STORM-FLOW RESPONSE IN A SMALL MEDITERRANEAN FORESTED CATCHMENT (CENTRAL PYRENEES, SPAIN). AN EXAMPLE OF HIGHLY NON-LINEAR RAINFALL-RUNOFF RELATIONSHIPS

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Introduction

Although numerous studies have been conducted in forested research catchments (see for example reviews in Bosch and Hewlett, 1982; Whitehead and Robinson 1993; Bonell, 1993), there is still a large controversy on the hydrological role of forest on floods, low-flows or even on catchment water balance (Cosandey *et al.*, 2005). The large diversity of results may be explained by the multiplicity of factors influencing the role of forest on catchment runoff and confirms ultimately the necessity of further investigations, especially under climates where few studies have been carried on. The objective of this work, that analyses the storm-flow response in a small Mediterranean forested catchment, is to improve our understanding of the influence of forest on the rainfall-runoff relationships in areas with marked seasonality.

Study area

The San Salvador research catchment (Serrano-Muela *et al.*, 2005; 2008) is located in the upper basin of the Aragón River, Central Pyrenees, 10 km NW from the city of Jaca, Spain. The catchment, located in the Eocene flysch sector, has an area 0.92 km^2, altitudes between 1270 and 880 m and slopes varying from 15 to 25°. Climate is sub-Mediterranean with Atlantic influences, mean annual temperature is around 10°C and mean annual precipitation is close to 1100 mm, occurring mainly during spring and autumn. Well developed soils on the north facing slope are principally Haplic Kastanozems and Haplic Phaeozems, whereas Calcaric regosols y Cambisols dominate on the south facing slope. The whole catchment is covered by forest. Pine forest (*Pinus sylvestris*) dominates on the north facing slope, with some smaller areas covered by beech forest (*Fagus sylvatica*), in downslope areas. Sub-Mediterranean oak forest (*Quercus faginea*) is dominant on the south facing slope.

Equipment and methods

The San Salvador catchment was monitored in 1999. Current monitoring is composed of 3 tipping bucket pluviometers, one meteorological station and one H-Flume gauging station with all variables registered every

5 to 15 minutes. In 2006, three forest plots were equipped to measure rainfall interception by different forest cover (Serrano-Muela *et al.*, submitted). This work, that only uses rainfall and runoff data, is based on the analysis of 91 rainfall events higher than 8 mm, selected independently of their associated runoff response. Rainfall depth (P) was determined for each rainfall event. Storm-flow depth (R) was calculated for each flood event using the constant slope method for flow separation with a slope value of 1.83 l $s^{-1}km^{-2}d^{-1}$. Further on, storm-flow coefficient (C_{sf} = R/P) and baseflow at the start of the flood event (Q_b), were determined.

Results and discussion

Figure 1, that shows the annual evolution of the storm-flow coefficient (C_{sf}), illustrates the high variability of the rainfall-runoff relationship along the year in the San Salvador catchment. From November to April, C_{sf} values varied commonly between 3% and 50%, being always higher than 1%, except for rainfall events smaller than 10 mm. At the contrary, from May to September, C_{sf} values were generally lower than 1%, and most often close to 0, independently of the rainfall depth. C_{sf} values observed in October were more variable (from 0 to 10%), reflecting the transition from dry conditions, observed at the end of the summer, to wet ones at the end of the autumn period.

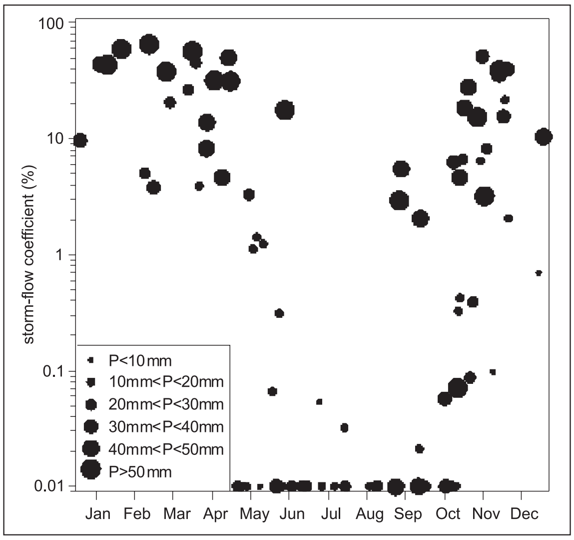

Figure 1. Seasonal evolution of the storm-flow coefficient in the San Salvador catchment. (P = rainfall depth)

