Changes in catchment hydrology in relation to vegetation recovery: a comparative modelling experiment

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1. INTRODUCTION

Mediterranean mountains are largely affected by **land abandonment** and subsequent **vegetation recovery**, with significant implications on their hydrological response (e.g., García-Ruiz *et al.*, 2010). **Forecasting the trends of water resources under future re-vegetation scenarios** is of paramount importance, especially in Mediterranean basins where **water management relies on reservoirs** that depend on **runoff generated in mountain areas**. With this purpose, a modelling experiment was designed based on the information collected in two neighbouring research catchments with a different history of land use, in the central Spanish Pyrenees.

2. THE CATCHMENTS

One (2.84 km²) is an abandoned agricultural catchment subjected to plant recolonization and at present mainly covered by shrubs. The other (0.92 km²) is a catchment covered by dense natural forest (*P. sylvestris*), representative of undisturbed environments.
In both catchments rainfall and discharge at the outlet are measured continuously.

3. THE MODEL

A process-based distributed hydrological model was used for simulating surface runoff at the outlet of the catchments at an hourly time step. The model was built using PCRaster Python scripting language (Karssenberg *et al.*, 2007).
The model includes a series of stores that are interconnected by water fluxes, representing the main hydrological processes. These are described by standard modules:

- Evapotranspiration → Penman-Monteith (Allen *et al.*, 1988)
- Infiltration → Green-Ampt
- Soil storage → one layer; subsurface flow → Darcy's law
- The overland flow was routed through the local drain network
- The model also includes a maximum surface storage and the effect of topography on incoming radiation

Time step: 1 hour			
	Land cover	**Soils**	**other**
MODEL INPUTS grid maps 10x10 m	Stand storage capacity (m)	Porosity (-)	DEM (m)
	Albedo (-)	Wilting Point (-)	Local Drain Direction (-)
	Vegetation Height (m)	Field Capacity (-)	Regolith Thickness (m)
	Vegetation Max. Stomatal conductance (m s^{-1})	Limiting Point to transpiration (-)	Maximum Surface Storage (m)
		Saturated conductivity m d^{-1}	Latitude, longitude (°)
		Suction Head (m)	

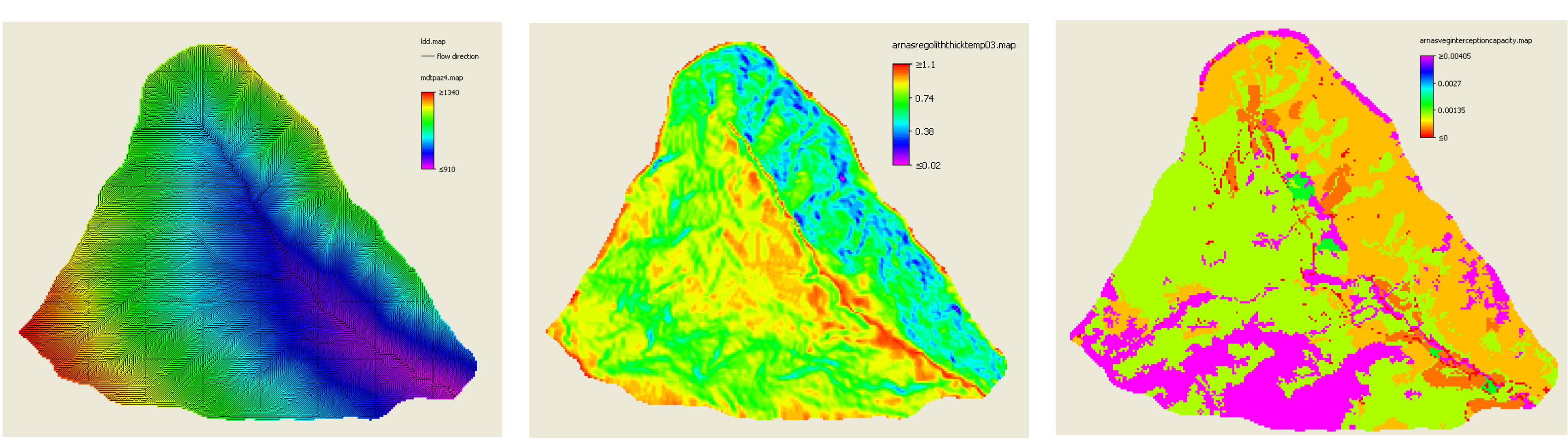

Fig 1. Example of inputs used in the model: a) DEM and local drain direction network; b) regolith thickness (m); b) stand storage capacity (m).

