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Statistical analysis and modelling of surface runoff from arable fields

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Surface runoff generation on arable fields is an important driver of (local) flooding, on-site and off-site damages by erosion and of nutrient and agrochemical transport. In general, three different processes generate surface runoff (Hortonian runoff, saturation excess runoff, and return of subsurface flow). Despite the developments in our understanding of these processes it remains difficult to predict, which processes govern runoff generation during the time course of an event and throughout the year while soil and vegetation on arable land are passing many states. We analysed the results form 317 rainfall simulations resolved in 14286 runoff measurements to determine temporal and spatial differences in dominating parameters governing surface runoff, and to derive and test a statistical model of surface runoff generation independent from an a priori selection of modelled processes types. Measured runoff was related to 20 time-invariant soil properties, three variable soil properties, four rain properties, three land use properties and many derived variables describing interactions and curvilinear behaviour. In an iterative multiple regression procedure six of these properties/variables described best initial abstraction and the hydrograph. To estimate initial abstraction percentage of stone cover above 10% and of sand content in the bulk soil were needed, while the hydrograph could be predicted best from rain depth exceeding initial abstraction, rainfall intensity, soil organic carbon content, and time since last tillage. Combining the multiple regressions to estimate initial abstraction and surface runoff allowed modelling event hydrographs without a priori assumption on the underlying process. The statistical model described the measured data well and performed equally well during validation. In both cases the model explained 71% of variability in runoff volume and 58% of runoff rate (RSME: 5.2 mm and 0.23 mm mm-1, respectively). Stone cover was most important for the initial abstraction while time since tillage was most important for the hydrograph. The latter variable is neither taken into account in typical lumped hydrological models (e.g. SCS CN approach) nor in more mechanistic models using Horton, Green & Ampt or Philips type approaches to address infiltration. This finding should foster a discussion regarding our ability to predict surface runoff from arable land, which seemed to be dominated by agricultural operations introducing a man-made seasonality in soil hydraulic properties.