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Characterizing the urban waterlogging variation in highly urbanized coastal cities: A watershed-based stepwise cluster analysis model approach

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Under the combined effects of climate change and rapid urbanization, the low-lying coastal cities are vulnerable to urban waterlogging events. Urban waterlogging refers to the accumulated water disaster caused by the rainwater unable to be discharged through the drainage system in time, which affected by natural conditions and human activities. Due to the spatial heterogeneity of urban landscape and the non-linear interaction between influencing factors, in this work we proposes a novel approach to characterize the urban waterlogging variation in highly urbanized areas by implementing watershed-based Stepwise Cluster Analysis Model (SCAM), which with consideration of both natural and anthropogenic variables (i.e. topographic factors, cumulated precipitation, land surface characteristics, drainage density, and GDP). The watershed-based stepwise cluster analysis model is based on the theory of multivariate analysis of variance that can effectively capture the non-stationary and complex relationship between urban waterlogging and natural and anthropogenic factors. The watershed-based analysis can overcome the shortcomings of the negative sample selection method employed in previous studies, which greatly improve the model reliability and accuracy. Furthermore, different land-use (the proportion of impervious surfaces remains unchanged, increasing by 5% and 10%) and rainfall scenarios (accumulated precipitation increases by 5%, 10%, 20%, and 50%) are adopted to simulate the waterlogging density variation and thus to clarify the future urban waterlogging-prone areas. We consider waterlogging events in the highly urbanized coastal city - central urban districts of Guangzhou (China) from 2009 to 2015 as a case study. The results demonstrate that: (1) the SCAM performs a high degree of fitting and prediction capabilities both in the calibration and validation data sets, illustrating that it can successfully be used to reveal the complex mechanisms linking urban waterlogging to natural and anthropogenic factors; (2) The SCAM provides more accurate and detailed simulated results than other machine learning models (LR, ANN, SVM), which more realistic and detailed reflect the occurrence and distribution of urban waterlogging events; (3)

Under different urbanization scenarios and precipitation scenarios, urban waterlogging density and urban waterlogging-prone areas present great variations, and thus strategies should be developed to cope with different future scenarios. Although heavy precipitation can increase the occurrence of urban waterlogging, the urban expansion characterized by the increase of impervious surface abundance was the dominant cause of urban waterlogging in the analyzed study area. This study extended our scientific understanding with theoretical and practical references to develop waterlogging management strategies and promote the further application of the stepwise cluster analysis model in the assessment and simulation of urban waterlogging variation.