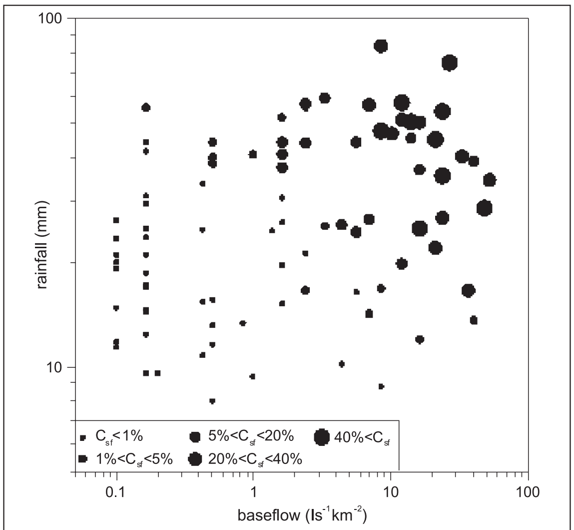

Figure 2. Storm-flow coefficient (C_{sf}) observed in the San Salvador catchment for different baseflow and rainfall depth values

The seasonal dynamics of the hydrological response observed in the San Salvador catchment is similar to those reported in other Mediterranean catchments partly forested (Lana-Renault *et al.*, 2007; Latron *et al.*, 2008). It appears however more marked than generally described, most likely because of the major role of forest cover (covering the whole catchment) on the seasonal evolution of catchment water reserves.

Figure 2 shows the combined influence of baseflow (Q_b) and rainfall depth (P) values on the observed storm-flow coefficients (C_{sf}) in the San Salvador catchment. Similar 40 mm rainfall events generated for highly different C_{sf} values depending on the baseflow at the start of the event. A C_{sf} value lower than 1% was for example observed when Q_b was lower than 0.5 l s^{-1} km^{-2}, whereas C_{sf} raised up to 40% when Q_b was around 20 l $s^{-1}km^{-2}$. Conversely, for similar baseflow values (Q_b around 10 l s^{-1} km^{-2}) the C_{sf} value in response to a 9 mm rainfall events remained lower than 1%, whereas it reached more than 40% for a 60 mm rainfall event. Results shown on figure 2 helped to explain the high seasonality of the storm-flow coefficient observed previously (Figure 1). Indeed, figure 2 shows that when baseflow was lower than 2 $ls^{-1}km^{-2}$, the storm-flow coefficient resulting from a rainfall event smaller than 35 mm always remained lower than 1%.

These results on the combined influence of baseflow and rainfall depth on the observed storm-flow coefficients are similar to those described by Latron (2003) in the Mediterranean Can Vila catchment. However, for rainfall events smaller than 30 mm, and for similar baseflow values, storm-flow responses observed in the San Salvador catchment (totally covered by forest) were always much lower than those observed in the Can Vila catchment (where forest covers only 30% of the catchment area). Such differences are most probably related to the role of forest interception.

Conclusions

This study offers some preliminary results on the factors influencing the storm-flow response in a small Mediterranean forested catchment, as a way to improve the understanding of the influence of forest on the rainfall-runoff relationships in areas with marked seasonality. Results shown in this study highlight the strong seasonal non-linearity of the rainfall-runoff relationships. Two clearly different periods were identified along the year in terms of storm-flow response: A wet period, when observed floods showed similar characteristics than those reported for other Mediterranean or more humid catchments. A dry period with a more extreme reduction of the storm-flow response than usually described in other Mediterranean conditions. Such reduction of the storm-flow response, most likely related to the role of forest interception, deserves further investigations to better quantify the hydrological role of Mediterranean forest.

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