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Erosion Processes and Rates on Road-Sides of Hill-Roads (Iberian System, La Rioja, Spain)

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ABSTRACT

The geomorphological evolution of hill-roads has been studied in the western Iberian System (La Rioja, Spain). The relative importance of erosion processes was determined in 118 sections of hill-roads. Using erosion pins, yearly and seasonal erosion rates have been estimated.

KEY WORDS

Hill-roads; erosion; erosion pins; Iberian System

INTRODUCTION

Road building in mountain areas has a notable geomorphological impact. Several factors (breaking of the hillslope profile, lack of vegetation protection on road-sides and alteration of hillslope hydrogeomorphological functioning) suggest an increase of erosion processes (both variety and intensity) and in sediment yield, particularly in those hill-roads that were built with low budgets, carry heavy traffic and do not include even minimal conservation techniques. In the mountains of La Rioja, hill-road building has been increasing in recent years to connect villages, to facilitate livestock access to pastures and to manage afforestation.

In this paper, different models of geomorphological evolution of road-cuts are explained and erosion rates in those affected by overland flow are analysed. In addition seasonal evolution of these rates is evaluated. The results have been related to climatic factors.

THE STUDY AREA

This study has been carried out in the western Iberian System, in the Sierra de la Demanda and Cameros. Seven hill-roads, representing different geoecological environments, have been chosen. The lithological and climatic characteristics of the studied areas have been summarized in Table 1. Experimental plots were installed at site P5 (Fig. 1, Table 1).

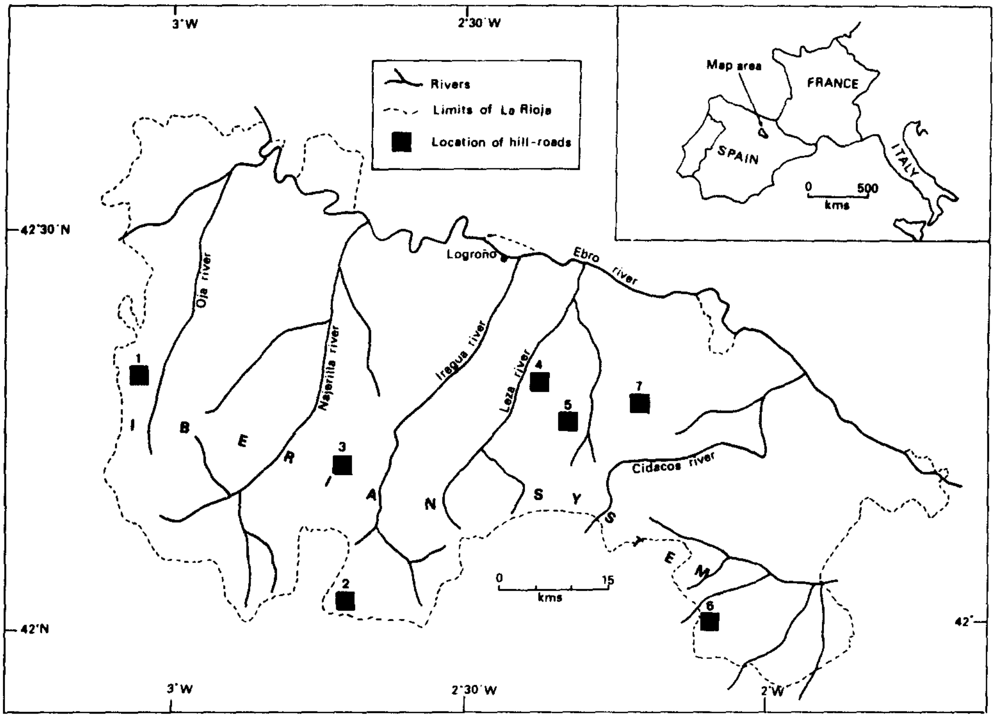


Fig. 1. Location of study area: 1. Valgañón-Ezcaray hill-road; 2. Hoyos de Iregua hill-road; 3. Nieva-Gamellones hill-road; 4. Zenzano hill-road; 5. Santa Marina hill-road; 6. Sierra de Alcarama hill-road; 7. Ocón-Arnedillo hill-road.

METHODS

On seven hill roads 118 sampling sections of 20 m were set up: 59 in road-cuts (T1), resulting from hillslope undercutting, and the other 59 in the first few metres downslope from the road, where there has been accumulation of debris excavated during road building (T2). The surface occupied by severe sheet wash erosion, incisions and slides was measured. In this way their relative significance could be calculated. The data were analysed using a range of statistical methods.

