DISCHARGE AND GULLY EROSION IN A SMALL RANGELAND CATCHMENT

Schnabel, S.[1*], Gómez Gutiérrez, A.[1], Sanjosé Blasco, J.J.[2]

[1]Universidad de Extremadura, Grupo de Investigación GeoAmbiental (GIGA), Avda. de la Universidad, 10071 Cáceres, Spain. *schnabel@unex.es
[2]Universidad de Extremadura, Grupo de Ingeniería Geomática, Avda. de la Universidad s/n, 10071 Cáceres, Spain.

1. Introduction

Valley bottom gullies are a common feature in rangelands. Although these gullies are found in the bottom of drainage lines, information about the relationship between discharge and gullying is scarce (Crouch, 1990; Thomas et al., 2004). This may in part be due to the large temporal variation of this phenomenon making necessary monitoring of runoff and erosion for a large number of years. Since 1990 research is carried out on the development of valley bottom gullies in small wooded rangeland catchments in southwest Spain. Erosion varies strongly along the gully section with high losses related to headcut retreat (Schnabel et al., 1999). The importance of extreme events producing exceptional sediment losses has also been demonstrated (Schnabel, 1997). In the year 2000 investigation started in the Parapuños experimental basin. The present paper aims at understanding the relationship between gully erosion and catchment hydrology.

2. Study Area

The Parapuños catchment (100 ha) is located northeast of the city of Cáceres, in a peneplain developed in Precambrian schist. Openly spaced evergreen Holm oaks cover grasslands which are grazed by sheep and pigs. The gullies are commonly developed in the valley bottom of the undulated landscape, where they are incised into an alluvial fill of 1 to 2 meters thickness. These sediments are roughly composed of 23% rock fragments, 45% sand and 32% clay and silt. The bulk density is 1.6 g cm^{-3}. Soils at the hillslopes are shallow sandy and silty loams with low organic matter content. Climate is Mediterranean with a pronounced dry season in summer and high rainfall variability (Schnabel, 1997). The gully is located in the lower part of the catchment. It is a second order channel with a short tributary gully joining the main branch at a distance of 174 m from the basin outlet. Table 1 shows the dimensions of the three gully sections. The tributary is a typical discontinuous gully with 2 active headcuts close to the junction. The main gully has a headcut in the upper part.

3. Methods

Gully monitoring is carried out by repeated measurements of 28 topographic cross sections using a laser total station, with a frequency of 6 months, and further measurements if there are exceptional rainfall events. Subsequent profiles are superposed and the area of erosion or deposition calculated. These two-dimensional values of erosion or deposition are used to estimate the volume of sediment gain or loss between two neighbouring cross sections (mean of two profiles multiplied by the distance between them). The total amount of net erosion or accumulation is determined by summing the volumes of the channel sections. Discharge is determined at the outlet of the basin (compound weir) and rainfall is registered with 6 tipping bucket devices. Data are registered with a resolution of 5 minutes. Table 2 shows the dates of measurement, the corresponding periods covered, together with their total amount of rainfall. The analysis is carried out on the basis of periods, i.e. the time between each field survey. The total net erosion or deposition is related with the discharge characteristics of the corresponding period.

Table 1. Dimensions of the gully sections and the total of erosion (negative values) and deposition.

	Length (m)	Catchment (ha)	Erosion, deposition (m^3)
Main branch, lower section	174	4.2	2.81
Main branch, upper section	630	49.9	-9.99
Tributary	133	45.4	-7.26

Table 2. Dates and periods of monitoring and corresponding amounts of rainfall and net erosion (negative values) or deposition of the complete gully system.

Measurement	Period	Rainfall season	Rainfall (mm)	Erosion, deposition (m^3)
December 2001				
July 2002	P1	Spring 02	247.5	-1.49
January 2003	P2	Autumn 02	410.5	-18.18
June 2003	P3	Spring 03	168.3	9.42
January 2004	P4	Autumn 04	296.2	-15.16
July 2004	P5	Spring 04	212.3	-5.02
January 2005	P6	Autumn 05	259.1	1.46
July 2005	P7	Spring 05	81.4	11.07
December 2005	P8	Autumn 05	212.3	0.74
June 2006	P9	Spring 06	208.8	2.72

4. Results and conclusions

Total net erosion of the complete gully during the 9 periods was 14.44 m^3. However, gullying varied between 18.18 m^3 of sediment loss (P2) and 11.07 m^3 of deposition (P7) (table 2). Besides the maximum erosion observed in P2, losses were also high during P4. Both were produced by discharge events registered during autumn and early winter (2003 and 2004). Considering the total amount, the lower

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branch showed net deposition and the upper branch and the tributary registered net erosion (table 1). More insight can be gained observing the losses and gains of the different channel sections, illustrated in figure 1. In the upper section of the main branch sediment losses took mainly place during the autumn periods (note that Autumn refers to the period which includes the autumn and early winter rains, and Spring includes late winter and spring). Deposition in this section was only observed during the spring periods. No seasonal tendency can be observed in the lower section of the main channel and the tributary. Table 3 presents the main characteristics of the discharge events for each period, including the total amount of runoff, the maximum peak discharge, the number of times total event discharge exceeded 1000 m^3 and the number of times maximum peak discharge exceeded 100 l s^{-1}. No relationship could be found between discharge and erosion for the tributary whereas for the upper branch the data indicate a relation between water flow and erosion (fig. 2).

