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Probabilistic floodplain hazard mapping: managing uncertainty by using a bivariate approach for flood frequency analysis

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Floods are a global problem and are considered the most frequent natural disaster world-wide. Many studies show that the severity and frequency of floods have increased in recent years and underline the difficulty to separate the effects of natural climatic changes and human influences as land management practices, urbanization etc. Flood risk analysis and assessment is required to provide information on current or future flood hazard and risks in order to accomplish flood risk mitigation, to propose, evaluate and select measures to reduce it. Both components of risk can be mapped individually and are affected by multiple uncertainties as well as the joint estimate of flood risk. Major sources of uncertainty include statistical analysis of extremes events, definition of hydrological input, channel and floodplain topography representation, the choice of effective hydraulic roughness coefficients. The classical procedure to estimate flood discharge for a chosen probability of exceedance is to deal with a rainfall-runoff model associating to risk the same return period of original rainfall, in accordance with the iso-frequency criterion. Alternatively, a flood frequency analysis to a given record of discharge data is applied, but again the same probability is associated to flood discharges and respective risk. Moreover, since flood peaks and corresponding flood volumes are variables of the same phenomenon, they should be, directly, correlated and, consequently, multivariate statistical analyses must be applied.
This study presents an innovative approach to obtain flood hazard maps where hydrological input (synthetic flood design event) to a 2D hydraulic model has been defined by generating flood peak discharges and volumes from: a) a classical univariate approach, b) a bivariate statistical analysis, through the use of copulas.
The univariate approach considers flood hydrographs generation by an indirect approach (rainfall-runoff transformation using input rainfall hydrographs derived from IDF curves) and a direct approach (statistical inference on measured flood peaks).
In the bivariate approach synthetic hydrographs were generated by means two different approaches: an indirect one, where rainfall were generated by a stochastic bivariate rainfall generator to be entered a distributed conceptual rainfall-runoff model that consisted of a soil moisture routine and a flow routing routine; and a direct one, where stochastic generation of flood peaks and flow volumes have been obtained via copulas, which are capable to describe and model the correlation between these two variables.
Finally, to highlight the advantages of the presented approach, probabilistic flood hazard maps (including uncertainty) derived by bivariate models are compared to maps from univariate analysis.
The procedure is applied to a real case study located in the southern part of Sicily, Italy, where flood hazard and risk maps have been obtained and compared.