MODELING THE IMPACT OF MICROTOPOGRAPHY ON THE RAINFALL-RUNOFF PROCESS

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Abstract

Microtopography on land surface has profound impact on hydrological responses. It produces concentrated flow paths in the depressed areas between mounds, and divergent flow paths on these mounds. The non-uniform flow pattern of mixed concentrated threads of relatively deep and fast flow and large areas of shallower, slower-moving sheet flow will result in different hydrograph than that generated from a planar area. As a result of spatially non-uniform runoff, the infiltration process and soil moisture distribution will be non-uniformly distributed. The transport of sediment, nutrients and contaminants in the surface runoff will also be affected by the flow pattern. This may have profound impact on the ecosystem development and sustainability. However, the impact of microtopography on hydrological processes has not been quantitatively understood.

To carefully examine the effect of microtopography, we developed a two-dimensional rainfall-runoff model to numerically study the problem. The model includes a two-dimensional surface runoff module based on diffusion wave equations, and the revised Green-Ampt equation for infiltration under rainfall conditions. On a structured grid with rectangular elements, a two-dimensional TVD type scheme is adopted for the diffusion wave equation to minimize the numerical oscillation and increase accuracy of the simulation. The Green-Ampt model is solved for each element using the Newton-Raphson iteration method.

The numerical investigation was conducted on a 20 m 30 m experimental plot in Mojave National Preserve. The topographic data of the plot were obtained through field survey and data interpolation. We measured the elevation for every vegetation mounds in the plot at 5-9 characteristic points and some representative interspace areas. The topographic data for each cell of a 20 cm resolution grid were then generated through interpolation based on the measured data. Soil hydraulic properties are estimated through Tension Infiltrometer experiments and pedo-transfer function prediction. The numerical experiment was conducted on the 20 cm resolution grid covering the whole plot. The two-dimensional model was used to simulate a 0.5-hour rainfall event with an intensity of the 100-year storm at the study area. We considered the impact of microtopography and vegetation in the modeling study. Through comparison of the runoff generation processes between the real plot, the plot without vegetation and the control case of a planar plot, it is found that the microtopography can significantly change the hydrograph, mainly because of the distorted flow path by topography. The more significant impact was shown on the spatial distribution of flow depth, discharge, and total infiltration depth, because the concentrated flow and the consequently altered local water availability. The highly non-uniform pattern of these distributions imply the localized erosion and transport processes, which will be dramatically different from the uniform flow field caused by neglecting the microtopography.