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Can additional urban development have major impacts on streamflow of a peri-urban catchment? A case study from Portugal

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It is well known that urban development brings about changes in hydrological response. Relatively little, however, is known about impacts on streamflow during urban development in the Mediterranean climate. This paper examines changes in streamflow resulting from the construction of an enterprise park, a major road and apartment blocks in a small partially urbanized peri-urban catchment (6.2 km^2) in central Portugal. These developments led to an increase in urban area from 32% to 40% over a five-year period (hydrological years 2008/09–2012/13). In the initial two-year period minor land-use changes increased impervious surfaces from 12.8% to 13.2%. The subsequent three-year period led to a further 17.2% increase in impervious area. Streamflow was recorded by a V-notch weir at the catchment outlet. Rainfall was recorded at a weather station 0.5km north of the catchment, and by five tipping-bucket raingauges installed in January 2011 within the study catchment.

Annual runoff and storm runoff coefficients ranged from 14% to 21% and 9% to 14%, respectively, recorded in 2011/12 and 2012/13. Although these differences in runoff were caused in part by variation in rainfall, the comparison between 2009/10 (pre-) and 2012/13 (post-additional urban development), with broadly similar rainfall (887mm vs 947mm, respectively) and evapotranspiration (740mm vs 746mm), showed a 43% increase in storm runoff (from 90mm to 129mm), resulting from additional overland flow generated largely by the 4.4% increase in impervious surfaces.

The additional urban development also led to changes in hydrograph parameters. The increase in storm runoff was not progressive over the study period, but regression lines of storm runoff against rainstorm parameters exhibited higher vertical positions in 2012/13 than 2008/09. Increasing peak flows, however, were more progressive over the study period, with annual regression lines displaying higher vertical positions, but with a clear distance between pre- and post- additional urban development periods. Response time to rainfall reduced from 60-75 minutes to 40 minutes and recession time fell from 21.3-29.5 h to 7.4-8.7 h, respectively.

The relatively low runoff and storm runoff coefficients given the extent of urban land-use is due to the dispersed urban pattern and movement of at least part of the overland flow from impervious surfaces into pervious soils (within urban areas and/or downslope woodland and abandoned fields). High soil permeability, linked to the sandstone and limestone bedrock, favours the establishment of water sinks. The additional extension of observed urban development during the study period, however, also included partial routing of overland flow from additional impervious surfaces into the stream network, enhancing flow connectivity, thus, increasing storm runoff and providing quicker hydrologic response.

Urban planning should consider the landscape mosaic of peri-urban areas in order to maximize water infiltration and minimize the impacts on streamflow regime and urban flooding.