Comparing the stream flow response of two sub-Mediterranean mountain catchments with different land covers

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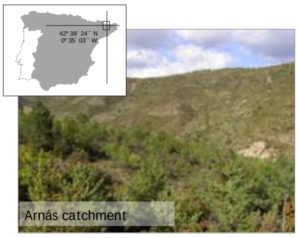
1. INTRODUCTION

Land abandonment and subsequent **re-vegetation** have significantly modified the hydrological behaviour of Mediterranean mountains (e.g., García-Ruiz and Lana-Renault, 2011). **Assessing the hydrological effect of such land-cover change** is particular relevant in this region where water resources are scarce and uneven, and water demand tends to increase (López-Moreno et al., 2008); for this purpose, it is essential to take a closer look at the hydrological behaviour of catchments with different land cover and **understand the role of vegetation and soils on flood generation**. Here we carried out a detailed analysis of the stream flow response of two neighbouring catchments differing in land cover, but with similar climatic conditions, lithology and topography, which enable us to separate the effects of soil and land cover on their hydrological responses.

2. THE CATCHMENTS



	Past agricultural catchment (Arnás)	Forested catchment (San Salvador)
Area (km^2)	2.84	0.92
Min-Max altitudes (m a.s.l.)	910-1340	875-1300
Bedrock	flysch	flysch
Main soils	compact and shallow calcaric regosols	well-developed kastanozems and cambisols
Dominant land cover (%)	Shrubs (71%)	Natural forest of *P. sylvestris* (98%)
Annual rainfall 1999-2008 (mm)	926±182	935±171

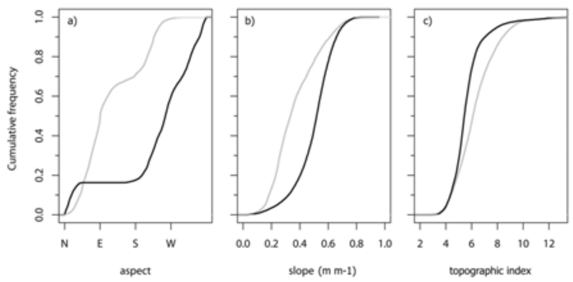


Fig 1. Comparison of topographical variables in the past agricultural (grey line) and forested (black line) catchments
Topographic index is ln (a/tan b) (-).

3. DATA COLLECTION

In both catchments **rainfall**, **discharge** at the outlet and **depth to water table** at different distance from the main stream are measured continuously. In Arnás information on **sediment** transport (solutes, suspended sediment and bed load) is also collected. In San Salvador **interception** under *P. sylvestris, F. sylvatica* and *Q. faginea* was measured at three plots (Lana-Renault et al., 2007; Serrano-Muela et al., 2008).

A **set of 26 rainfal-runoff events** that co-occurred in each catchment were selected. For each rainfall-runoff event several variables were derived from the hyetograph and hydrograph. For each hydrograph parameter Q, **the relative difference *q* between the two catchments** was calculated as:

$$q = \frac{Q_{pastagricultural} - Q_{forested}}{(Q_{pastagricultural} + Q_{forested})/2}$$

4. COMPARISON BETWEEN HYDROGRAPH CHARACTERISTICS

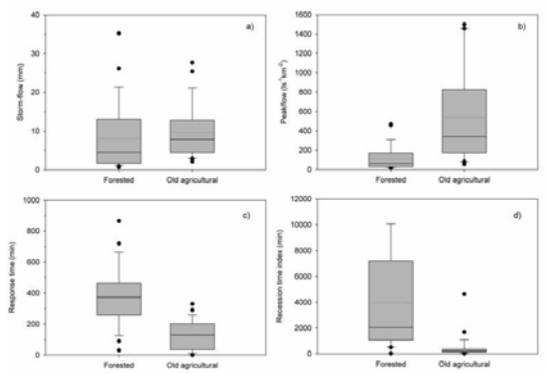
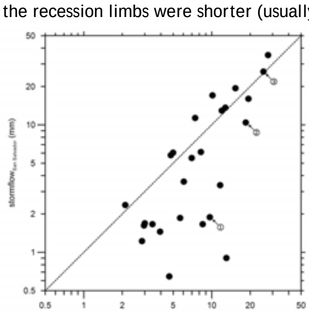


Fig 2. Storm flow (a), peak flow (b), response time (c) and recession time index (d) for the forested and the past agricultural catchments (median value, 1st and 3rd quartiles, 1st and 9th deciles, outliers; average is the dotted line).

A paired samples *t*-test showed that **peak flow** specific discharge, the **response time** and the **recession time index** were statistically different, whereas storm flow depth was not.

In the past agricultural catchment peak flows were always greater (usually one order of magnitude) compared with the forested catchment, the response was 2- to 3-fold faster, and the recession limbs were shorter (usually 1–2 orders of magnitude) (Fig. 2b,c,d).



