Runoff coefficients to predict peak discharge at hillslope scale: a small contribution to theoretical hydrology

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The science of hydrology holds a central role in the field of environmental Earth science, being intimately connected to meteorology, climatology, hydrogeology and ecology. In particular, the knowledge of hillslope hydrology is fundamental for understanding the flood phenomenon, for predicting the peak discharge and its probability distribution, which is necessary in many practical applications (design of hydraulic structures, urban, extra-urban planning, etc.).

Using different approaches, there have been a multitude of studies on the hydrologic response at hillslope scale. One approach for deriving the 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. This approach seemingly mimics the complete hydraulics of flow. However, the very complex patterns generated by spatial heterogeneity can cause considerable doubts in the prediction of hillslope response (Sivapalan, 2003; Blöschl et al., 2013; Baiamonte and Singh, 2017) even by very sophisticated approaches. Sivapalan (2003) stated that «the root cause of the difficulties is the tremendous heterogeneity of the land surface condition, soils, vegetation, land use, etc., and the space–time variability of climatic inputs, occurring over a wide range of space and time scales. The heterogeneity is pervasive, and never seems to disappear at whatever scale we observe, ranging from largescale geological formations, the soil catena at hillslope and basin scales, down to the macropores that are ubiquitous at the plot scale». Sivapalan (2003) also emphasized that theory development will advance only if we can develop simple models (which may be mere caricatures of the basin system), provided, that they can be proved with large-scale patterns extracted from observed data. As theory advances, the simple models will give way to the development and testing of more complex ones that capture more of the essential characteristics of real hillslopes and basins.

In agreement with this line of thinking, recently, under the assumption that the runoff generation is mainly Hortonian, a simplified analytical solution of the probability distribution of peak discharge, for infiltrating hillslopes, was derived (GABS model, Baiamonte and Singh, 2017). This result was obtained by joining three consolidated simplified models: (1) the Green-Ampt model to account for the infiltration, (2) the kinematic wave model to account for the rainfall excess transportation, e (3) the intensity-duration-frequency curves to describe the maximum rainfall intensity. In this work, differently from the past, it is shown that this kind of approach leads to arranging rational runoff coefficient tables where no qualitative descriptions need to be fixed. These tables reproduce the physically based solutions of the mentioned approach (GABS model), where the characteristics of rainfall, soil and hillslope geometry are set according to parameters of clear physical meaning. Thus, they can be used for a rivisited rational method in place of the classical tables that are usually derived on empirical bases and for this reason can be applied only when strictly hydrological similitudes with the conditions for their derivations are established.