Table 3. Discharge characteristics during the study periods (Qmax - maximum peak discharge, Q>1000 – number of times the total event discharge exceeded 1000 m^3, Qmax>100 – number of times the peak discharge exceeded 100 l s^{-1}).

Period	Discharge (m^3)	Qmax (l s^{-1})	Q>1000 m^3 (n)	Qmax>100 l s^{-1} (n)
P1 Spring	3436.6	457.8	1	2
P2 Autumn	58164.8	454.3	11	8
P3 Spring	15355.0	302.7	4	4
P4 Autumn	22556.6	1157.9	6	5
P5 Spring	16035.6	325.1	4	4
P6 Autumn	26437.8	1115.0	6	5
P7 Spring	12.8	2.9	0	0
P8 Autumn	16875.1	1586.7	2	2
P9 Spring	8073.1	273.4	1	2

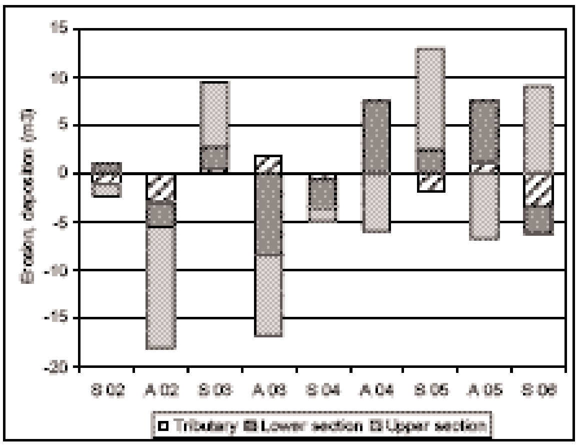

Fig. 1. Total erosion and deposition of the different gully sections for each study period (S – spring, A – autumn).

Although data suggest a positive relation between discharge and gullying, no simple relationship exists. The main upper reach of the channel showed a clear seasonality, with higher losses during the autumn and early winter, presumably related with the higher erosive capacity of the runoff events registered during these periods. In addition, sediment availability is presumably also higher in autumn. The erratic evolution of the tributary, however, indicates that the erosion processes are more complex. The higher losses during the spring periods indicate the importance of soil moisture content, reducing the cohesion of the sediments. As a consequence, bank failures are observed at the wall of headcuts and also in other places along the gully banks.

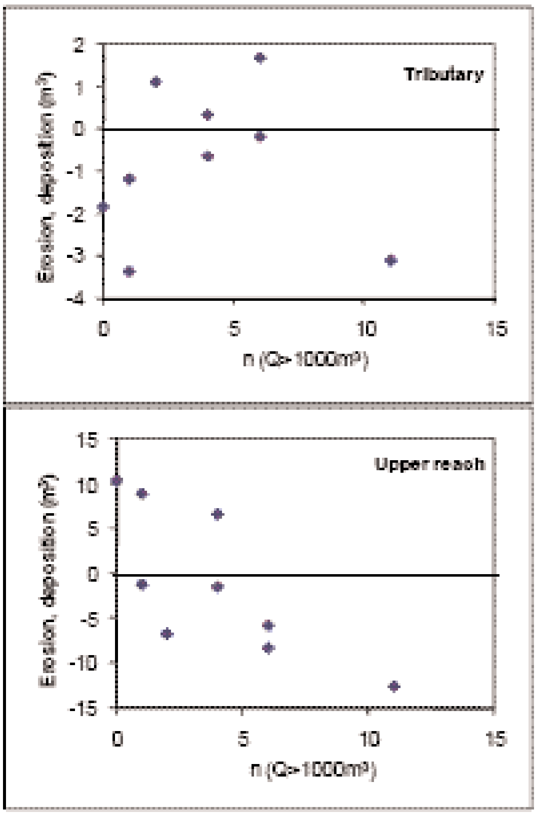

Fig. 2. Relationship between discharge and gully erosion for the upper reach of the main channel and the tributary (explanation see text).

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References

Ceballos, A. & Schnabel, S. 1998. Hydrological behaviour of a small catchment in the dehesa land use system (Extremadura, SW Spain). *Journal of Hydrology*, 210, 146-160.

Crouch, R.J. 1990. Rates and mechanisms of discontinuous gully erosion in a red-brown earth catchment, New South Wales, Australia. *Earth Surface Processes and Landforms*, 15: 277-282.

Schnabel, S. 1997. *Soil erosion and runoff production in a small watershed under silvo-pastoral land use (dehesas) in Extremadura, Spain*. Geoforma Ediciones, Logroño.

Schnabel, S., Gómez Amelia, D. y Ceballos Barbancho, A. 1999. Extreme events and gully erosion. *Proceedings of the International Seminar on Land Degradation and Desertification, International Geographical Union*, Lisbon 1988, 17-26.

Thomas, J.T., Iverson, N.R., Burkart, M.R. and Kramer, L.A. 2004. Long term growth of a valley-bottom gully, western Iowa. *Earth Surface Processes and Landforms*, 29, 995-1009.