An Overview of a Development of Methodological Framework for Flood Risk Assessment under Climate and Social Changes at ICHARM

Floods are among the most common water-related disasters in river basins across many countries, causing severe damage such as loss of life and destruction of infrastructure and property. Recently, the frequency and severity of flooding have been increasingly amplified by climate and social changes. Flood disasters are exacerbated by the intensifying impact of climate changes such as occurrence of frequent extreme events, as well as by increased social vulnerability resulting from urbanization, population growth, and inadequate infrastructure. These combined factors can lead to more destructive floods that threaten lives and cause significant economic losses, particularly in flood-prone areas of developing countries, where resources for flood management are limited.

Understanding potential future variations in flood damage due to climate and social changes is crucial for effective flood risk management. Therefore, it is essential to develop robust flood-risk assessment methods and evaluate potential damage and risk levels in flood-prone areas while taking into account the impacts of future climate and social changes. Such assessments support the enhancement of flood management strategies, including the implementation of preventive and adaptive measures, as well as land-use regulations.

In order to enhance future societal management, ICHARM has been actively engaged in the development of robust and innovative methodologies for the assessment of flood risk under changing climatic and social conditions. This article provides an overview of the methodological framework developed at ICHARM for flood risk assessment under these evolving conditions. The framework integrates hydrologic-hydraulic modeling with a flood damage estimation model to generate useful information and science-based practical solutions for disaster risk reduction. A detailed description of the developed methodology and the findings of the flood risk assessment for the Solo River basin in Indonesia, conducted using the developed methodology under scenarios of climate and social changes, are presented below.

The methodological framework was developed by coupling climate model outputs, a water and energy budget-based rainfall-runoff-inundation model, and a flood loss model (Figure 1). The method was designed to quantitatively assess flood damage to the agriculture sector and residential areas, under scenarios of climate and social changes (here, social changes refer to land use, land cover, and population). To quantify the damage, flood damage curves were developed for agricultural crops and for residential buildings and contents (Figure 2) (Shrestha et al., 2025a, b). Then, flood damage to agricultural crops and residential households was assessed under scenarios of climate and social changes, focusing on the Solo River basin of Indonesia. Figure 3 shows the location of the case study area.

This study used MRI-AGCM climate model outputs for the past (1979–2002) and far-future (2075–2098) periods. To account for future changes in paddy-field area when assessing agricultural flood damage, land use and land cover (LULC) changes were analyzed using historical land cover maps, and future changes in LULC were projected based on a learning process using historical maps and static variables. The effects of possible changes in future population growth and development on flood damage to residential households were analyzed using population projections based on shared socio-economic pathways (SSPs). The developed method was first validated for a severe past flood event by comparing calculated results with

reported damage data. Flood exposure and damage were then assessed for the past and far-future periods.

