

Grazing and soil erosion in dehesas of SW Spain

S. Schnabel, A. Gómez Gutiérrez, J.F. Lavado Contador

Grupo de Investigación GeoAmbiental, Universidad de Extremadura, Avda. de la Universidad,s/n,
10071 Cáceres (Spain). E-mail: schnabel@unex.es

ABSTRACT

Water erosion and its relation to livestock grazing in semi-arid to dry subhumid Mediterranean rangelands with a disperse tree cover is analyzed, based on a variety of studies carried out since 1990 in Extremadura, Spain. The dominant factors of sheetwash are rainfall intensity and soil surface cover, the latter being controlled by rainfall amounts and livestock density. The discontinuous valley bottom gullies present a complex relationship with catchment hydrology. Giving the high temporal variability of sediment losses, the influence of livestock on gully erosion is difficult to determine with short-term studies. Analysis of aerial photographs (1945–2006) of the Parapuños study catchment point to an enhanced gully activity during the last decade as a consequence of increased livestock numbers.

Key words: sheetwash, gully erosion, vegetation cover, grazing, dehesas.

INTRODUCTION

In the semi-arid and subhumid parts of the south-western Iberian Peninsula open evergreen woodlands dominated by *Quercus* species are widespread (*dehesa*). They are composed of grasslands with a varying degree of tree cover, ranging from treeless to more than 80 individuals per hectare. In some areas shrubs form a third component of the vegetation. Dehesas are subject to a complex exploitation system with agro-silvopastoral land use. The present paper reviews results obtained in a variety of studies carried out since 1990 in Extremadura, emphasizing on the relationship between water erosion and grazing of domestic animals. Sheetwash (interrill erosion) is the dominant process on hillslopes, whereas gully erosion is mainly observed in valley bottoms with an alluvial sediment fill. Rill erosion occurs where the land has been ploughed for cultivation or shrub cleaning. Climate is Mediterranean with mean annual temperatures of about 16°C and average annual precipitation ranging from 450 to 800 mm. Rainfall variation is high, both seasonally and interannually. Soils are frequently shallow, have a sandy silt texture and low organic matter content. They commonly have low pH values and very low phosphorus content. The landscape is dominated by old erosion surfaces giving rise to undulating relief, interrupted by small mountain ridges. The land is grazed by sheep, cattle, pigs and goats and the trees are pruned for firewood production.

METHODS

Research was carried out at different spatial scales. Sheetwash and overland flow were investigated along hillslopes and in microplots, whereas gully erosion and runoff production were monitored in small experimental catchments. Between 1990 and 1997 work was carried out in the Guadalperalón study catchment (35,4 ha) and from the year 2000 onwards research is conducted in the Parapuños basin (99.5 ha). Rainfall data with a time resolution of 5 minutes was registered in both study areas. Soil losses due to sheetwash were determined using open plots with 0.5 m wide sediment troughs from 1990 until 1996

(Schnabel, 1997). During two hydrological years a detailed survey of the soil surface cover, including herbaceous cover and some small shrubs, was carried out using the pin-hit method with a metal frame (one square metre with 100 sample points) in order to study its temporal and spatial variation. For the rest of the study period photographs of the plots are available to document vegetation cover change.

Gully monitoring is based on repeated measurements of topographic cross sections. In Guadalperalón (1990-1997) this was done by means of measuring tapes and in Parapuños (2001-) a laser total station was used (Schnabel, 1997; Schnabel et al., 2007). In both catchments discharge was determined at the outlet of the basin at 5-minute intervals. In order to determine the relationship between gully erosion and land use/vegetation cover for a longer time period (60 years), series of aerial photographs were analyzed (Gómez Gutiérrez et al., in press).

The variations of the physical factors as well as of land use and management requires investigating areas apart from the study catchments. Therefore, in a selection of farms, representing the most important types of rangelands in Extremadura, soil degradation was evaluated. Depending on the erosion process, different features, easily recognizable in the field, were considered. For sheetwash, for example, root exposure and tree mounts were considered. Gullies and headcuts were mapped and ranked by signs of activity.