Table 1. Lithologic and climatic characteristics of the studied hill-roads

Hill-roads	Massifs	Lithology	T°C	P (mm)
P1	S. Demanda	shales	9.8	947
P2	S. Cebollera	quartzsandstones	-	800
P3	Cameros Nuevo	limestones	8.5	636
P4	Cameros Viejo	gypsum/limes.	11.4	606
P5	Cameros Viejo	quartzsandstones	11.4	606
P6	S. Alcarama	clays	12.5	500
P7	Cabimonteros	conglomerates	12.5	403

P1 (Valgañón-Ezcaray), P2 (Hoyos de Iregua), P3 (Nieva-Gamellones), P4 (Zenzano), P5 (Santa Marina), P6 (Sierra de Alcarama), P7 (Ocón-Arnedillo)

Erosion rates have been estimated using erosion pins (Haigh, 1977; Sancho *et al.*, 1991). An area of rills and interrills on T1 and two areas affected by sheet wash erosion on T2 were selected. In the first case, one row of pins was nailed on the rill (TSR) and the interrill (TSI), following the road-cut gradient. In the second case, pins were placed covering a surface of 12 m^2 (20 pins spaced at 1 m) and an other of 6 m^2 (12 pins spaced at 1 m). The data were collected monthly during two years: 1992-1993 (Table 2).

Table 2. Characteristics of the studied plots

	TI1	TI2	TSR	TSI
Years	1992	1992-93	1992-93	1992-93
Surface (m^2)	12	6	-	-
Altitude (m)	790	915	1020	1020
Exposure	E	W	E	E
Road cut angle (º)	36	35	39	45
R. cut length (m)	14.10	4	5.70	5.20
Plant cover	-	-	-	-

RESULTS

The significance of geomorphological microenvironments (slides, severe sheet wash erosion and incisions) in hill-roads is variable. Therefore in an attempt to simplify the large number of cases, a cluster analysis has been used in order to identify similar groups of geomorphological evolution. Three models have been obtained with the following characteristics (Table 3):

Model I reveals a moderate erosion on T1 as well as on T2. Percentages of erosion caused by slides and severe sheet wash are 14.4% and 3.1% respectively in the former, and 4.2% and 8.4% on the latter. The most important processes, then, are slides on the road-cut (T1). The cases conforming to this model are located between 1200 and 1250 m, on hillsides covered with forest and on hill-roads where plant recolonization of road-cut has been important. Model II is characterized by the predominance of severe sheet wash erosion on T2 (72.6%). The surface occupied by slides on T1, 23.1%, is also significant.

Table 3. Erosion models on hill-roads and predominant erosion processes (SL=slides; SSWE=severe sheet wash erosion)

	T1		T2	
	SL	SSWE	SL	SSWE
Model I	14.4 %	3.1 %	4.2 %	8.4 %
Model II	23.1 %	10.1 %	5.2 %	72.6 %
Model III	12.9 %	65.8 %	2.3 %	36.6 %

These models are related to the functioning of subsurface flow that, on reaching the road-cut (T1), emerges at the surface, wetting the road-cut itself. These saturated road-cuts, with a gentle angle, are mainly eroded by slides. The material of mass movement remains partially stored at the road-cut foot, intercepting the drainage channels. In some cases, the water that saturates the cut of the hill-road (T1) emerges from the soil and runs downslope as overland flow. In others, this cut intercepts the flow circulation through small pipes. Both overland flow and pipes can activate severe sheet wash erosion and incisions on T2, if there is no control to prevent them (Arnáez and Larrea, 1994).

The development of severe sheet wash erosion on T2 occurs with different intensities and importance. In model I this process has a limited representation (8.4 %), whereas in model II it erodes 72.6 % of T2. This variability in the action of severe sheet wash erosion is linked to two controls: percentage of plant cover and dimensions of T2 (Arnáez and Larrea, 1994).

In model III, severe sheet wash erosion is the more dominant process on T1 (65.8 %) and T2 (36.6 %). In this group, overland flow, coming from the top of hillslopes, moves over hill-roads built on impermeable materials. This flow activates severe sheet wash erosion and incisions on road-cuts (T1) with scarce vegetal cover, reaching the road surfaces and T2 quite rapidly.

Erosion pins have been installed on the hill-road of Santa Marina that has the characteristics of model III. In 1992 an average ground lowering of 9.13 mm in the rill (TSR) and 8.40 mm in the interrill (TSI) was recorded. Erosion was more moderate during the following year (1.88 mm in the rill and 4.40 mm in the interrill). On the plot TI1, affected by severe sheet wash erosion, the ground lowered 5.18 mm during 1992. On the contrary, TI2 shows deposition in 1992 (0.58 mm) and erosion in 1993 (0.08 mm). The data, then, reflect significant spatial and temporal variability in the activity of geomorphic processes (Table 4).