4. ANALYSIS OF FIELD DATA

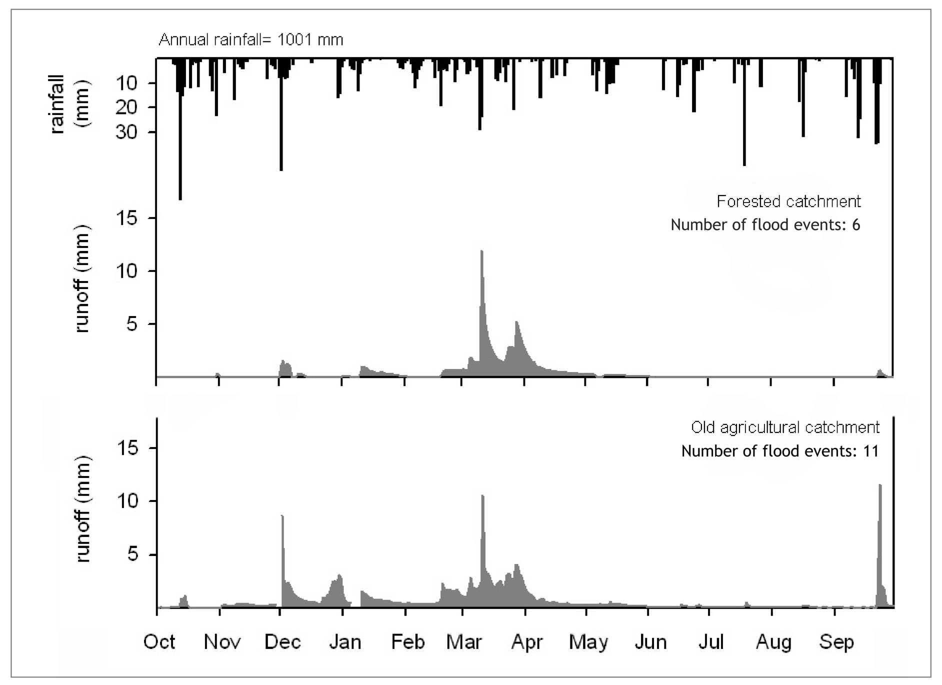

Fig 2. Example of daily rainfall and runoff in the two catchments during one hydrological year (2005-2006).

The hydrological response of the forested catchment was characterized by a marked seasonality, with high flows mostly concentrated in spring. Compared to the old agricultural catchment, the forested catchment reacted much less in autumn and winter, and almost no floods were recorded in summer, despite the occurrence of several intense rainstorms.

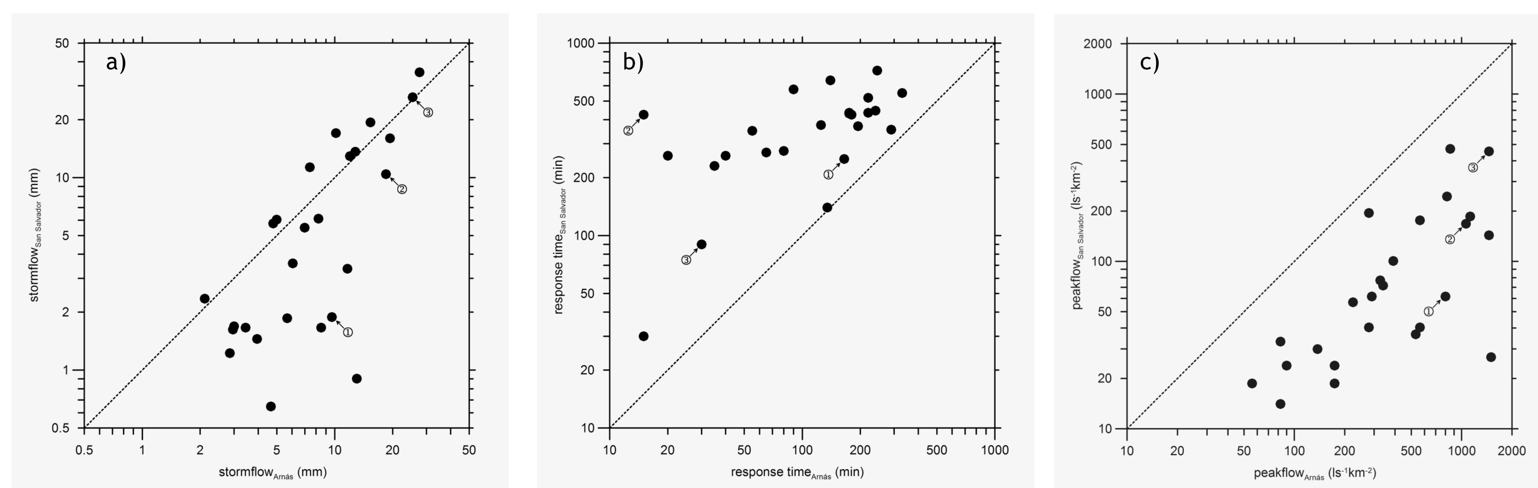

Fig 3. Relationships between stormflow (a), response time (b) and peakflow (C) of comparable flood events recorded in the forested (San Salvador) and the old agricultural (Arnás) catchments .

