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Land-use change impacts on soil hydrological properties and overland flow in Mediterranean periurban areas

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Urbanization leads to significant land-surface changes that affect soil properties and hydrological processes. Understanding landscape pattern and its impact on flow connectivity is still a challenge. In relation to a catchment undergoing active peri-urbanization, this paper aims to: 1) assess the spatiotemporal variability of soil hydrological properties in different land-uses; 2) understand how overland flow processes and spatial patterns change with season and weather; 3) discuss the impact of landscape pattern on flow connectivity and urban planning in order to prevent flood hazards.
The study has been carried out in a Portuguese periurban catchment (620ha) with a sub-humid Mediterranean climate and part-limestone, part-sandstone lithology. Due to its proximity to the expanding city of Coimbra, the urban area increased from 6% to 30% between 1958 and 2009, and this trend is expected to continue. Currently the catchment is dominated by forest (62%), with only 8% under agriculture. Repeat field surveys and hydrological monitoring provided data to assess spatiotemporal dynamics of overland flow for different land-uses. Measurements of moisture content, hydrophobicity and infiltration capacity were carried out at 31 sites under different land-uses on nine occasions over a one-year period. Overland flow in eucalypt, oak and scrub forest was measured using 8mx2m runoff plots from Autumn 2010 (3 plots per forest type). Five raingauges and nine water-level recorders provided continuous records of hydrological data for upstream sub-catchments and the catchment outlet.
The results showed spatiotemporal variations in hydrological processes and responses with land-use and geology. In dry weather, urban soils were hydrophilic and soil matrix infiltration capacity reached 12mm/h, while soils under forest and agriculture were hydrophobic and infiltration capacities were only 3-6 mm/h. In agricultural and scrub areas, hydrophobicity was easier to break down after rainfall events, whereas under eucalyptus it was more resistant. In wet periods, hydrophilic conditions became dominant in forest soils and infiltration capacity reached 12mm/h. However, increased soil moisture led to decreased infiltration in urban and agricultural soils and saturation was attained in areas of low slope and shallow soil (<40cm). Hortonian overland flow was prevalent in forest areas in storms after dry weather, whereas urban and agricultural soils tended to provide sinks. In contrast, saturation overland flow dominated on urban and agricultural soils in the wet season. High wet-season infiltration of forest soils was shown by the low runoff coefficients recorded at the plots. Even under hydrophobic conditions, overland flow did not exceed 3% of rainfall, demonstrating the important role of preferential flow paths on water infiltration The sub-catchment dominated by forest (80%) also produced lower river discharge (contributing <10% catchment discharge) and delayed peak flows (>2h). Annual catchment discharge (14%-18% of rainfall) reflects the high infiltration promoted by both sandstone and limestone. Nevertheless, the quick flow response (<1.5h) demonstrates the susceptibility of the catchment to flashier floods with urbanization. Nevertheless, landscape discontinuity provided by patch nature of peri-urban land-use provides many sinks for local runoff that break flow connectivity. This patch nature should be considered in urban planning in order to minimize flood hazards.