Hydrology in a Mediterranean mountain environment – the Vallcebre research basins (northeastern Spain). III. Vegetation and water fluxes

PILAR LLORENS¹, RAFAEL POYATOS², ALEKSANDRA MUZYLO¹, CARLES RUBIO³, JÉRÔME LATRON¹, JULIANA DELGADO¹ & FRANCESC GALLART¹

¹ Institute of Environmental Assessment & Water Research (IDÆA), CSIC, Barcelona, Spain
² School of Biological and Biomedical Sciences, University of Durham, Durham, UK
³ Department of Agri-Food Engineering and Biotechnology, UPC, Castelldefels, Spain
⁴ Lab-Ferrer Soils and Environmental Consulting, Cervera, Spain

Abstract The Vallcebre research basins are representative of Mediterranean mountain areas originally covered by Quercus pubescens, but deforested for agricultural use in the past. Nowadays they are mainly covered by mesophyle grasses with spontaneous afforestation by Pinus sylvestris covering 64% of the basins’ area. Various projects to study water fluxes in the soil–vegetation–atmosphere continuum have been undertaken since 1994. The main objective of these studies was to analyse the effect of vegetation cover on basin water balance in a framework of climate and land use change. The dynamics and temporal variability of soil moisture, transpiration and rainfall interception by Pinus sylvestris and Quercus pubescens are investigated in terms of their dependence on meteorological conditions and, in the case of transpiration, on soil moisture and water table depth. The role of vegetation in basin water balance is also analysed. The results underline the importance of rainfall interception losses, accounting for about 24% of bulk rainfall for the Scots pine and between 6 and 24% for the pubescent oak. The high temporal variability of interception dependent on the meteorological conditions and on rainfall event characteristics was also stressed. The effect of forest cover was apparent when comparing neighbouring soil moisture profiles under forest and under grassland, with the former being characteristically drier mainly due to interception losses. Transpiration of the Scots pines was double that found in the nearby pubescent oak stand. Scots pine showed a strong reduction of transpiration during the dry summer periods, even in the studied area where the annual rainfall exceeds the reference evapotranspiration. Pubescent oak was less affected by soil moisture deficits. The physiological responses to water deficits of both species indicated that Scots pine was more vulnerable to xylem embolism while the pubescent oak was more resistant to extreme drought events. The results also show a link between water table depth and the ability of the Scots pine to meet the evaporative demand, suggesting that trees are able to extract water from rather deep water storage. Rainfall interception and tree transpiration processes have been modelled (Gash and Jarvis-type models, respectively) at the plot scale with two objectives: the comprehension of the two processes, and the analysis of the uncertainty associated with the modelling. Finally, understanding of vegetation-related hydrological processes was used to develop the TOPBAL model which is a TOPMODEL modification developed for an improved simulation of the response of basins with diverse vegetation types and high climatic seasonality. TOPBAL explicitly considers rainfall interception by vegetation and the two-way exchanges between the root-unsaturated store and the phreatic store. It allows simulation of semi-distributed soil moisture. The results indicate that compared to the original TOPMODEL, TOPBAL has improved the simulation of recession curves and water balance.

Key words Mediterranean mountains; rainfall interception; forest transpiration; soil water content; Vallcebre