Relationships between soil erosion risk, soil use and soil properties in Mediterranean areas. A comparative study of three typical sceneries

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European Geosciences Union
General Assembly 2013
Vienna | Austria | 07 – 12 April 2013
SSS9.11 Soil erosion and desertification processes in Mediterranean areas

Introduction

Generally, literature shows that the high variability of rainfall-induced soil erosion is related to climatic differences, relief, soil properties and land use. Very different runoff rates and soil loss values have been reported in Mediterranean cropped soils depending on soil management practices, but also in soils under natural vegetation types (fig. 1).

Objectives

The aim of this research is to study the relationships between soil erosion risk, soil use and soil properties in three typical Mediterranean areas from southern Spain: olive groves under conventional tillage, minimum tillage and no-till practices, and soils under natural vegetation.

Figure 1. Soil erosion processes in the study area.

Figure 2. Rainfall simulation.

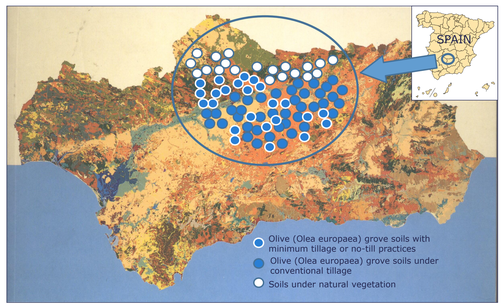

Figure 3. Study area.

Methods

Rainfall simulation experiments (fig. 2) have been carried out in order to assess the relationship between soil erosion risk, land use, soil management and soil properties in olive-cropped soils under different types of management and soils under natural vegetation type from Mediterranean areas in southern Spain (fig. 3).

Results

Runoff rate and soil erosion

Results show that mean runoff rates decrease from 35% in olive grove soils under conventional tillage to 25% in olive (*Olea europaea*) grove soils with minimum tillage or no-till practices (table 1), and slightly over 22% in soils under natural vegetation (table 2). Moreover, considering the different vegetation types, runoff rates vary in a wide range, although runoff rates from soils under holm oak (*Quercus rotundifolia*), 25.70%, and marginal olive groves, 25.31%, are not significantly different. Results from soils under natural vegetation show that the properties and nature of the organic residues play a role in runoff characteristics, as runoff rates above 50% were observed in less than 10% of the rainfall simulations performed on soils with a organic layer. In contrast, more than half of runoff rates from bare soils reached or surpassed 50%.

Quantitatively, average values for runoff water losses increase up to 2.5 times in unprotected soils. This is a key issue in the study area, where mean annual rainfall is above 600 mm.

Table 1. Mean ± standard deviation (SD) runoff rate, sediments in runoff and soil loss from olive groves under different types of management. N = 44 at each case.

	Runoff rate (%)	Sediments (g m^{-2})	Soil loss (t ha^{-1})
Conventional olive groves	35.24 ± 20.54	48.43 ± 53.39	7.95 ± 8.889
Olive groves under minimum or no-till	25.31 ± 25.22	3.77 ± 6.05	0.60 ± 0.97

Table 2. Mean and standard deviation (SD) moisture increase, runoff rate and soil loss from vegetation-covered and bare soils from areas with different vegetation types.

	N	Covered soil			Bare soil		
		Moisture (%)	Runoff rate (%)	Soil loss (g m^{-2})	Moisture (%)	Runoff rate (%)	Soil loss (g m^{-2})
Pine woodland	8	21.28 ± 10.05	17.63 ± 20.18	5.82 ± 4.30	19.84 ± 8.79	40.29 ± 20.15	46.04 ± 54.07
Holm oak forest	9	17.10 ± 5.83	25.70 ± 19.48	3.64 ± 3.23	9.97 ± 6.99	53.18 ± 25.60	46.03 ± 41.33
Shrubland	5	13.78 ± 10.41	24.00 ± 29.48	2.56 ± 1.48	11.80 ± 5.57	46.00 ± 22.69	51.52 ± 37.31
All groups	22	17.86 ± 8.71	22.38 ± 21.44	4.19 ± 3.51	13.97 ± 8.45	46.86 ± 22.74	47.28 ± 43.54