RESULTS AND DISCUSSION

Regarding interrill erosion, a total of 133 events were sampled with rainfall amounts in excess of 5.2 mm, the threshold for runoff generation at hillslopes. A proportion of 10% of these events was responsible of nearly 76% of the total amount of soil loss, and only two events caused 50.7% of the total loss. Stocking rates were constant from 1990 until 1993 with 1.1 sheep per hectare, but suffered changes from 1994 onwards. Maximum stocking density was reached in 1997, when also cattle grazed the farm, resulting in 2.6 sheep and 0.3 cattle per hectare.

Soil losses were mainly related with the characteristics of the rainfall events and the degree of soil cover. Fig. 1 illustrates the relationship between vegetation cover and soil loss for different rainfall intensities. With a vegetation covering more than 60% of the ground surface, even exceptionally high intensity storms ($1-30 > 40 \text{ mm}\cdot\text{h}^{-1}$) produce soil losses below 0.3 t ha^{-1} . On the other hand, with less than 20% of ground cover moderately intense storms, which are more frequent, may produce significant losses. Changes in soil cover are influenced by seasonal and interannual variations of precipitation, but also by livestock density. In the study catchment a great reduction of surface cover was observed with a low to moderate stocking density during a prolonged dry period (drought), but also during a period when rainfall was abundant being the consequence of an important increase of livestock numbers.

Table 1 presents a comparison of soil losses produced by different erosion processes. For comparison, the whole dataset of sheetwash events was separated into two groups, one representing high ground cover (VEG) and the second with a reduced surface cover (DEG) As mentioned above, the reduction of vegetation cover was produced by a drought during the first part of the study period and by an increase of livestock density at the end of the monitoring period. As a result mean erosion rates varied between 0.12 and $1.34 \text{ t ha}^{-1}\text{a}^{-1}$.

Rill erosion is not a frequent phenomenon in rangelands, limited mainly to areas which are ploughed for cultivation or shrub cleaning. However, very high erosion may occur when tillage practices immediately precede exceptional rainstorms. Soil losses produced by rill erosion of approximately 100 t ha^{-1} were registered as a consequence of an exceptional

rainfall event with a recurrence interval of 200 years in a field which had been ploughed recently (Schnabel et al., 2001).

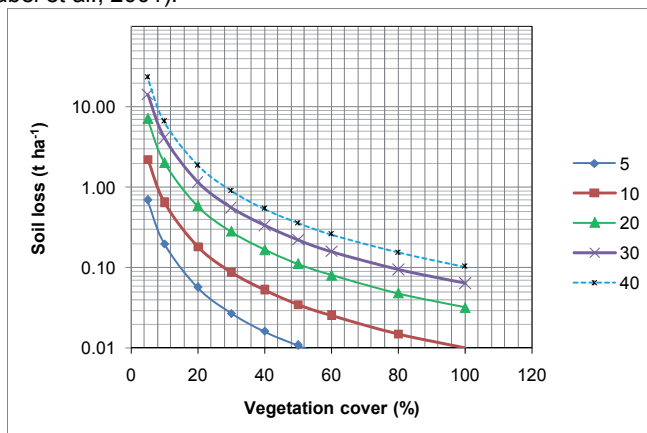


Figure 1. Relationship between soil loss and vegetation cover for different 30-minute maximum intensities (see text for explanation). Based on mean of 12 erosion plots and 88 events. Variance accounted for is 0.901, $p=0.00000$.

In Extremadura, gullies represent only a small fraction of the total land and are mainly located in first or second order valley bottoms with an alluvial sediment fill. Individual gullies may present high soil losses, constitute an obstacle for traffic and enhance drainage of subsurface flow. They are more frequent on schist and greywacke than on granites, the dominant rock types in southwest Spain. In Guadalperalón mean gully erosion amounted to $39.05 \text{ m}^3 \text{ a}^{-1}$, varying between $+4.92$ and -219.20 m^3 (see table 1 for values in tons per hectare). In Parapuños mean gully erosion was lower, with $4.18 \text{ m}^3 \text{ a}^{-1}$. Sediment losses are related with high amounts of overland flow generated on the slopes which are characterized by shallow soils with low infiltration capacity. However a close relationship between discharge and gully erosion does not exist. This is partly due to the complex hydrological response of the catchments. During dry antecedent moisture conditions Hortonian type overland flow dominates, whereas during humid conditions saturation excess overland flow is more important. Temporal rainfall distribution is a crucial factor in two ways. Low frequency, high magnitude events (high intensity rainstorms) generate rapid runoff response with peak discharges, of importance especially during dry soil conditions. Continuous rainfall, on the other hand, reaching amounts in excess of 250 mm, produces water saturation of the sediment fill in the valley bottom, thereby enhancing greatly runoff production. Highest sediment losses were observed under the latter condition. Of further importance are bank failures which are related with high soil moisture content.

