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Flood Risk Assessment for Agricultural Production in a Tropical River Delta Considering Climate Change

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Abstract : With the changing climate, precipitation events are intensified in the tropical river basins. Since these river basins are significantly influenced by the monsoonal rainfall pattern, critical impacts are observed on the agricultural practices in the downstream river reaches. This study analyses the crop damage and associated flood risk in terms of net benefit in the paddy-dominated tropical Indian delta of the Mahanadi River. The Mahanadi River basin lies in eastern part of the Indian sub-continent and is greatly affected by the southwest monsoon rainfall extending from the month of June to September. This river delta is highly flood-prone and has suffered from recurring high floods, especially after the 2000s. In this study, the lumped conceptual model, Nedbør Afstrømnings Model (NAM) from the suite of MIKE models, is used for rainfall-runoff modeling. The NAM model is laterally integrated with the MIKE11-Hydrodynamic (HD) model to route the runoffs up to the head of the delta region. To obtain the precipitation-derived future projected discharges at the head of the delta, nine Global Climate Models (GCMs), namely, BCC-CSM1.1(m), GFDL-CM3, GFDL-ESM2G, HadGEM2-AO, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC5, MIROC-ESM-CHEM and NorESM1-M, available in the Coupled Model Intercomparison Project-Phase 5 (CMIP5) archive are considered. These nine GCMs are previously found to best-capture the Indian Summer Monsoon rainfall. Based on the performance of the nine GCMs in reproducing the historical discharge pattern, three GCMs (HadGEM2-AO, IPSL-CM5A-MR and MIROC-ESM-CHEM) are selected. A higher Taylor Skill Score is considered as the GCM selection criteria. Thereafter, the 10-year return period design flood is estimated using L-moments based flood frequency analysis for the historical and three future projected periods (2010-2039, 2040-2069 and 2070-2099) under Representative Concentration Pathways (RCP) 4.5 and 8.5. A non-dimensional hydrograph analysis is performed to obtain the hydrographs for the historical/projected 10-year return period design floods. These hydrographs are forced into the calibrated and validated coupled 1D-2D hydrodynamic model, MIKE FLOOD, to simulate the flood inundation in the delta region. Historical and projected flood risk is defined based on the information about the flood inundation simulated by the MIKE FLOOD model and the inundation depth-damage-duration relationship of a normal rice variety cultivated in the river delta. In general, flood risk is expected to increase in all the future projected time periods as compared to the historical episode. Further, in comparison to the 2010s (2010-2039), an increased flood risk in the 2040s (2040-2069) is shown by all the three selected GCMs. However, the flood risk then declines in the 2070s as we move towards the end of the century (2070-2099). The methodology adopted herein for flood risk assessment is one of its kind and may be implemented in any world-river basin. The results obtained from this study can help in future flood preparedness by implementing suitable flood adaptation strategies.

Keywords : flood frequency analysis, flood risk, global climate models (GCMs), paddy cultivation
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