Fractal analysis of rain gauges’ inhomogeneous distribution and the associated hydrological impacts: the case study of Muriaé River basin

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The urban population growth requires an improvement in the resilient behavior of these areas to extreme weather events, especially heavy rainfall. In this context, well-developed urban planning should address the problems of infrastructure, sanitation, and installation of communities, primarily related to insufficiently gauged locations. The main objectives of this study were to analyze the impacts of in-situ rain gauges’ distribution associated with the elaboration of a spatial diagnosis of the occurrence of floods in the municipality of Itaperuna, Rio de Janeiro – Brazil. The methodology consisted of the spatial analysis of rain gauges’ distribution with the help of the fractal dimension concept and investigation of flood susceptibility maps prepared by the municipality based on transitory factors (which consider precipitation in the modeling) and on permanent factors (natural flood susceptibility). Both maps were validated by the cross-tabulation method, crossing each predictive map with the recorded data of flood spots measured during a major rainfall event. The results pointed that the fractal analysis of the rain gauges’ distribution presented a scaling break behavior with a low fractal dimension at the small-scale range, mostly concerned in (semi-)urban catchments, highlighting the incapacity of the local instrumentation to capture the spatial rainfall variability. Thereafter, the cross-tabulation validation method indicated that the flood susceptibility map based on transitory factors presented an unsatisfactory probability of detection of floods when compared to the map based on permanent factors. These results allowed us to take into account the hydrological uncertainties concerning the insufficient gauge network and the impacts of the sparse distribution on the choice and elaboration of flood susceptibility maps that use rainfall data as input. Finally, we performed a spatial analysis to estimate the population and habitations that can be affected by floods using the flood susceptibility map based on permanent factors.