Table 1. Comparison of soil loss rates for different erosion processes and their variations.

Sheetwash ($\text{t ha}^{-1} \text{a}^{-1}$)	Mean	0.63
	Mean periods VEG	0.12
	Mean periods DEG	1.34
Gully erosion ($\text{t ha}^{-1} \text{a}^{-1}$)	Mean Guadalperalón (1990-1997)	1.55
	Guadalperalón Sep 1990 - Dic 1995	0.12
	Guadalperalón Sep 1996 - Dic 1997	5.57
	Mean Parapuños (dic 2001- jun 2007)	0.07
Rill erosion (t ha^{-1})	on ploughed slope, extreme event (4/11/97)	100.50

In Guadalperalón high sediment losses coincided with above average annual rainfall amounts, an extreme rainstorm and also with a strong increase of livestock numbers. It is hence impossible to determine the influence of grazing animals on gully erosion with this database. In Parapuños no significant changes in animal number took place during the monitoring period (2000-2007). However, a study of the same gully system for the period from 1947 until 2002 has evidenced a relationship between land use/management and gully activity (Gómez Gutiérrez et al., in press). An increase of animal numbers during the last decade is reflected by an increase of gully activity and the appearance of lateral bank headcuts. The latter are mainly related with animal trampling in the vicinity and along the margins of the gully.

CONCLUSIONS

Soil erosion varies strongly with regard to the natural factors, but also with respect to land use and management. Sheetwash is the dominant process on hillslopes, with a mean annual soil loss of 0.63 t ha^{-1} . However rainfall variation and land management, especially livestock density, produce changes in soil cover. With low to moderate livestock densities and during prolonged periods with low rainfall, the vegetation cover may be strongly reduced, provoking high soil losses, whereas during normal or humid periods interrill erosion is low. Excessive stocking rates may exacerbate sheetwash, producing severe soil degradation, regardless of the antecedent rainfall conditions. Rill erosion is not a frequent phenomenon in dehesas, limited mainly to areas which are ploughed for cultivation or shrub cleaning. Very high erosion may occur when tillage practices immediately precede exceptional rainstorms. Gullies are more frequent on schist and greywacke than on granites, the dominant rock types in SW Spain. Gully erosion is related with catchment hydrology (rainfall and runoff). However, studying a longer time period has revealed the influence of cultivation and livestock grazing on gully activity. Increased animal numbers increment gully activity, especially through trampling close to the margins of the gully.

ACKNOWLEDGEMENTS

This investigation was made possible through funding offered by the Spanish Ministry of Science and Technology (AMB92-0580, AMB95-0986-C02-02, HID98-1056-C02-02, CGL2004 -04919-C02-02), the Government of Extremadura and Fondos FEDER.

REFERENCES

- ❖ Schnabel, S. 1997. *Soil Erosion and Runoff Production in a Small Watershed under Silvo-pastoral Landuse (Dehesas) in Extremadura, Spain*. Geoforma Ediciones, Logroño, Spain.
- ❖ Schnabel, S., Gómez Gutiérrez, A., Sanjosé Blasco, J.J. 2007. Discharge and gully erosion in a small rangeland catchment. In Casali, J. and R. Giménez (Eds.) *Progress in gully erosion research*. Universidad Pública de Navarra, Spain, pp. 116-117.
- ❖ Gómez Gutiérrez, Á., Schnabel, S., Lavado Contador, J.F. (in press). Gully erosion, land use and topographical thresholds during the last 60 years in a small rangeland catchment in SW Spain. *Land Degradation and Development*.
- ❖ Schnabel, S., González, F., Murillo, M., Moreno, V. 2001. Different techniques of pasture improvement and soil erosion in a wooded rangeland in SW Spain. In Conacher, A. (Ed.), *Land Degradation*. Kluwer Academic Publishers, Dordrecht, pp. 241-257.