Soil properties

Correlation between soil properties and runoff rates, sediments in runoff and soil loss are shown in tables 3-5. Organic matter from soils under minimum tillage or no-till is strongly related with runoff, the amount of sediments in runoff and soil loss. In soils from olive groves, the amount of sediments in runoff was significantly related to soil pH. Moreover, for olive-cropped soils under conventional tillage, soil loss is strongly related with clayey texture, which is a main property of these soils.

Table 3. R-Spearman correlation coefficients between soil properties and runoff rate, sediments in runoff and soil loss from olive groves. (*) p ≤ 0.05.

	Runoff rate	Sediments	Soil loss
pH	0.015549	0.379669*	0.396878*
Permeability	-0.238498	-0.408408*	-0.459320*
Calcium carbonate	0.234290	0.425784*	0.395370*
Organic matter	-0.238317	-0.155083	-0.178906
Coarse sand (2-0.25 mm)	0.016710	-0.360743*	-0.344592*
Fine sand + silt (0.25-0.002 mm)	-0.027461	0.344704*	0.343710*
Clay (≤ 0.002)	0.015549	0.379669*	0.396878*

Table 4. R-Spearman correlation coefficients between soil properties and runoff rate, sediments in runoff and soil loss from olive groves under conventional tillage. (*) p ≤ 0.05.

	Runoff rate	Sediments	Soil loss
pH	-0.114548	0.176029	0.222802
Permeability	-0.144705	-0.228003	-0.312878
Calcium carbonate	0.120123	-0.082326	-0.157826
Organic matter	0.164890	0.226481	0.188629
Coarse sand (2-0.25 mm)	0.233256	-0.027915	-0.002714
Fine sand + silt (0.25-0.002 mm)	-0.144700	0.200825	0.204258
Clay (≤ 0.002)	-0.103881	-0.041800	-0.083007

Table 5. R-Spearman correlation coefficients between soil properties and runoff rate, sediments in runoff and soil loss from olive groves under minimum or no-till practices. (*) p ≤ 0.05.

	Runoff rate	Sediments	Soil loss
pH	-0.136780	0.057043	0.068272
Permeability	-0.117300	-0.150425	-0.152279
Calcium carbonate	-0.032110	0.039023	0.058282
Organic matter	-0.661864*	-0.710240*	-0.691487*
Coarse sand (2-0.25 mm)	0.237233	0.114572	0.101577
Fine sand + silt (0.25-0.002 mm)	-0.279136	-0.096275	-0.101139
Clay (≤ 0.002)	-0.131165	-0.048356	-0.029773

Regression equations for runoff rate, sediments in runoff and soil loss and soil properties are shown in table 6. The relationship between soil loss and coarse sand content is highly significant, and shows that medium-sized soil particles are most prone to detachment and transport by runoff. Thus, the average content of these fractions in soils under conventional management is more than two times that from olive groves under minimal or no tillage, which are more coarsely textured.

Table 6. Regression equations for runoff rate, sediments in runoff and soil loss and soil properties. Only significant regressions are shown (p ≤ 0.05).

X / Y	Intercept	Coefficient
Soils from olive groves under minimum or no-till practices		
Runoff rate / organic matter	77.673	-71.273
Sediments / organic matter	14.538	-14.651
Soil loss / organic matter	2.325	-2.346
Soils from all olive groves		
Runof rate / pH	-178.079	27.616
Sediments /pH	7.485	0.027
Soil loss / coarse sand	10.180	-0.099

In fine-textured soils, hydraulic conductivity is reduced, thus increasing soil erosion risk. In addition, in sandy and silty soils with low clay content, infiltration rates are high even when soil sealing is observed. At the scale of this experiment, runoff generation and soil erosion risk decrease significantly in areas under natural vegetation, with lower clay contents.