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Model reduction of the numerical analysis of Low Impact Developments techniques

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Mechanistic models have proven to be accurate and reliable tools for the numerical analysis of the hydrological behavior of Low Impact Development (LIDs) techniques. However, their widespread adoption is limited by their complexity and computational cost. Recent studies have tried to address this issue by investigating the application of new techniques, such as surrogate-based modeling. However, current results are still limited and fragmented. One of such approaches, the Model Order Reduction (MOR) technique, can represent a valuable tool for reducing the computational complexity of a numerical problems by computing an approximation of the original model. While this technique has been extensively used in water-related problems, no studies have evaluated its use in LIDs modeling. Thus, the main aim of this study is to apply the MOR technique for the development of a reduced order model (ROM) for the numerical analysis of the hydrologic behavior of LIDs, in particular green roofs. The model should be able to correctly reproduce all the hydrological processes of a green roof while reducing the computational cost.

The proposed model decouples the subsurface water dynamic of a green roof in a) one-dimensional (1D) vertical flow through a green roof itself and b) one-dimensional saturated lateral flow along the impervious rooftop. The green roof is horizontally discretized in N elements. Each element represents a vertical domain, which can have different properties or boundary conditions. The 1D Richards equation is used to simulate flow in the substrate and drainage layers. Simulated outflow from the vertical domain is used as a recharge term for saturated lateral flow, which is described using the kinematic wave approximation of the Boussinesq equation.

The proposed model has been compared with the mechanistic model HYDRUS-2D, which numerically solves the Richards equation for the whole domain. The HYDRUS-1D code has been used for the description of vertical flow, while a Finite Volume Scheme has been adopted for lateral flow. Two scenarios involving flat and steep green roofs were analyzed. Results confirmed the accuracy of the reduced order model, which was able to reproduce both subsurface outflow and the moisture distribution in the green roof, significantly reducing the computational cost.