Flood Inundation Mapping Using Hydraulic Analysis Models and GIS and Verification of Inundation Reproducibility : A Case Study of the 2015 Kinugawa River Flood

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In recent years, global warming has increased the frequency of extreme precipitation caused by localized heavy rainfall and typhoons, resulting in more severe flood damage due to river overflow. In river basins that include urban areas, where population and assets are concentrated, flood damage can be particularly serious.
During the Kanto–Tohoku Heavy Rainfall event in September 2015, overtopping and levee breaches occurred along the Kinugawa River in Joso City, Ibaraki Prefecture, inundating approximately one-third of the city area. This event, characterized by sudden and unsteady flooding accompanied by levee failure, highlights the need for advanced flood inundation analysis.
Flood inundation analysis is essential for disaster prevention and mitigation planning; however, discrepancies between simulated and observed inundation areas remain a challenge. Surface roughness coefficients are a key factor influencing inundation reproducibility. This study investigates the effects of roughness coefficient settings on inundation extent and agreement with observed inundation areas through a two-dimensional flood inundation analysis of the 2015 Kinugawa River flood using HEC-RAS and ArcGIS Pro.
A 5 m resolution digital elevation model (DEM) from the Geospatial Information Authority of Japan and land use/land cover data from JAXA were used. Hydraulic simulations were conducted using a coupled 1D–2D HEC-RAS model, with the river channel represented as one-dimensional and the floodplain as two-dimensional. Hourly discharge data from the Kinugawa–Mitsukaido gauging station were applied as upstream boundary conditions under unsteady flow. Overtopping and levee breaches were reproduced based on observed damage using HEC-RAS breach functions. Surface roughness coefficients were assigned by land cover, and multiple cases with varying roughness values were analyzed.
Simulated inundation areas were compared with observed inundation maps published by the Geospatial Information Authority of Japan. Model performance was evaluated using precision, recall, and false positive rate.
The model successfully reproduced inundation processes associated with overtopping at the Wakayamado area and a levee breach near the left bank at approximately 21 km. Inundation expanded toward low-lying areas after overtopping and spread extensively in the north–south direction following the levee breach. Maximum inundation occurred mainly in low-lying areas on the left bank, reflecting surrounding topography.
Differences in roughness coefficients resulted in variations in inundation extent and agreement with observations. The reference case achieved a precision of 82.1% and a recall of 98.4%, indicating good reproducibility of unsteady flood behavior. Some overestimation was observed, likely due to the exclusion of buildings, uniform roughness assignment, and neglect of artificial drainage effects.
Although the simulated inundation areas do not fully reproduce actual damage, they represent potential flood risks under insufficient flood control conditions. The results emphasize the importance of appropriate roughness coefficient settings and provide insights for improving future flood risk assessment and disaster mitigation planning.

