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Impact of distinct spatial patterns of impervious surfaces on runoff and sediment fluxes: laboratory evaluation

Carla Ferreira (1), Rodrigo Moruzzi (2), Marcelle Vargas (2), Micaela Tudor (2), João Abrantes (2), Jorge Isidoro (2), António Ferreira (1), and João Pedroso de Lima (2)

(1) CERNAS, Escola Superior Agrária de Coimbra, Bencanta, P-3040-316 Coimbra, Portugal, (2) MARE – Marine and Environmental Sciences Centre, Departamento de Engenharia Civil, Faculdade de Ciências e Tecnologia Universidade de Coimbra (Pólo II) Pinhal de Marrocos 3030-290 Coimbra, Portugal

Urbanization alters the hydrological cycle, namely due to increasing runoff, which affects sediment fluxes. The magnitude of the impacts, however, are still a research challenge due to, among other reasons, the influence of distinct patterns of impervious and pervious surfaces, determining the number of overland flow sources and sinks and, thus, flow and sediment connectivity between the urban area and the stream network. This study aims to (1) investigate the impact of (i) pervious vs impervious surfaces, (ii) location of the impervious surfaces at the hillslope and (iii) spatial patterns of the impervious surfaces (aggregated vs distributed) on rainfall-runoff response (e.g. runoff coefficient, response time and peak flow) and sediment delivery; (2) assess temporal changes on runoff generation and sediment fluxes during (i) individual rainfall events, and (ii) subsequent storms, from dry to saturated soil conditions; and (3) explore the impact of distinct spatial patterns of impervious surfaces on water and sediment connectivity. The study is based on rainfall simulation experiments, using an intensity of 50 mm/h, representing a 3 year return period storm in Coimbra, Portugal. The experiments were performed in a 1.0 m $\times$ 1.0 m plot, with 0.05 m soil depth and 9° slope. The soil used was a sandy loam, with a bulk density of 1.5 kg/m3. Distinct surface covers were tested during the experiments: i) bare soil, ii) continuous impervious surfaces (60%) located upslope; iii) continuous impervious surfaces (60%) located downslope; iv) different patterns of distributed impervious surfaces (60%); and v) 100% impervious cover. The impervious surface was simulated with regular concrete blocks. The 60% sealing was selected because it represents the maximum impervious cover in Coimbra, according with regulations for urban areas. Each experiment comprised three sequential rainfall simulations of 20 minutes, with 30 minutes interval, in order to represent dry, wet and wettest conditions. Three replicates per experiment were performed. During the experiments overland flow volume was measured at 1-minute time-step, and the time to runoff start and runoff stop was recorded. The quantity of sediments transported by overland flow was measured after dryness (105°C). Soil moisture content was also monitored every minute with five sensors, installed at 2.5 cm depth and connected to a data logger.

Contrasting runoff responses were measured for distinct surface covers, ranging from no runoff in bare soil to 65%-70% runoff coefficient in experiments with 100% impervious cover. These results indicate that sandy loam soil is able to provide a good infiltration of rainfall under simulated conditions, even under few storms. Furthermore, concrete blocks are relatively permeable, despite decreasing infiltration capacity with increasing wetness. In dispersed impervious cover (60%), for example, runoff coefficient increased from 3% in experiments performed under dry to 30% under wettest settings, with quicker runoff initiation (being reduced from 12 to less than 1 minute). Hydrological impacts of urbanization may be minimized in planning by enhancing the infiltration of runoff from impervious areas into the soil, through dispersed urban patterns and upslope settlings.