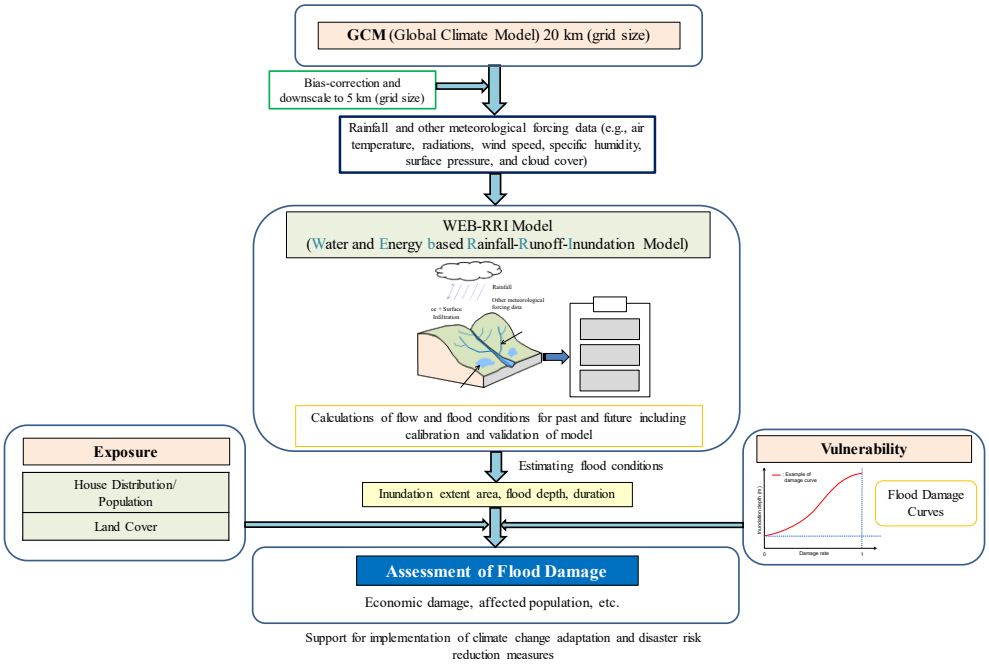


Figure 1 Overview of the methodology for quantitative flood damage assessment

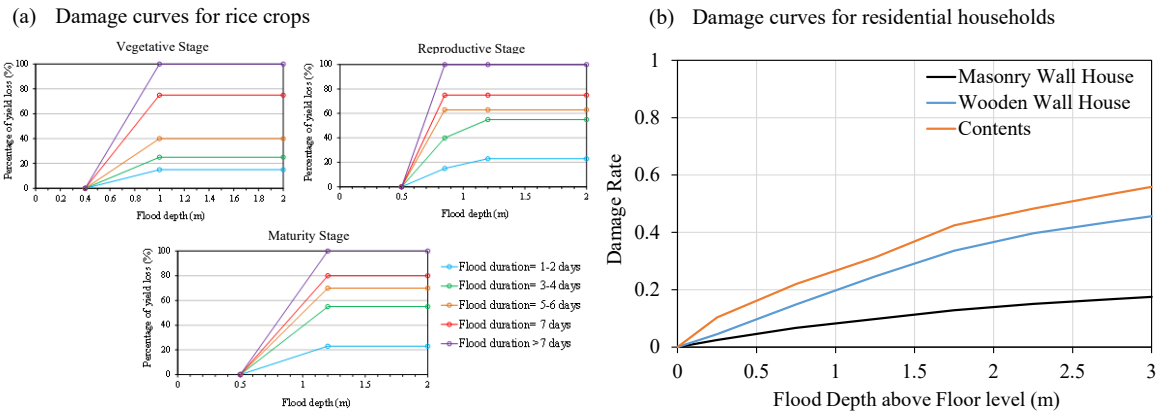


Figure 2 Developed flood damage curves: (a) agricultural crops (rice crops) and (b) residential households

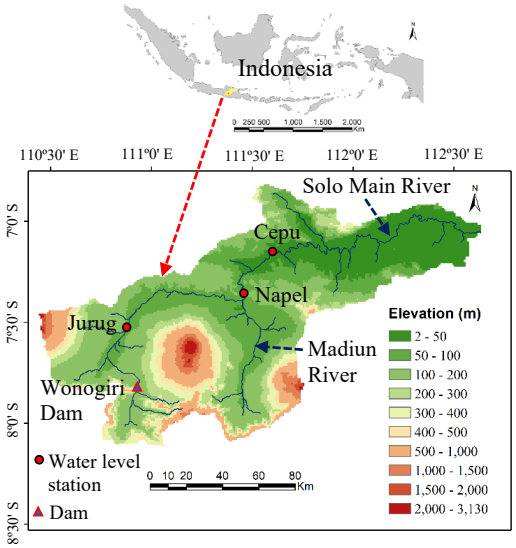


Figure 3 Location of the Solo River basin, Indonesia

The calculated flood inundation area and peak inundation volume (flood depth > 0.5 m) for the past period and the far-future period are presented in Figure 4. The results indicate that both the inundation area and peak inundation volume are projected to increase in the future due to climate change. Compared with the past period, the future period shows larger inundation extents and higher peak flood volumes, suggesting that a greater area of land will be exposed to more frequent flooding with deeper floodwaters in the future.

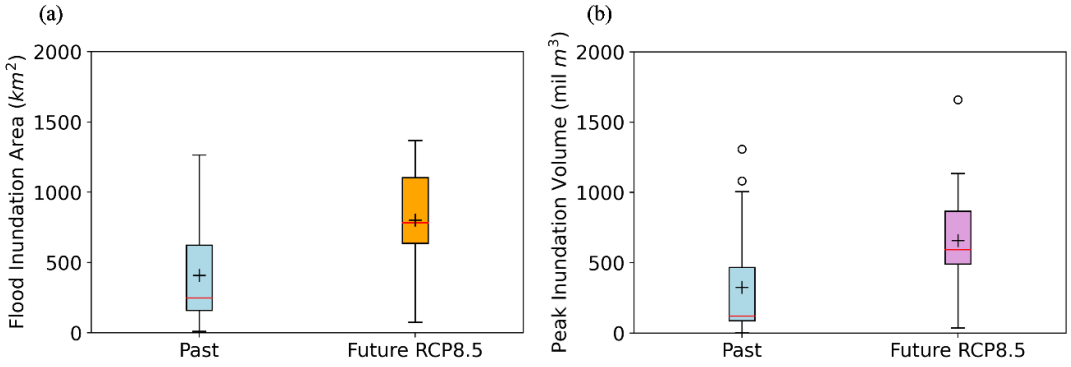


Figure 4 (a) Calculated inundation area and (b) peak flood volume for the past period (1979–2002) and the far-future period (2075–2098)

