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Determining the Probability Distribution of Hillslope Peak Discharge Using an Analytical Solution of Kinematic Wave Time of Concentration

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Hillslope hydrology is fundamental for understanding the flood phenomenon and for evaluating the time of concentration. The latter is a key variable for predicting peak discharge at the basin outlet and for designing urban infrastructure facilities. There have been a multitude of studies on the hydrologic response at the hillslope scale, and the time of concentration has been derived for different approaches. One approach for deriving hillslope response utilizes, in a distributed form, the differential equations of unsteady overland flow, specifically developed at the hydrodynamic scale, in order to account for the spatial heterogeneity of soil characteristics, topography, roughness and vegetation cover on the hillslope. Therefore, this approach seemingly mimics the complete hydraulics of flow. However, the very complex patterns generated by spatial heterogeneity can cause considerable error in the prediction even by very sophisticated models. Another approach that directly operates at the hillslope scale is by averaging over the hillslope the soil hydraulics, the topography, and the roughness characteristics. A physically-based lumped model of hillslope response was first proposed by Horton (1938), under the assumption that the flow regime is intermediate between laminar and turbulent regimes (transitional flow regime), by applying the mass conservation equation to the hillslope as a whole and by using the kinematic wave assumption for the friction slope (Singh, 1976, 1996). Robinson et al. (1995) and Robinson and Sivapalan (1996) generalized Horton's approach, suggesting an approximate solution of the overland flow equation that is valid for all flow regimes. Agnese et al. (2001) derived an analytical solution of a nonlinear storage model of hillslope response that is valid for all flow regimes, and the associated time of concentration.

Recently, the well-known kinematic wave equation for computing the time of concentration for impervious surfaces has been extended to the case of pervious hillslopes, accounting for infiltration. In particular, an analytical solution for the time of concentration for overland flow on a rectangular plane surface was derived using the kinematic wave equation under the Green-Ampt infiltration (Baiamonte and Singh, 2015). The objective of this work is to apply the latter solution to determine the probability distribution of hillslope peak discharge by combining it with the familiar rainfall duration-intensity-frequency approach.

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