Stormflow was generally higher in the old agricultural catchment (Fig. 3a), especially for low to intermediate size events; only for large events the stormflow in the forested catchment was sometimes greater. The forested catchment always reacted more slowly to rainfall (Fig. 3b), with lower peakflows (generally one order of magnitude lower) (Fig 3c). Under drier conditions, the difference in the stormflow between the two catchments tended to increase whereas under wet conditions they tended to be similar.

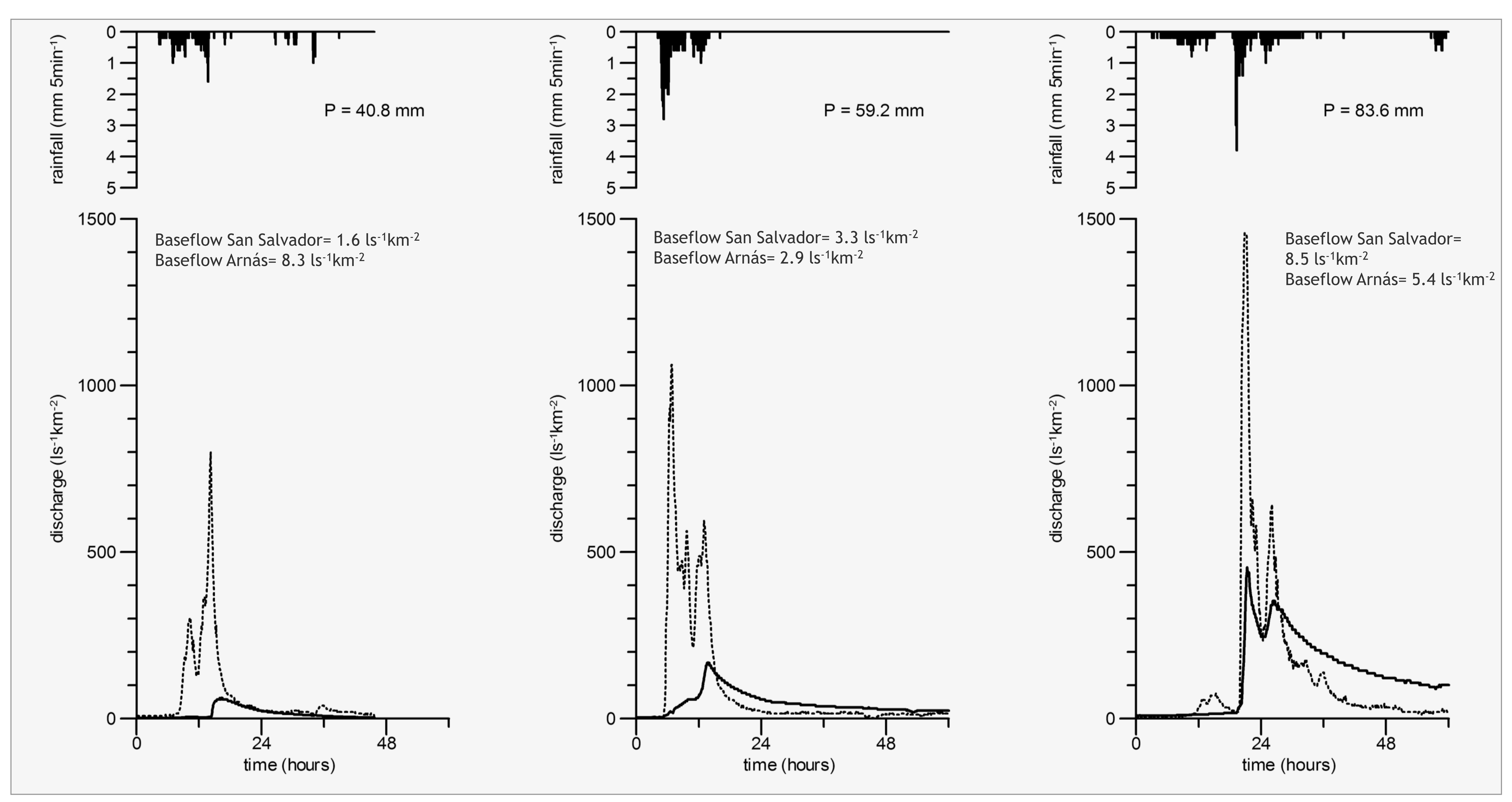

Fig 4. Hydrographs observed in the forested (San Salvador; solid line) and in the old agricultural (Arnás; dotted line) catchments, from dry to wetter conditions.