Figure 5 shows the calculated flood damage to rice crops and to residential houses and contents for the past and far-future periods (Shrestha et al., 2025a, b). The results indicate that the average annual damage to rice crops in the study area may increase by 93.7% in the future due to climate change impacts alone, assuming no changes in paddy field area (Shrestha et al., 2025a). When both climate change effects and future changes in paddy field area are considered, the average annual damage to rice crops is projected to increase by more than 50%, with the lower percentage increase attributable to a projected decrease in paddy field area. These results suggest that rice production may decrease in the future not only due to climate change impacts but also due to decreases in paddy field area. Rice production may decline by 24.6% in the future due solely to decreases in paddy field area (Shrestha et al., 2025a).

The calculation results also show that future increases in household damage may vary widely depending

on future population scenarios. The estimated building and content damage for the far-future period is relatively higher across all future population scenarios than that for the past period with the base-year population. The average annual household damage value may increase by 146% in the future in the case of the base-year population (Shrestha et al., 2025b). The increases in average annual household damage for the far-future period in the cases of SSP1, SSP2, SSP3, SSP4, and SSP5 compared to that for the past period are projected to be 150%, 193%, 259%, 121%, and 146%, respectively (Shrestha et al., 2025b). Flood damage to residential households is likely to be the most severe in the case of the SSP3 projected population scenario compared with the other future population scenarios.

The developed methodology, which integrates climate model outputs, hydrologic-hydraulic modeling, and flood loss estimation models, can be applied to other areas to quantitatively assess flood damage under changing climatic and social conditions and to evaluate the effectiveness of existing or planned flood preventive measures. The quantitative results of flood damage assessments under changing climatic and socio-economic conditions can be useful to understand future flood damage conditions, which can help implement practical mitigation and adaptation actions in response to climate and social changes. The outcomes of flood damage assessments, obtained by applying the developed methodological framework, provide information on flood hazards and associated damages that can help policymakers and decision-makers formulate policies and strategies for disaster risk reduction.

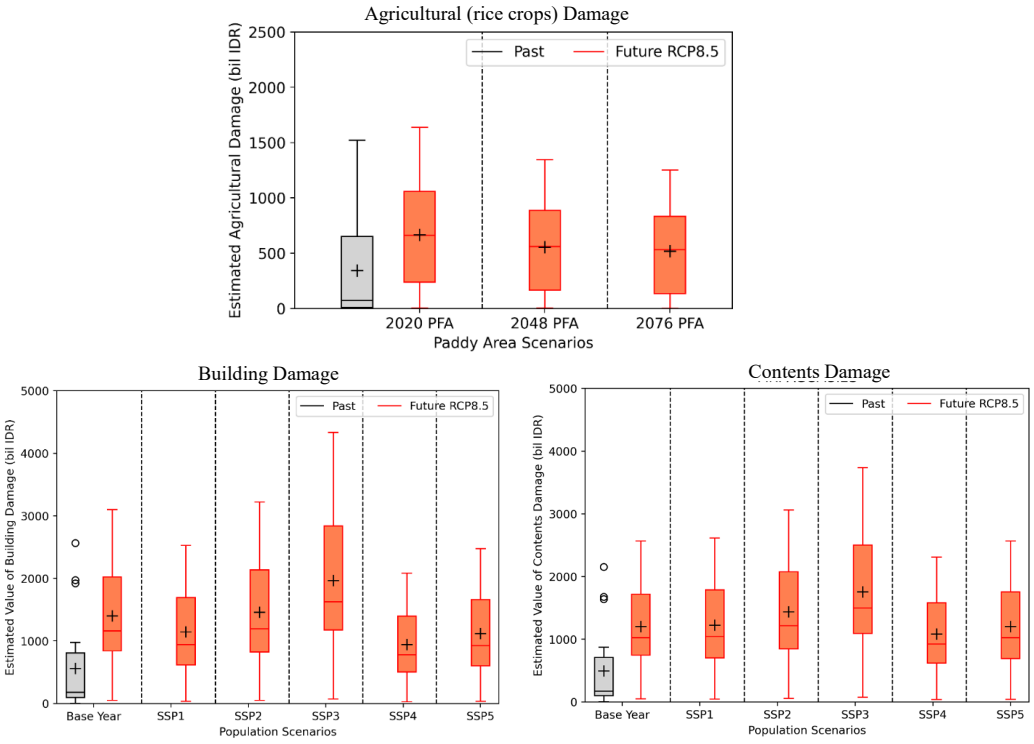


Figure 5 Calculated values of agricultural damage, building damage, and content damage for the past and far-future periods (Shrestha et al., 2025a, b).

References:

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