Table 4. Erosion (-) and accumulation (+) on Santa Marina hill-road (mm)

	TI1	TI2	TSR	TSI
1992	-5.18	+0.58	-9.13	-8.40
1993		-0.08	-1.88	-4.40
mean		+0.25	-5.50	-6.40

Figure 2 shows the evolution of erosion-sedimentation rates during the two years of sampling in the studied areas. Initially, the functioning is very similar. Two cycles can be identified that are repeated in 1992 and 1993: one, winter (with data collected in the periods April 1992 and March 1993), and the other, spring-summer (with data collected in June-September) (Larrea and Arnáez, 1994).

The first cycle suggests sedimentation. TI1, TI2, TSR and TSI show accumulation rates that are linked to weathering by freeze-thaw and particles raising by pipkrake action. The correlation coefficient between the number of frost days and average rates of erosion-accumulation is 0.86 (Fig. 3). Of the four plots, the rill shows the most important accumulation rates. Schumm (1956) suggests that rills, incised by the rainfall of summer, are filled with particles produced by frost heaving in the winter.

The second cycle of geomorphological functioning of road-cuts (spring/summer) is markedly erosive. Although the correlation coefficient is not very high (-0.55), a relationship between erosion and total amount of precipitation exists. In 1992, between April and June, 232.4 mm of rainfall were recorded (8 days with precipitation above 10 mm and 1 day above 30 mm). In these conditions the rill was lowered 13.25 mm. These high erosion rates were also detected in September (9.43 mm), with a cumulative precipitation of 188.8 mm (4 days with rainfall above 10 mm). The model is repeated again in the following year, with highest erosion rates occurring in spring and summer.

CONCLUSIONS

Several erosion processes have been detected on the road-sides of hill-roads of La Rioja Iberian System. Slides, severe sheet wash erosion and incisions operate with different intensities. Three models of geomorphological functioning of hill-roads have been detected. Model I shows a moderate erosion, with slides as the dominant process on road-cuts (T1). Model II is determined by the behaviour of slides on the road-cut (T1) and severe sheet wash erosion on T2. Model III involves the functioning of severe sheet wash erosion on T1 and T2, though its significance diminishes substantially on the latter.

Erosion and sedimentation rates on the road-sides affected by significant erosion processes (sheet wash erosion and incisions) have been evaluated. The results show a high annual and seasonal variability that is related to rainfall, freeze-thaw cycles and the action of sheet and concentrated flows. A similar variability also has been detected by authors in other study areas (Haigh, 1985).