5. THE MODELLING EXPERIMENT

The modelling experiment aims at separating the effect of land cover from other differences (e.g. catchment area, morphology) between the two catchments. This approach allows us to make general statements on effects of land cover, required for future predictions for larger areas.

Here we present the results of a preliminary phase of the experiment. The calibration of the model was conducted using one year data from the old agricultural catchment and was based on an error-and-trial approach in order to estimated appropriate values for the most important parameters (soil saturated conductivity, soil infiltration capacity, regolith thickness). Using the calibrated model and the same meteorological inputs, we simulated runoff under a re-vegetated scenario:

Re-vegetated scenario → Complete catchment covered by forest (*P.sylvestris*)
Re-vegetated scenario → Regolith Thickness x 2

Results showed that under a re-vegetated scenario runoff decreases (with peakflows 3 to 5 times lower than in the old agricultural scenario; Fig. 6b) and the response time was slightly slower, especially for the small events (Fig., 6a).

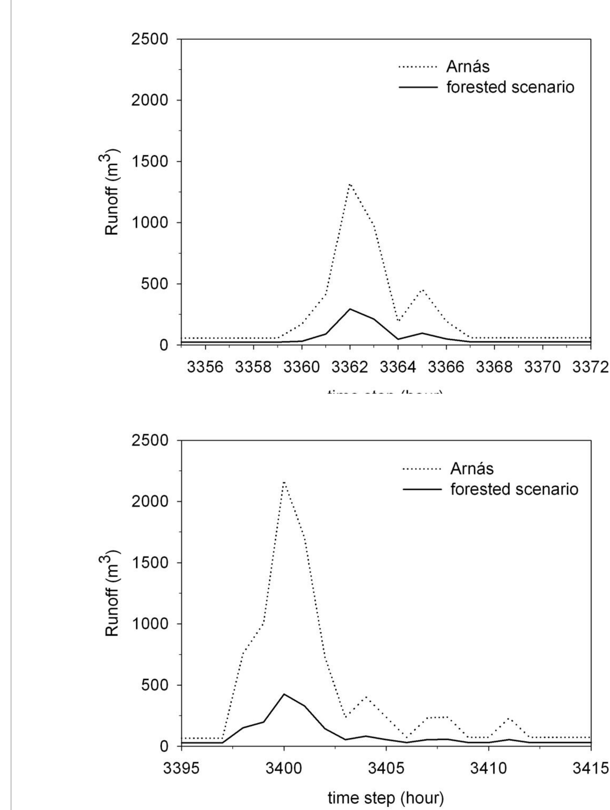

Fig 5. Examples of hydrographs in the old gricultural scenario (Arnás; dotted line) and in the re-vegetated scenario (forested scenario; solid line).

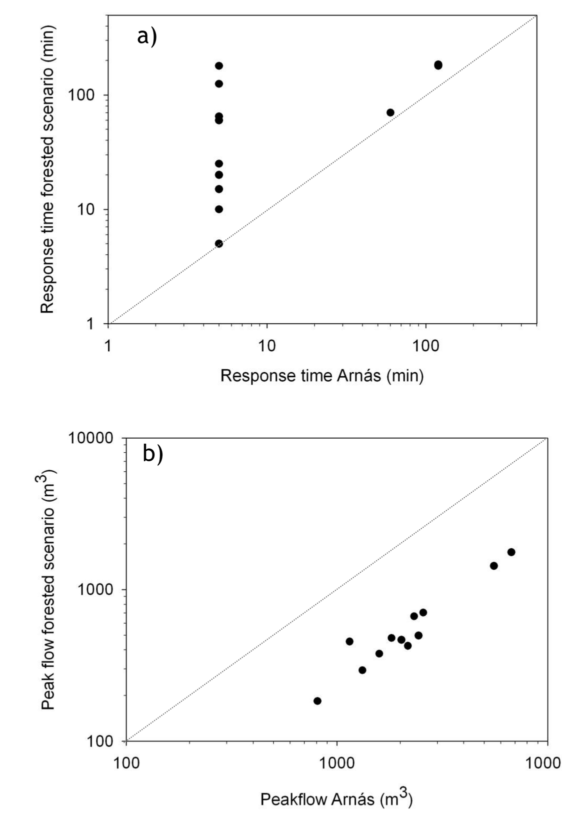

Fig 6. Relationships between response time (a) and peakflow (b) of flood events in the old agricultural scenario (Arnás) and in the re-vegetated scenario (forested scenario).

6.CONCLUSIONS AND FURTHER WORK

Significant differences were observed between the hydrological response of an old agricultural catchment and a forested one. A preliminary phase of a modelling experiment showed that the model was able to reproduce the trends observed in the field. Next step will be to calibrate the model using data from the two catchments, then "swap" land cover between catchments. The effects of the land cover change will be determined by analysing the differences between the first and the "swapped" simulations.

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