GIS based Multicriteria Decision Analysis for Flash Flood Hazard Mapping Using Frequency Ratio in Bavaria

Junqi Mao[1*]

1Technical University of Munich, Munich, Germany

*Correspondence: junqi.mao@tum.de

Abstract

A flash flood is an emergency that develops rapidly at an hourly timescale between rainfall and the onset of flooding. This study intends to assess flood conditioning factors by introducing a new multicriteria decision making (MCDM) method, which applies and further develops frequency ratio (FR) based on standing water records in real events. Standing water record databases were generated using the frequency ratio method by counting record numbers in each index layer under a GIS framework. The frequency ratio results were then applied to weighting index. Flash flood hazard maps were generated for visualization and for comparing different conditioning indices, together with sensitivity analysis, calibration and validation. Subsequently, an evaluation framework of flash flood hazard, named as MCDM-FR, was developed that is not only relevant for the catchments with recorded events but which also serves as flash flood hazard analysis for Bavaria.

Keywords: flash flood, weighting index, frequency ratio

Methods

This study used four indices for decision making: slope, land use, soil type and flow accumulation. Each index was classified into several classes. Frequency ratio can be expressed as the proportion of flooded area to non-flooded area in the total study area (equation 1) .The effect of each category in an index is classified under five different hazard classes: very high, high, moderate, low and very low. Each hazard index is attributed with a weight referring to its influence on the flood processes. The flood-hazard map can then be generated using the weighted sum of frequency ratio values.

$$FR = (E/F)/(M/L) \quad (1)$$

where E: flood records for each index; F: the total number of flood records; M: the number of pixels per subclass of effective flash flood factors; L: total number of pixels in a region.

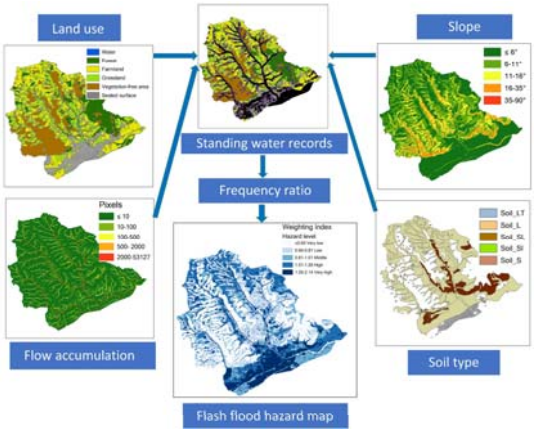

Figure 1: The workflow to create a flash flood hazard map.

Results

Each pixel in the study site can form a specific hazard value and build up a flash flood hazard map(Figure 2b). For hazard classification, the Jenks optimization method is to determine the best arrangement of values into different classes with five hazard levels (Figure 2c).

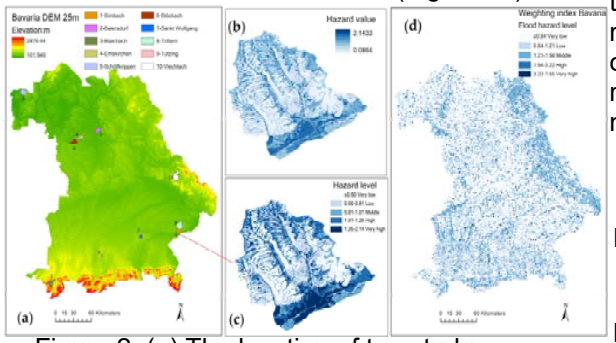

Figure 2. (a) The location of ten study catchments in Bavaria; (b) hazard map and (c) after Jenks natural break of Simbach am Inn Catchment; (d) hazard map of Bavaria

For the whole of Bavaria, the average values of indicators were obtained from the ten catchments to draw a hazard map (Figure 1d). Sensitivity analysis methods were carried out to check the proper utility and weight of each index. For validation, the seed cell areas index (SCAI), as the ratio of area extent of hazard class to flood in each hazard class, was used as an indicator to test the reliability of flood hazard maps. More than 80% of standing water records with inundation depth >0.25m are included in high hazard and very high hazard regions together with high frequency ratio values and low SCAI values.

Conclusions

The analysis and evaluation for flash flood is needed for more efficient management and response to the emergency. This framework of MCDM is recommended for hazard planning as it promotes the interaction between real events and topographic/human factors, explores the representative measure to draw maps from city-scale to state-scale, while frequency ratio/SCAI values are found to be effective measures.

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