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Influence of landscape mosaic on streamflow of a peri-urban catchment under Mediterranean climate

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Peri-urban areas tend to be characterized by patchy landscape mosaics of different land-uses. Although the impact of land-use changes on catchment hydrology have been widely investigated, the impact of mixed land-use patterns on the streamflow of peri-urban areas is still poorly understood. This study aims to (i) explore and quantify streamflow delivery from sub-catchments characterized by distinct landscape mosaics; (ii) assess the impact of different urbanization styles on hydrograph properties; and (iii) explore the influence of urbanization type on flow connectivity and stream discharge.

The study was carried out in Ribeira dos Covões, a small (6.2km^2) peri-urban catchment in central Portugal. The climate is Mediterranean, with a mean annual rainfall of 892mm. Catchment geology comprises sandstone (56%), limestone (41%) and alluvial deposits (3%). Soils developed on sandstone are generally deep (>3m) Fluvisols and Podsols, whereas on limestone the Leptic Cambisols are typically shallow (<0.4m). Forest is the dominant land-use (56%), but urban areas cover an extensive area (40%), whereas agricultural land has declined to a very small area (4%). The urban area comprises contrasting urban styles, notably older discontinuous urban areas with buildings separated by gardens of low population density (<25 inhabitants km^{-2}), and recent well-defined continuous urban cores dominated by apartment blocks and of high population density (9900 inhabitants km^{-2}).

The study uses hydrological data recorded over three hydrological years, starting in November 2010, in a monitoring network comprising eight streamflow gauging stations (instrumented with water level recorders) and five rainfall gauges. The gauging stations provide information on the discharge response to rainstorms of the catchment outlet and upstream sub-catchments of different size, urban pattern (in terms of percentage urban land-use and impervious area, distance to the stream network, and storm water management), and lithology (either sandstone or limestone).

Annual storm runoff coefficients were lowest (13.7%) in catchments dominated by forest (>80%) and greatest (17.3-17.6%) in the most urbanized sub-catchments (49-53% urban). Impervious area seems to control streamflow particularly during dry periods. Winter runoff (streamflow per unit area) was 2-4 times higher than summer runoff in highly urbanized areas, but was 21-fold higher in winter than in summer in the least urbanized sub-catchment, indicating greater flow connectivity in winter, enhanced by increased soil moisture. Lithology also played an important role on hydrology, with sandstone sub-catchments exhibiting greater annual baseflow index values (23-46%) than found in limestone ones (<5%). For sub-catchments underlain by both lithologies, linear relationships were found between storm runoff coefficients and percentage urban and percentage impervious area, but with greater runoff responses in the sandstone ones. Nevertheless, linear regression lines for both lithologies get close to each other when the extent of urban areas reached about 50%. The proximity of urban areas to the stream network and whether urban storm runoff is directly piped to the stream network were important parameters influencing peak flows and response time. Landscape mosaics that include land-use patches of high soil permeability tend to provide locations of surface water retention and enhanced infiltration, thereby breaking flow connectivity between hillslope urban surfaces and the stream network. This kind of spatial pattern should be considered for urban planning, in order to minimize flood hazards.