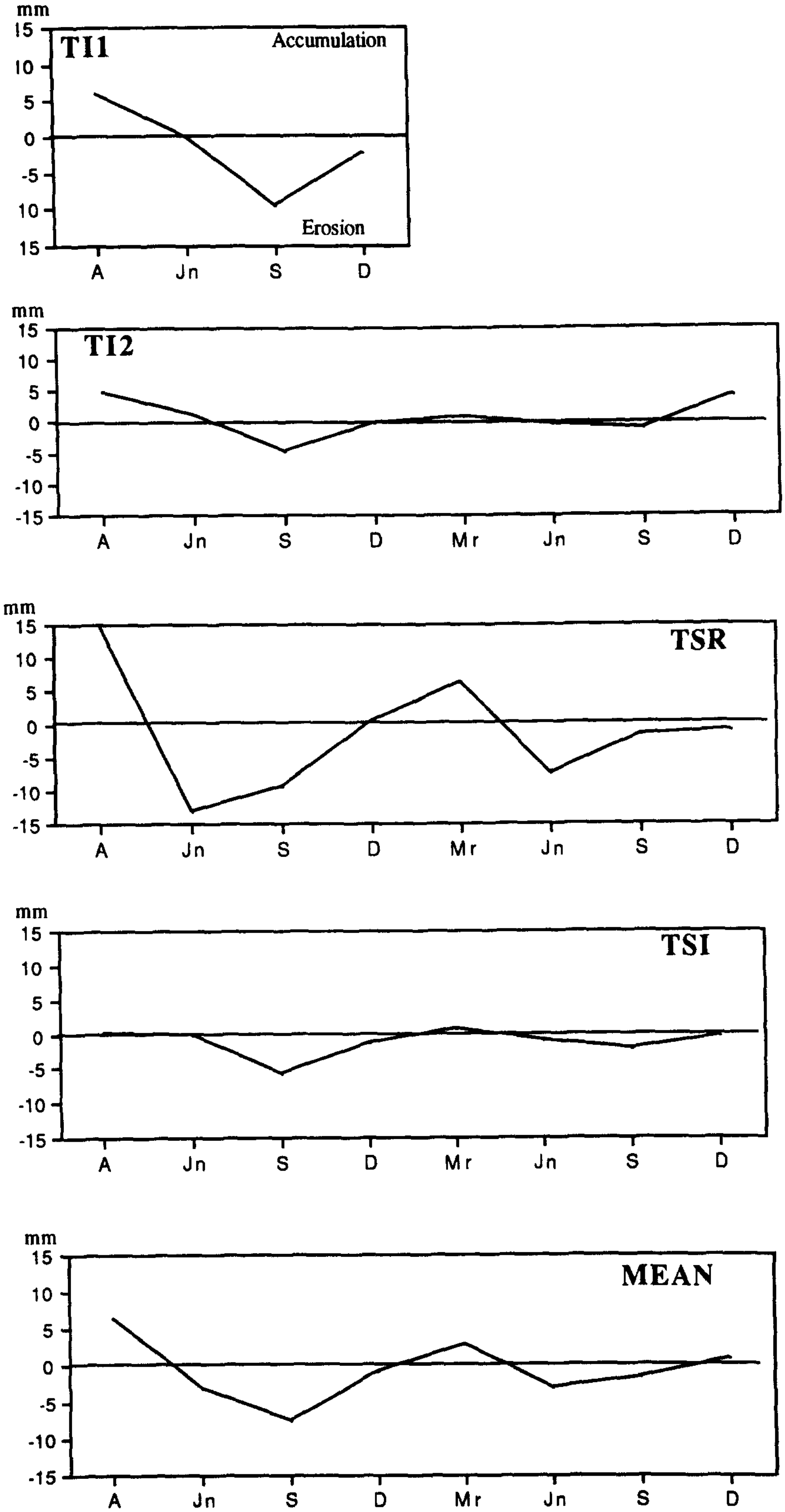
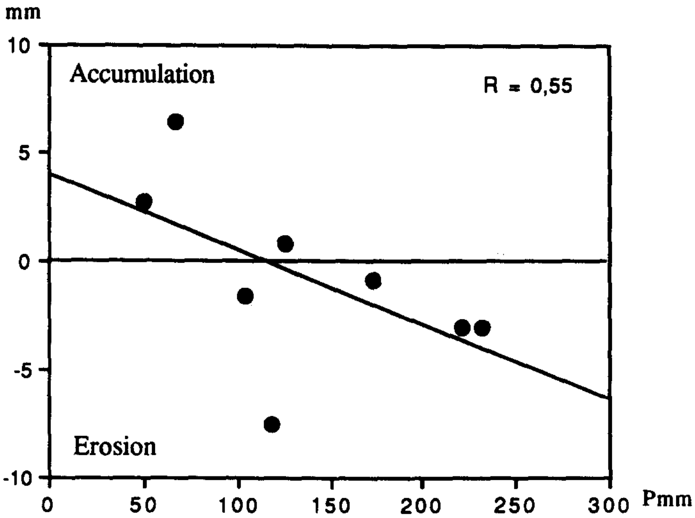


Fig. 2. Evolution of erosion and accumulation rates in road-cuts of the Santa Marina hill-road during 1992-1993



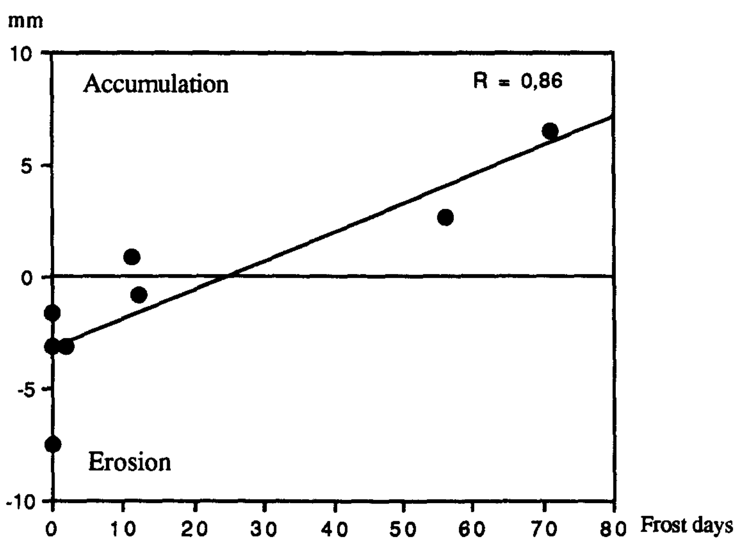


Fig. 3. a) Relationship between cumulative rainfall (mm) for each measurement period and average rates of erosion-accumulation. b) Relationship between the number of frost days and average rates of erosion-accumulation

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