scenarios, including tail risks. Analyses of flood return period and frequencies are also essential for the design of hydraulic infrastructures and flood prevention planning.
- ▶ **Develop integrated modeling platforms** that combine physics-based and data-driven methods to support both real-time operations and long-term planning.