Geophysical Research Abstracts
Vol. 13, EGU2011-694, 2011
EGU General Assembly 2011

Urban impact on hydrological processes: methodology and first results of a small Mediterranean catchment

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In actively urbanizing catchments, the urbanization process leads to changes in land use and landscape patterns and alterations to the connectivity of water flows between different sub-catchments, with potential consequences for rainfall-runoff relationships, flood frequency and water resources. Although general engineering methods have been developed for urban areas, they have not been tested in areas with a Mediterranean climate. This paper presents the methodology and the first results of a study that is being carried out to assess the impact of the urbanization process on the hydrological regime of a small Mediterranean catchment.
The study focuses on the Ribeira dos Covões, a rapidly urbanizing 6 km2 experimental catchment on the urban fringe of Coimbra, the main city of central Portugal. It has a humid Mediterranean climate, with an average annual temperature of +15ºC and a mean annual rainfall of 980 mm with strong seasonal and interannual variability. The population of the catchment was estimated at 7000 inhabitants in 2001. By 2008, the land use of the basin comprised 55.5 % forest (pine and eucalyptus), 13.0 % farmland and 31.5 % urban land. The geology is in part limestone and in part sandstone. The soils are generally deep and are water-repellent for part of the year, particularly in the forested areas.
The study uses a combined approach of field survey and hydrological monitoring to assess spatiotemporal hydrological dynamics. The continuous-recording monitoring network includes a weather station and a river water-level recorder at the catchment outlet, both installed in 2005. Three additional raingauges installed in summer 2010 assess spatial rainfall variability within the study catchment. Six additional water level recorders, also installed in summer 2010, monitor streamflow generated in different sub-catchments. This hydrological network provides the data to assess the hydrological responses to rainfall and contribution to catchment river flow of sub-catchments characterized by different geology, soil characteristics, land-use and urbanization intensity.
Streamflow monitoring results indicate distinct spatial and temporal variations in hydrological processes. Whereas limestone areas are only hydrologically active during rainfall events, the sandstone areas provide continuous discharge from several springs throughout the year. Overland flow (providing the quickflow of streams) is generated by water-repellent soils, modified urban surfaces and saturated areas. Some of the overland flow, however, infiltrates into the soil in downslope areas and leaves the watershed via a well-developed regional subsurface flow system. The nature of urbanization in the catchment appears to be causing breaks in landscape connectivity (generally a major driving force in overland flow and runoff generation processes) and this means that flood risk assessment is needed as part of urban planning.

The runoff coefficient at the catchment outlet in 2008 and 2009 was around 10% of total rainfall and has not increased despite an increase in the impermeable urban surface area. A further increase in impermeable surface area, however, may lead to a tipping point in surface runoff generation (because of a renewed increase in connectivity of surface flows), whereby peak runoff might increase by 200-300% with disastrous flooding consequences for down town area.

The ultimate goal of the study is, therefore, to gather the information to feed, parameterize, calibrate and validate a physical-based and spatially-distributed hydrological model, in order to simulate the impact of intensification of the urban areas on flood response. It is argued that only by the development of mitigation planning strategies including preserving the areas where water is infiltrating to the regional subsurface flow system can flooding calamities to the city areas be avoided.