Sediment balance in four small catchments with differeint land cover in the Central Pyrenees (Spain)

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ABSTRACT

Four experimental catchments in the Central Pyrenees were monitored by the Department of Geo-environmental Processes and Global Change (Pyrenean Institute of Ecology, CSIC) to assess the hydrological and geomorphological consequences of various land uses and vegetation cover. The catchments were selected along an altitudinal and land-use gradient and included: (i) a sub-Mediterranean environment affected by intense weathering and erosion processes on marls, (ii) an old abandoned cultivated area undergoing vegetation regrowth, (iii) a barely-disturbed forest area, and (iv) a sub-alpine grassland in the high mountains, affected by snow accumulation and melting processes. The results demonstrate that plant cover is a key factor influencing the suspended sediment concentration, total sediment yield and proportion of different types of sediment.

Keywords: sediment balance, land cover change, experimental catchments, Spanish Pyrenees

INTRODUCTION

The evolution of plant cover directly influences the evolution of the quantity and quality of water resources, as well as soil erosion and conservation. Mediterranean mountains are particularly sensitive to these changes resulting from: (i) the abandonment of south-facing slopes and consequent expansion of scrublands and forests after centuries of cultivation (Lasanta-Martínez et al., 2005), and (ii) new scenarios of climate change, that have pronounced effects in southern Europe (López-Moreno et al., 2008). Experimental catchments are considered the most appropriate approach to studying runoff generation, soil erosion and sediment transport (Walling, 1991). Numerous experimental research catchments (of tens or hundreds of hectares in size) have been monitored over several decades to quantify and understand the hydrological and sediment dynamics of contrasting/differing environments, and to provide the detailed information necessary to improve the accuracy of hydrological and sedimentological models. For this reason, detailed studies in catchments with varying land uses are of paramount importance.

The Department of Geo-environmental Processes and Global Change (IPE-CSIC) has monitored four experimental catchments with different land use histories and vegetation cover in the Central Pyrenees, to enable comparison of their hydrological response and sediment balances. The purpose of this study was to assess how land use and vegetation cover influence sediment dynamics and balances.

METHODS

Study area: the catchments

Four experimental catchments (the Izas, Arnás, San Salvador and Araguás catchments) along an altitudinal and land use/vegetation cover gradient in the Central Pyrenees (Figure 1 and Table 1) were monitored.

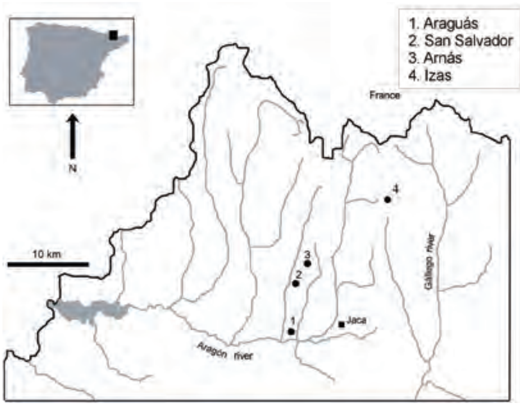

Figure 1. Location of the Araguás, San Salvador, Arnás and Izas catchments.

Table 1. Main physiographic characteristics of the experimental catchments.

		Izas	Arnás	San Salvador	Araguás
Catchment area	km^2	0.33	2.84	0.92	0.45
Minimum elevation	m a.s.l.	2060	900	878	780
Maximum elevation	m a.s.l.	2280	1340	1325	1105
Mean annual precipitation	mm	2000	1000	1000	800
Maximum peak flow	$m^3 s^{-1}$	1	4.2	1.2	4.5
Maximum SSC	$g l^{-1}$	1	16	1.9	>1000
Lithology		Schist	Flysch	Flysch	Marls and Flysch
Forest cover	%	0	20	98	30
Shrub cover	%	0	72	1	38
Grassland cover	%	85	6	0	6
Bare land	%	15	2	1	26

(i) The Izas catchment (0.33 km^2; 2060-2280 m a.s.l.) is located in the high Gállego valley, in an environment strongly affected by the presence of snow during at least six months per year. The lithology consists mainly of schist, and the vegetation cover is high mountain pasture with rocky outcrops in the steeper areas.

(ii) The Arnás catchment (2.84 km^2; 900-1340 m a.s.l.) includes a complex mosaic of different shrubs and forested patches, and eroded areas resulting from agricultural practices in the past and recent abandonment. The lithology is Eocene flysch, composed of thin alternating layers of sandstones and marls.

