Abstract

Casualties and damages from urban pluvial flooding are increasing. Triggered by short, localized, and intensive rainfall events, urban pluvial floods can occur anywhere, even in areas without a history of flooding. Urban pluvial floods have relatively small temporal and spatial scales. Although cumulative losses from urban pluvial floods are comparable, most flood risk management and mitigation strategies focus on fluvial and coastal flooding. Numerical-physical-hydrodynamic models are considered the best tool to represent the complex nature of urban pluvial floods; however, they are computationally expensive and time-consuming. These sophisticated models make large-scale analysis and operational forecasting prohibitive. Therefore, it is crucial to evaluate and benchmark the performance of other alternative methods.

The findings of this cumulative thesis are represented in three research articles. The first study evaluates two topographic-based methods to map urban pluvial flooding, fill–spill–merge (FSM) and topographic wetness index (TWI), by comparing them against a sophisticated hydrodynamic model. The FSM method identifies flood-prone areas within topographic depressions while the TWI method employs maximum likelihood estimation to calibrate a TWI threshold (τ) based on inundation maps from the 2D hydrodynamic model. The results point out that the FSM method outperforms the TWI method. The study highlight then the advantage and limitations of both methods.

Data-driven models provide a promising alternative to computationally expensive hydrodynamic models. However, the literature lacks benchmarking studies to evaluate the different models' performance, advantages and limitations. Model transferability in space is a crucial problem. Most studies focus on river flooding, likely due to the relative availability of flow and rain gauge records for training and validation. Furthermore, they consider these models as black boxes. The second study uses a flood inventory for the city of Berlin and 11 predictive features which potentially indicate an increased pluvial flooding hazard to map urban pluvial flood susceptibility using a convolutional neural network (CNN), an artificial neural network (ANN) and the benchmarking machine learning models random forest (RF) and support vector machine (SVM). I investigate the influence of spatial resolution on the implemented models, the models' transfer-

ability in space and the importance of the predictive features. The results show that all models perform well and the RF models are superior to the other models within and outside the training domain. The models developed using fine spatial resolution (2 and 5 m) could better identify flood-prone areas. Finally, while aspect is the most important predictive feature for the CNN models, altitude is for the other models.

While flood susceptibility maps identify flood-prone areas, they do not represent flood variables such as velocity and depth which are necessary for effective flood risk management. To address this, the third study investigates data-driven models' transferability to predict urban pluvial floodwater depth and the models' ability to enhance their predictions using transfer learning techniques. It compares the performance of RF (the best-performing model in the previous study) and CNN models using 12 predictive features and output from a hydrodynamic model. The findings in the third study suggest that while CNN models tend to generalise and smooth the target function on the training dataset, RF models suffer from overfitting. Hence, RF models are superior for predictions inside the training domains but fail outside them while CNN models could control the relative loss in performance outside the training domains. Finally, the CNN models benefit more from transfer learning techniques than RF models, boosting their performance outside training domains.

In conclusion, this thesis has evaluated both topographic-based methods and data-driven models to map urban pluvial flooding. However, further studies are crucial to have methods that completely overcome the limitation of 2D hydrodynamic models.