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Sediment Sources in a Small, Abandoned Farmland Catchment, Central Spanish Pyrenees

C. González[1], J. M. García-Ruiz[1], C. Martí[1], S. White[1], M. P. Errea[1] and J. Arnáez[2]

[1]Instituto Pirenaico de Ecologia, CSIC, Campus de Aula Dei, Apartado 202, 50080 Zaragoza, Spain
[2]Area of Geography, University of La Rioja, 26004 Logroño, Spain

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Abstract. In an abandoned farmland catchment the eroded areas have been mapped in order to locate the possible sediment sources. Besides large, non functional mass movements, three types of processes and geoforms stand out: small debris flows, areas where sheet wash erosion prevails and scars located in the taluses flanking the main ravine. Fieldwork and the first results obtained on sediment transport at the outlet of the catchment suggest that the sediment contributing area, representing less than 1 percent of the basin, is mostly the channel itself and its taluses.

1. Introduction

Loma de Arnás is a small experimental catchment (250 ha in surface) in the Borau Valley, Central Spanish Pyrenees. It was completely cultivated until 30 years ago, both on sunny and shady slopes. Since then, plant colonization has resulted in a complex mosaic of vegetation in which grazing meadows alternate with different shrub communities. As in many other disturbed environments, one of the most important geomorphic problems is to identify sediment sources in order to manage the basin and to reclaim the areas of worst deterioration. The results should contribute to an explanation of the hydrologic and geomorphic behaviour of the catchment as well as to an interpretation of the characteristics of the sediments carried away through the outlet of the catchment. This paper seeks to identify the most important sediment sources in an intensely disturbed environment.

2. The study area

Loma de Arnás experimental catchment is located in the Borau Valley, in the Eocene flysch of the Central Spanish Pyrenees (Fig. 1). It is oriented from northwest to southeast, showing a clear contrast between sunny and shady exposures. The layers dip towards the north and the relief is mainly structural, with an abrupt sunny aspect and a smooth shady one. The highest altitude is 1347 m and the lowest, 900 m.

Climate is submediterranean with some oceanic influences. Average annual precipitation is around 900 mm at the mouth of the ravine, falling mainly between November and May.

The catchment has been completely farmed in the past with sloping fields (no bench terraces). At present almost all of the territory has been abandoned, and the old fields are subject to different stages of plant colonization (Lasanta,1989). Extensive grazing with sheep flocks is the only human use of the catchment.

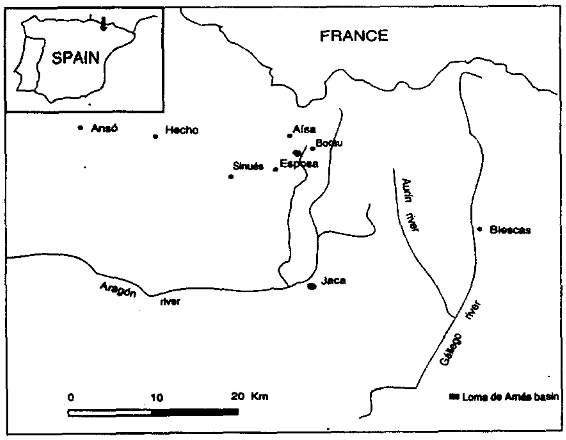

Fig.1. Location of the study area

3. Methods

The catchment is equipped at the outlet with a gauging station consisting of a pressure transducer and a rain gauge. Sediment transport is monitored by means of a turbidimeter and an automatic water sampler for suspended and dissolved solids concentration, and a trap for bed load, with a trapping capacity of 2,000 kg. A geomorphological map has been elaborated using aerial photographs and, above all, field work, mapping the possible sources of sediments and the saturated areas.

Correspondence to: J. M. García-Ruiz

4. Results

In this paper some of the first results are presented in order to identify the main sediment sources and to establish the relative importance of different types of materials transported during individual storm events.

The geomorphological map (Fig.2) shows two types of geomorphic processes. Firstly, processes related to large mass movements, belonging to past conditions, mainly before human settlement, since cultivated fields are well adapted to the shape of tongues and scars. Very probably they have been subject to small movements in recent centuries -as some minor scars prove- but, in general, they can be considered as fossil, non functional geoforms (García-Ruiz & Puigdefábregas, 1984).