(iii) The San Salvador catchment (0.92 km^2; 878-1325 m a.s.l.) is covered by dense forest (*Pynus sylvestris*, *Fagus sylvatica* and *Quercus gr. faginea*) and is representative of undisturbed environments in the Central Pyrenees. The lithology is also Eocene flysch.
(iv) The Araguás catchment (0.45 km^2; 780-1105 m a.s.l.) is characterized by a dense network of badlands in the lower part, typical of highly degraded environments. The lithology in the upper part of the catchment is Eocene flysch (artificially reforested in the 1960s), and Eocene marls in the lower part of the catchment, related to badlands development.
The Izas, Arnás, San Salvador and Araguás catchments were monitored in 1986, 1996, 1998 and 2004, respectively.

Instrumentation
All the catchments had tipping bucket rain gauges, a comprehensive weather station, and a gauging station at which discharge and suspended sediment concentrations were recorded continuously. Solutes were recorded during floods, when the water level reached a threshold and operation of the water sampler (ISCO 3700) was initiated. In the Arnás, San Salvador and Izas catchments bedload transport was estimated using sediment traps; bedload was not measured in the Araguás catchment. Bedload in the Arnás catchment was also estimated by a volumetric approach using a large profilometer to evaluate the accumulation of coarse sediment at the gauging station, just upstream the sediment trap.

RESULTS AND DISCUSSION

In the Araguás catchment, 11% of monitored floods attained suspended sediment concentration peaks greater than 500 g l^{-1}, whereas in the Arnás catchment they rarely exceeded 15 g l^{-1}, and never exceeded 2 g l^{-1} and 1 g l^{-1} in the San Salvador and Izas catchments, respectively (Table 1). Large differences were observed in the sediment yield distribution among the four catchments with respect to solutes, suspended sediment and bedload (Figure 2). García-Ruiz et al. (2008) reported that sediment outputs from the Araguás catchment were two orders of magnitude higher than in the Arnás and San Salvador catchments, with a clear predominance of suspended sediment transport over solutes and bedload (96%, 1.5% and 2.5%, respectively). In the Arnás catchment, the suspended sediment yield was similar with respect to solutes (34-46% and 48-61%, respectively), and bedload was relatively high (5-6%). In the San Salvador catchment, the transport of solutes predominated over that of suspended sediment. In the Izas catchment, the sediment balance was dominated by solutes (60-85%), followed by suspended sediment (5-20%) and bedload (1-30%), with the latter showing a high interannual variability (Alvera & García Ruiz, 2000).

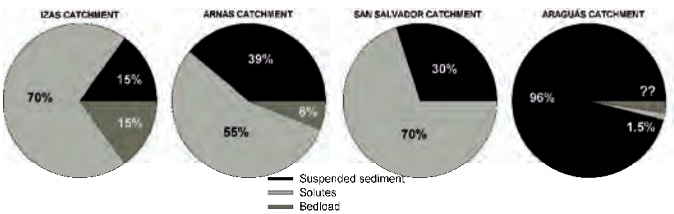

Figure 2. Distribution of sediment outputs. For the Araguás catchment, the bedload was an undirected estimation, based on Castelltort (1995; PhD Thesis).

In the Araguás catchment the seasonal trend of sediment transport was linked to weathering processes and to the seasonality of soil erosion and discharge (Nadal-Romero et al., 2008). In the Arnás catchment the main sources of sediment are the taluses close to the main channel and some bare areas affected by sheet wash erosion. Here sediment transport is determined by the seasonal dynamics of the different runoff-contributing areas (Lana-Renault

& Regüés, in press). In the Izas catchment, where the main source of sediment is a small area far away from the catchment outlet, the dynamics was related to the protective role of the snow cover in winter and spring, and the grasslands in summer and autumn. Finally, in the San Salvador catchment the suspended sediment was derived only from channel taluses during the highest floods. An initial estimation of sediment outputs from each catchment indicated a clear decrease of sediment output with increasing density of plant cover. Thus, the estimated average rate of sediment output was about 120 Mg km^{-2} yr^{-1} in the San Salvador catchment, 120-190 Mg km^{-2} yr^{-1} in the Arnás catchment, 200-300 Mg km^{-2} yr^{-1} in the Izas catchment, and 15,300 Mg km^{-2} yr^{-1} in the Araguás catchment (57,500 Mg km^{-2} yr^{-1}, if only the badland areas were considered).

CONCLUSIONS

The results of this study confirm that plant cover is the key factor influencing sediment transport, suspended sediment concentration and total sediment yield. The results also suggest that vegetation regrowth in Mediterranean mountains could lead to a shift in the hydrological and sedimentological behavior of previously cultivated and/or degraded areas.

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