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Spatial and temporal variability of water infiltration: impacts on catchment hydrology

Carla Ferreira (1,2), Daniel Soares (2), Tammo Steenhuis (3), Rory Walsh (4), António Ferreira (2), and Celeste Coelho (1)

(1) CESAM, Department of Environment and Planning, Aveiro University, Aveiro, Portugal, (2) CERNAS, Environment, Portugal (carla.ssf@gmail.com), (3) Department of Biological and Environmental Engineering, Cornell University, New York, USA, (4) Department of Geography, Swansea University, Swansea, United Kingdom

The hydrological behaviour of catchments is often determined largely by the infiltration process. Although there has been considerable research on infiltration and its relation to other soil properties, few studies have focussed on its catchment-scale spatial and temporal variability. This paper presents the methodology and first results of a study that is being developed to monitor spatial and temporal variability of water infiltration within a partly urbanizing catchment with different land uses and soils, and to understand how it affects the catchment hydrological response.

The study has been carried out in Ribeira dos Covões, a small catchment (6 km2) located in the central Portugal on the outskirts of the city of Coimbra. The Ribeira dos Covões basin is characterized by a humid Mediterranean climate, with an annual temperature of 15 ºC and a mean annual rainfall of 980 mm with strong seasonal and interannual variability. The catchment is characterized by sandstone and limestone lithology and soils. In 2006, catchment land-use comprised 55.5 % forest, 13.0 % farmland and 31.5 % urban land.

The spatial and temporal variability in infiltration capacity was determined via measurements at 62 different locations in the catchment at monthly intervals since the summer 2010.. Infiltration capacity was measured at each site using a Minidisk infiltrometer (Decagon Devices) for 30 minutes. In addition, surface soil moisture content at the 0-5cm depth was determined using the gravimetric method and the hydrophobicity was measured at 0, 2 and 5 cm depths at each site using the Molarity of Ethanol Droplet technique. Finally, soil samples were collected at each experimental location at different soil depths (0-5cm, 5-10cm, 15-20cm and 45-50cm) and were analysed for bulk density (using the core method), organic content (by measuring carbon dioxide emission after combustion at 1200ºC) and particle size distribution (using the Robinson pipette method).
Initial results indicate a high spatial and temporal variability in soil infiltration capacity within the study catchment. Forest areas have the lowest infiltration capacity due to the water-repellent nature of their soils especially during dry periods. In the most highly repellent soils, no water infiltrated. After the first rains following a dry period, soil hydrophobicity in the pine forests decreases and infiltration capacities increased. In eucalyptus forest, however, even after several rainfall events, water-repellency remained high and infiltration capacities (and the amount of water infiltration) were almost zero. In contrast, in limestone areas, which are mainly dominated by farmland and artificial paved surfaces, the soil is hydrophilic throughout the year and infiltration capacities sometimes exceeded 20 mm h-1. In these areas, infiltration capacities declined with increasing soil moisture associated with rainfall events.

Implications of the high spatial and temporal variability in infiltration capacity for rainfall-runoff relationships of the catchment are then explored. Hortonian overland flow tends to be important in the isolated rainstorms of the dry summer months and at the beginning of the autumn/winter wet season when forest soils are impermeable because of their hydrophobicity. In contrast, in the wet part of the year, infiltration capacities tend to be much higher than rainfall intensities, and Hewlett saturation-excess overland flow is confined to the lower, less steep parts of the catchment.