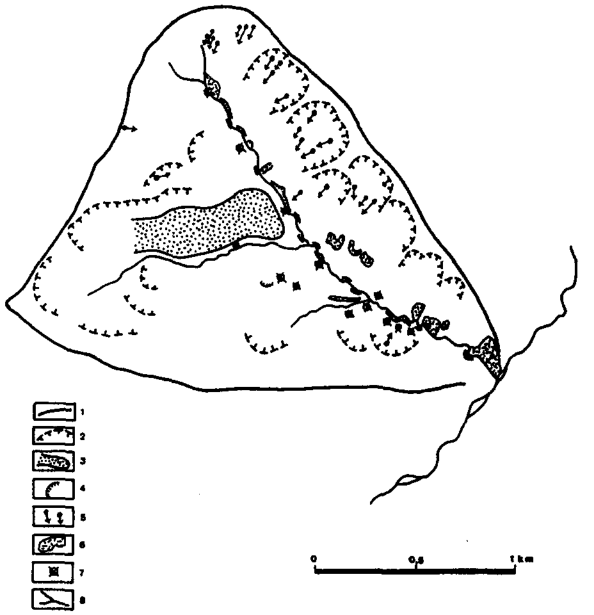

Fig. 2. Geomorphic map of the Loma de Arnás catchment. 1: Main divide; 2: Old scars of mass movement; 3: Tongues of mass movement; 4: Active scars; 5: Debris flows; 6: Sheet wash erosion areas; 7: Saturated areas and springs; 8: Drainage network.

Secondly, other geomorphic processes are very active, although they occupy very limited areas in the catchment. Three types of processes and geoforms stand out:

- Small debris flows with a scar and short tongue. These are very frequent on the sunny aspect, relatively close to the divides and more abundant on concave than on convex hillslopes. They do not connect with the fluvial network, so they hardly contribute to the sediment load of the stream.

- Areas where severe sheet wash erosion prevails. They are mainly located close to the valley bottom, on the sunny aspect, where plant colonization is more sparse than on the shady one. They are characterized by a very high stoniness of the soil surface and even by the formation of small, non concentrated rills which only exceptionally reach the main channels (Ruiz-Flano *et al.*, 1992). Frequently the sheet wash erosion areas are separated from the channels by old fields located in the valley bottom, which do not show evidence of recent sediments carried down from the hillslopes.

- Scars located in the taluses flanking the main ravine. From head to mouth, the Arnás ravine incises several metres in the flysch, resulting in an almost continuous erosion talus, with live scars directly connected with the channel. These scars lack plant cover and behave as areas of small movements (slumps) which fall into the channel, most of the time encouraged by the undermining action of the channel itself.

The conclusion is that the sunny aspect is geomorphologically more active than the shady one, where only evidence of old deep mass movements has been detected, with no supply of important volumes of bed load and suspended sediments toward the main channel. On the sunny aspect, with a steeper slope, debris flows and severe sheet wash erosion affect several parts, some of them very close to the river channel. The river itself runs entrenched between very steep taluses and seems to be the most important sediment source in the whole catchment.

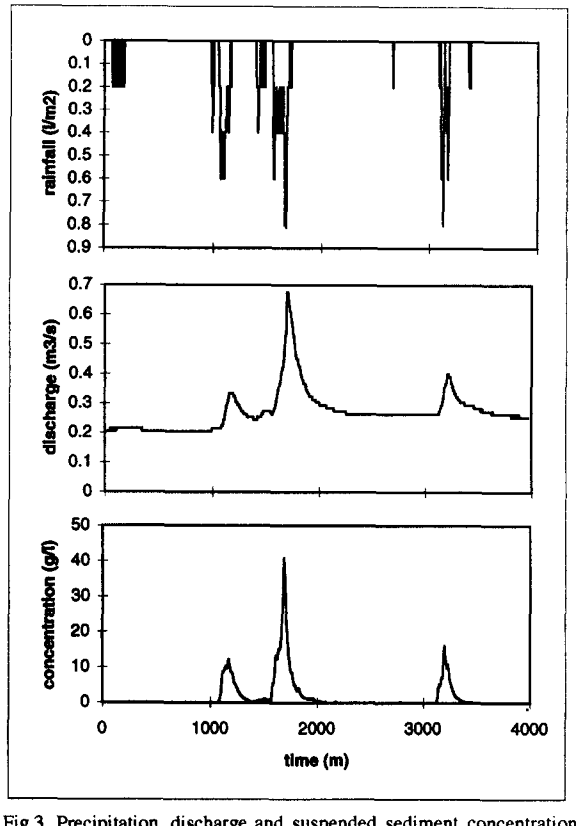

Fig.3. Precipitation, discharge and suspended sediment concentration during a short rainfall period.

