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Influence of urbanization pattern on stream flow of a peri-urban catchment under Mediterranean climate

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The demand for better life quality and lower living costs created a great pressure on peri-urban areas, leading to significant land-use changes. The complexity of mixed land-use patterns, however, presents a challenge to understand the hydrological pathways and streamflow response involved in such changes. This study assesses the impact of a actively changing Portuguese peri-urban area on catchment hydrology. It focuses on quantifying streamflow delivery from contributing areas, of different land-use arrangement and the seasonal influence of the Mediterranean climate on stream discharge.
The study focuses on Ribeira dos Covões a small (6 km2) peri-urban catchment on the outskirts of Coimbra, one of the main cities in central Portugal. Between 1958 and 2012 the urban area of the catchment expanded from 8% to 40%, mostly at the expense of agriculture (down from 48% to 4%), with woodland now accounting for the remaining 56% of the catchment area. The urban area comprises contrasting urban settings, associated with older discontinuous arrangement of buildings and urban structures and low population density (<25 inhabitants/km), and recent well-defined urban cores dominated by apartment blocks and high population density (9900 inhabitants/km).
The hydrological response of the catchment has been monitored since 2007 by a flume installed at the outlet. In 2009, five rainfall gauges and eight additional water level recorders were installed upstream, to assess the hydrological response of different sub-catchments, characterized by distinct urban patterns and either limestone or sandstone lithologies.
Annual runoff coefficients range between 14% and 22%. Changes in annual baseflow index (36-39% of annual rainfall) have been small with urbanization (from 34% to 40%) during the monitoring period itself. Annual runoff coefficients were lowest (14-7%) on catchments >80% woodland and highest (29% on sandstone; 18% on limestone) in the most urbanized (49-53% urban) sub-catchments. Percentage impermeable surface seems to control streamflow particularly during dry periods. Winter runoff was 2-4 times higher than total river flow in the summer dry season in highly urbanized areas, but was 21-fold higher in winter in the least urbanized sub-catchment, denoting greater flow connectivity enhanced by increased soil moisture.
Although impermeable surfaces are prone to generate overland flow, the proximity to the stream network is an important parameter determining their hydrological impacts. During the monitoring period, the enlargement of 2% of the urban area at downslope locations in the Covões sub-catchment, led to a 6% increase in the runoff coefficient. In contrast, the urban area increase from 9 to 25% mainly in upslope parts of the Quinta sub-catchment did not increase the peak streamflow due to downslope infiltration and surface retention opportunities. Despite impermeable surfaces enhance overland flow, some urban features (e.g. walls and road embankments) promote surface water retention. The presence of artificial drainage systems, on the other hand, enhances flow connectivity, leading to increasing peak flow and quicker response times ($\sim$10 minutes versus 40-50 minutes) as in the Covões sub-catchment.
Urbanization impact on streamflow responses may be minimized through planning the land-use mosaic so as to maximize infiltration opportunities. Knowledge of the influence of distinct urban mosaics on flow connectivity and stream discharge is therefore important to landscape managers and should guide urban planning in order to minimize flood hazards.