Storm flow depth was slightly greater in the past agricultural catchment compared with the forested catchment (Fig. 2a), although this was not a general rule.

For flood events of low-to-intermediate size the storm flow depth was greater in the past agricultural catchment than in the forested catchment, but smaller for large-sized events (Fig.3)

Fig 3. Relationship between storm flow in the forested and the past agricultural catchments.

5. FACTORS INFLUENCING THE HYDROLOGICAL DIFFERENCES BETWEEN THE CATCHMENTS

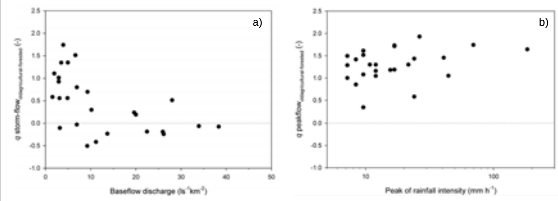


Fig 4. Relationship between *a) q* in the storm flow depth and the base flow discharge, and *b) q* in the peak flow and the peak of rainfall intensity.

Fig. 4a suggests a base flow threshold (~10 $ls^{-1}km^{-2}$), below which storm flows in the past agricultural catchment were typically greater, whereas above it the storm flows tended to be greater in the forested catchment. Fig. 4b suggests that peak flows were sometimes higher in the past agricultural catchment with more intense rainfall.

Fig. 5 illustrates the differences in the hydrological responses of the two catchments as a function of **catchment wetness conditions**.

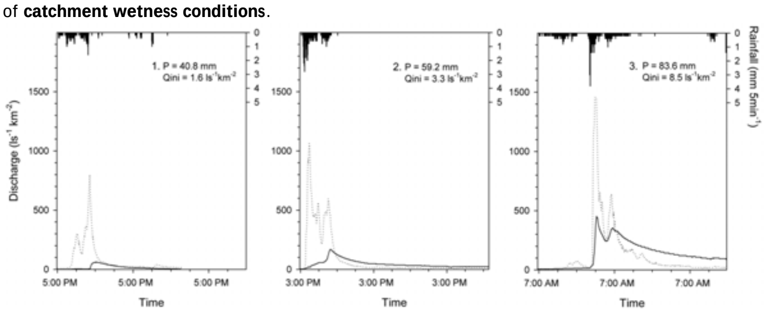


Fig 5. Hydrographs of the past agricultural (Arnás, dotted line) and forested (San Salvador, solid line) catchments for different preceding conditions. P: rainfall; Qini: baseflow discharge at the start of the event.

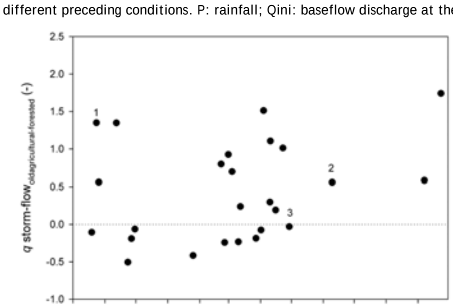


Fig 6. Seasonal evolution of the relative difference (q) in storm flow between the two catchments. The numbers 1-3 refer to the hydrographs shown in Fig.5.

Differences in storm flow showed marked seasonality and can be linked to **dominant runoff generation processes** in each catchment.

In Arnás, runoff is generated during the entire water year, through both surface (i.e. infiltration excess and saturation excess overland flow) and subsurface flow (Lana-Renault et al., 2007). In San Salvador a "switching" behaviour -controlled by soil moisture conditions which may regulate the hydrological connectivity- can favour the release of large amounts of subsurface flow.

6. CONCLUSIONS

Storm flow differences between the catchments were closely related to catchment wetness conditions and hence showed a marked seasonal pattern. Differences between their hydrographs characteristics were dictated by the contrasting dominant runoff generation processes operating in each catchment. These can be explain by differences in land cover, and especially soil properties (soil depth and permeability), and the presence of degraded areas, inherited from past human activities.

REFERENCES

García-Ruiz J.M, Lana-Renault N. (2011). Hydrological and erosive consequences of farmland abandonment in Europe – a review. Agriculture, Ecosystems & Environment, 140: 317-338. 10.1016/j.agee.2011.01.003

Lana-Renault, N., Latron, J., Regüés, D. (2007). Streamflow response and water-table dynamics in a sub-Mediterranean research catchment (Central Pyrenees). Journal of Hydrology, 347: 497-507.

López-Moreno, J.I., Beniston, M., García-Ruiz, J.M., 2008). Environmental change and water management in the Pyrenees: Facts and future perspectives for Mediterranean mountains. Global and Planetary Change 61, 300-312

Serrano-Muela, M.P., Lana-Renault, N., Nadal-Romero, E., Regüés, D., Latron, J., Martí-Bono, C., García-Ruiz, J.M. (2008). Forests and their hydrological effects in Mediterranean mountains: The case of the Spanish Pyrenees. Mountain Research and Development, 28(3): 279-285.

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