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The role of subsurface hydrology in soil erosion and channel network development on a laboratory hillslope

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Ephemeral gully erosion is currently considered one of the dominant sources of soil loss from the agricultural landscape. It is assumed to be the result of surface flow concentration with hydraulic properties exceeding a given threshold for channel initiation. In this paper, we devised a laboratory experiment to show how subsurface hydrology impacts channel network development and soil loss. A series of rainfall-runoff experiments were conducted on a 9.75 m x 3.66 m laboratory hillslope set under drainage or oversaturation (seepage) condition. Soil loss was monitored by collecting runoff samples and by digitizing the soil surface at regular time intervals using digital photogrammetry. We found that the seepage condition produced erosion rates 2.1 times as high as those measured under drainage condition for a high rainfall-runoff intensity $(6.8 \cdot 10^{-4} \mathrm{m}^3 \cdot \mathrm{s}^{-1})$ and 1.6 times as high for a low intensity $(3.4 \cdot 10^{-4} \mathrm{m}^3 \cdot \mathrm{s}^{-1})$. After $1.2\ \mathrm{m}^3$ of runoff the soil under seepage condition lost on average 1.9 times more soil than the one under drainage condition. Digital photogrammetry performed well at quantifying elevation changes due to channel network development and suggested that channel erosion rates were 1.5 times higher for the seepage condition. We also found an effect of rainfall-runoff intensity on interrill sediment load, supporting a previously proposed model for interrill erosion relating sediment load to rainfall intensity and to the square root of runoff rate. Finally, elevation change patterns observed during each rainfall-runoff event were found to be more consistent with the simultaneous erosion deposition theory as opposed to the sediment transport capacity concept as a sediment transport mechanism. This study demonstrated that subsurface hydrology might be a controlling factor in the location, initiation and rate of development of ephemeral gullies.