Nevertheless, it is important to take into account that debris flows are not well connected to the drainage network and are unable to supply sediments -especially coarse sediments- to the ravine. Likewise, sheet wash erosion areas can supply relatively important volumes of suspended sediment and solutes, but not gravels or blocks, since abandoned meadows located in the valley bottom between the eroded areas and the river channel do not have coarse sediments after 30 years of abandonment. In fact, in the same environmental context, Ruiz-Flaño & García-Ruiz (1990) demonstrated that during rainstorms of different intensity, coarse sediments represent between 0.5 and 5 percent of the total sediments transported from sheet wash erosion.

According to the geomorphological map, the extent of the sediment contributing area -including debris flows, severe sheet wash erosion areas and scars flanking the main ravine- only represent 1 percent of the catchment.

Table 1. Discharge and sediment transport during some rainfall events

	Event A	Event B	Event C	Total
TR (l.)	3,120,000	38,480,000	17,160,000	58,760,000
TD (l.)	143,061	2,866,895	745,464	3,755,420
TSST (kg)	33.9	1,060.3	31.3	1,125.47
MRI (l/m2)	0.6	0.8	0.8	
MD (m3/s)	0.344	0.675	0.401	
MSSC (g/l)	12.1	40.8	16.2	
RC (%)	4.86	7.45	4.34	6.39
TPR (m)*	115	270	40	
TPD (m)*	195	305	130	
TPC (m)*	190	258	105	

TR: Total rainfall; TD: Total discharge; TSST: Total susp. sed. transp.; MRI: Max. rainfall intensity; MD: Max. discharge; MSSC: Max. susp. sed. concent.; RC: Runoff coefficient; TPR: Time to peak rainfall; TPD: Time to peak dischar.; TPC: Time to peak concentr.
* Time from rainfall initiaton

Fig. 3 shows the evolution of rainfall, discharge and suspended sediment concentration during a short rainstorm period of January, 1996, a month with very high precipitation. A close relation between the three parameters can be observed, with an important peak of discharge and suspended sediment concentration during the second flood (40 $g.l^{-1}$). Discharge shows a flashy response to rainfall, and suspended sediment transport reacts somewhat earlier than the discharge, a behaviour that can be considered as normal.

Table 1 summarizes the most important features of the three studied events. Discharge during peakflows ranges between 0.334 and 0.675 m^3s^{-1} and the runoff coefficient (here considered as immediate storm runoff) represents around 6 percent during individual storms. Suspended sediment transport reaches a total of 1125 kilograms, with the highest values during event B. During the same period, bed load amounted to around 5,000 kilograms. A first evaluation of solutes (with a concentration of around 250 $mg.l^{-1}$) allows us to estimate a total loss from the catchment of 930 kilograms.

5. Discussion and conclusions

During the period of maximum demographic pressure, the Loma de Arnás catchment was very active from a geomorphological point of view. In fact, many fields -especially on the sunny slopes - show a very high stoniness on the soil surface, proof of intense erosion processes carrying away fine particles but not stones. Other studies show that shifting agriculture and the alternating of cereal crops and fallow land yielded much sediment, being to a large extent the cause of landscape degradation (García-Ruiz *et al.*, 1995 and 1996). At present, farming activity has been abandoned and the geomorphic activity seems to be more restricted. This is why the area contributing the sediment load of the main ravine is so small (around 1 percent of the catchment).

The geomorphological map suggests that the most important sediment sources are the bare taluses close to the channel and the channel itself, where large volumes of coarse sediments are stored, while the rest of the basin behaves quite moderately as a consequence of plant colonization after farmland abandonment. The first results on sediment transport confirm the importance of the channel and neighbouring areas in the sediment budget of the Loma de Arnás catchment. Gravels and blocks represent a great proportion of the sediment load, but they do not come from debris flows or from the severe sheet wash areas, thus the channel becomes the most important sediment source.

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