

Abstract

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Impact of Pavement Distribution on Hillslope Runoff in Peri-Urban Landscapes, Based on Laboratorial Experiments ⁺

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Abstract: It is widely accepted that urbanization modifies the hydrological processes, increasing runoff and flood hazard. However, after decades of research, the magnitude of the impacts is not well understood. This is partially due to spatial-temporal differences in rainfall-runoff processes over complex landscapes comprising different land-uses, typical of peri-urban areas. This study aims to investigate the impact of different spatial patterns of pavement on surface runoff, under distinct weather conditions (dry vs wet). Inspired on urban cores observed in peri-urban catchments, 7 spatial patterns were investigated: 100% pavement, 100% pervious, and 60% pavement (and 40% pervious) under continuous placement located upslope or downslope, and under dispersed patterns with regular, irregular and linear distribution. Concrete blocks were used as pavement material, whereas pervious surfaces were simulated using either bare soil, 1.5 kg·m⁻³ with sandy-loam texture, or commercial natural grass carpets. The 13 configurations of pavement and pervious materials, pavement-soil and pavement-grass were simulated in the laboratory, in a 1.0 × 1.0 m² flume, with 0.05 m soil depth and 9° slope. Three rainfall simulation experiments were performed for each spatial configuration. Each experiment comprises a set of four sequential storms with 50 mm·h⁻¹ over 20-min, interrupted by 30-min intervals, to simulate dry and increasingly wet antecedent settings. Results show that runoff is driven by both spatial pattern and soil moisture. Runoff coefficients ranged from 70–81% in fully paved surfaces to 1.4–40% in bare soil and 0.2–3.8% in grass, exhibiting increasing values from dry to wet antecedent moisture conditions, especially in bare soil. Under dry conditions, continuous pavement generates more runoff if placed downslope than upslope (28% vs 5% with grass and 37% vs 33% with bare soil). Under wet settings, however, continuous pavement generated (i) higher runoff if associated with downslope than upslope bare soil (63% vs 52%), due to saturation-excess favored by cumulative rainfall and upslope runoff; and (ii) lower runoff if associated with downslope than upslope grass surface (33% vs 24%). When considering dispersed pavement, runoff increased from dry to wet conditions, ranging from 32% to 62% and 1.3% to 23% when distributed with soil and grass covers, respectively. Adequate urban planning based on spatial patterns that maximize runoff sinks over the landscape should be considered to enhance urban flood resilience. Grass (as other covers) has higher capacity to retain and infiltrate rainfall and runoff than bare soil, and may represent a nature-based solution to mitigate flood hazard in peri-urban areas.

Keywords: pavement distribution; grass; bare soil; runoff; dry and wet settings



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