Seasonal variations in rainfall-induced soil erosion from forest roads in a Mediterranean area

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Introduction

Most efforts to reduce in situ soil erosion and off-site sedimentation in Mediterranean countries have traditionally focused on the improvement of soil tillage and soil conservation techniques in agricultural areas, which show the highest soil erosion rates. However, the development of unpaved road networks (Fig. 1) during the recent decades in Mediterranean forest areas brings out the role played by roads as runoff and sediment sources, which has not been sufficiently considered.

Most of forest roads cause significant hydrological and geomorphological impacts at different scales, altering the runoff-runon patterns, the direction and properties of runoff water, and subsurface water flow. Some of these effects are caused by the removal of native vegetation from backslopes (Fig. 2), which contributes to increased soil erosion and sediment yield in areas where natural soil erosion risk is usually low.

Figure 1. Unpaved forest road in the study area.

These processes are of particular interest in forested areas, where, usually, natural erosion rates are very low. A better understanding of road-sediment production rates is needed to guide future development and erosion control efforts.

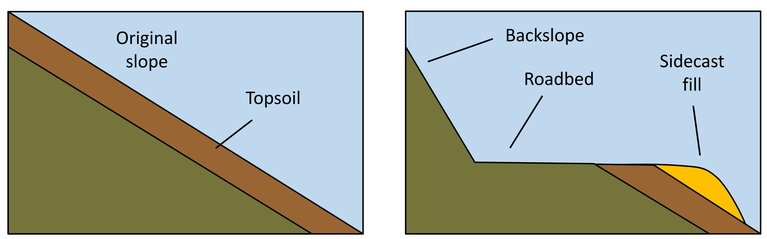

Figure 2. Cross section of an unpaved road showing the three main parts: backslope, roadbed and sidecast fill.

Simulated rainfall is a widely used method for studying soil erosion in undisturbed soil samples under laboratory conditions, but few experiments have been carried out under field conditions in Spain. Simulated rainfall experiments allow the researcher to control rainfall amount, rainfall intensity and time, so that they are suitable for the study of soil processes under precipitation episodes. As a disadvantage, data from rainfall simulations cannot be easily extrapolated to natural conditions, although they can be used for comparative purposes.

The main objective of this research is to study the seasonal variation of the intensity of rainfall-induced soil erosive processes in unpaved forest roads from the province of Huelva (SW Spain) using rainfall simulation experiments under different plant rock fragment and biological crust cover classes.

Objectives

The main objective of this research is to study the seasonal variation of the intensity of rainfall-induced soil erosive processes in unpaved forest roads from the province of Huelva (SW Spain) using rainfall simulation experiments.

Due to the local characteristics of soils in this area, the influence of plant cover, rock fragment cover and biological crusts were considered in the study.

Methods

Sixty backslopes with plant cover varying between dense shrubs and bare soil were selected. Rainfall simulations (90 mm/h during 20 minutes) were performed in winter (December 2012 – January 2013) and summer (August – September 2013) to study the effect of rainstorms at the end and beginning of the rainy season using a portable rainfall simulator (Fig. 3). Surface runoff was collected to determine runoff rates and sediment yields. Plant cover, rock fragment cover and the area covered by biological crusts were determined at each plot using image analysis techniques (Fig. 5). At each site, slope was determined with a portable clinometer (all selected plots were in the range 41-76%).

Figure 3. Portable rainfall simulator used during the experiments.

Figure 4. Bare road backslope from the study area.

Results

The hydrological behavior of hillslopes is highly modified by the backslopes of forest roads. Unpaved forest roads enhance surface erosion by acting as points where accelerated runoff flow initiates on hillslopes; in addition, backslopes are the main source of sediments on forest roads.

Table 1. Runoff rate (%) from backslopes recorded in summer and winter under different plant cover classes.

Season	Summer			Winter		
Plant cover	0-25%	25-75%	>75%	0-25%	25-75%	>75%
Mean	42.0	25.0	12.0	88.2	37.5	27.6
SD	3.8	4.1	2.8	5.3	4.2	4.8

Table 2. Sediment yield (g/L) from backslopes recorded in summer and winter under different plant cover classes.

Season	Summer			Winter		
Plant cover	0-25%	25-75%	>75%	0-25%	25-75%	>75%
Mean	9.1	5.5	2.0	22.8	11.6	4.4
SD	5.5	4.2	3.2	4.1	5.9	3.2

Table 3. Runoff rate (%) from backslopes recorded in summer and winter under different rock fragment and biological crust cover classes.

	Summer			Winter		
Rock fragment cover (%)	0-25%	25-75%	>75%	0-25%	25-75%	>75%
Mean	52.0	22.0	8.0			
SD	2.4	2.4	2.8	3.8	4.8	5.7
Biological crust cover	0-25%	25-50%	>50%	0-25%	25-50%	>50%
Mean	48.0	23.0	15.0	105.6	46.0	31.5
SD	3.4	4.7	5.2	4.4	3.4	4.0

Table 4. Sediment yield (g/L) from backslopes recorded in summer and winter under different rock fragment and biological crust cover classes.

	Summer			Winter		
Rock fragment cover (%)	0-25%	25-75%	>75%	0-25%	25-75%	>75%
Mean	12.8	7.3	1.6	28.2	11.7	3.7
SD	2.9	3.8	2.6	5.1	3.4	5.4
Biological crust cover	0-25%	25-50%	>50%	0-25%	25-50%	>50%
Mean	10.7	8.7	3.4	16.1	20.0	7.1
SD	5.1	4.8	4.1	2.5	4.0	2.6

Although soil loss was increased in winter, when soil moisture is higher, small differences were observed at vegetation cover above 75%. Plant cover above 40% considerably reduced sediment yield and runoff flow. In contrast, differences triggered between different plots with decreasing vegetation cover.

In bare areas, rock fragments and biological crusts (mosses, lichens, liverworts and fungi) caused great differences between bare areas both during summer and winter periods.

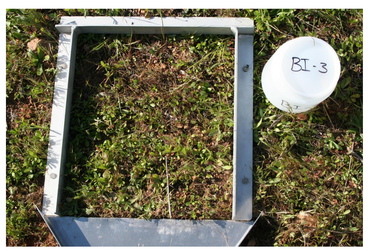

Figure 5. Picture of one of the studied plots for assessment of plant cover, rock fragment cover and biological crusts by image analysis.