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Use of Some Natural Plant Species for Erosion Control in Southern Turkey

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ABSTRACT

An investigation on the use of common natural pasture plants, *Rosmarinus officinalis* (L.) Benth and *Putoria calabrica* (L. fil) DC for water erosion control in Southern Turkey was carried out for 3 years (1995-97). The slope of the experimental fields was 30% and the size of the plots was 7.0 m in length along the slope and 3.0 m in width. During the studied period, the total precipitation was 1859 mm; 57 out of 92 rainfall events were erosive due to runoff on the bare soil plot. The amount of soil and water losses by runoff were found to be 30126, 91752 and 194185 kg ha^{-1}; 113, 373 and 488 mm for *R. officinalis (L.) Benth, P. calabrica* (L. fil) DC and bare soil plots, respectively. Results revealed that both of the plants can be used for controlling soil erosion. Moreover, it was found that soil loss from *R. officinalis* plot was 67% and 84% less than those of *P. calabrica* and bare soil plots.

INTRODUCTION

Soil erosion is one of the most important natural resource management problems in the world. It is a primary source of sediment that pollutes streams and fills reservoirs. Total soil losses due to sheet and rill erosion estimated from cropland were 1.2 billion tons annually in 1992 in the United States, with a decrease of 30 percent since 1982 because of improved management practices and a reduction in cropland acres due to the conservation reserve program (Schwab et al., 1996).

Soil erosion causes widespread soil degradation and desertification. Cultivated soils in the humid and sub-humid tropics are at the risk of accelerated erosion. Water erosion is particularly severe in semi-arid regions. Both wind and water erosion are severe in arid regions (Lal, 1995, p. 16).

Vegetation protects the soil from water and wind erosion, acting as a shield against raindrop impact, binding the soil into a resistant root mat and decreasing the erosive energy of flowing water by decreasing its velocity (Holy, 1980). If the vegetation disappears, erosion may be intensified because of structural breakdown of the soil (Bridge et al., 1983). The importance of plant cover in reducing erosion and protecting soil against degradation is well demonstrated by many experiments (see Morgan [1986] for a review). When vegetative cover declines, soil bulk density increases and organic matter content and aggregate stability decrease, rate of water infiltration decreases and sediment production increases (Bari et al., 1995; McIvor et al., 1995).

Several strategies have been developed to control erosion after deforestation or other loss of vegetation. These include terracing, trenches, silt traps, earth dams, reforestation, crop rotations and planting of shrubs or other plant species (Kwaad and Van Mulligen, 1991; Hudson, 1992).

Several plant species have been tried (*Dactylis glomerata*, *Agropyron cristatum*, *Medicago arborea*, *Brachypodium pinnatum*, *Oryzopsis miliacea* (L.) Benth, *Hyparrhenia hirta* (L.) Stapf, etc.) depending on their availability and cost. Among them the *Oryzopsis miliacea* (L.) Benth, *Hyparrhenia hirta* (L.) Stapf, and *Rosmarinus officinalis* are determined to be useful both for grazing and erosion control as well (Celik, 1998).

R. officinalis is a Labiatae of Mediterranean origin. It has a dense, aromatic, usually erect but sometimes prostrate evergreen shrub readily distinguished by its narrow dark green leaves which are inrolled and white-felted beneath, and its lilac flowers. Corolla two-lipped, 2 stamens and styles, all curving outwards well beyond the corolla. *Matorral*, rocks and stony ground. Inflorescence densely woolly-haired; flowers violet with violet-blue tips. Leaf stalk, flower stalk, and calyx with star-shaped and long simple glandular hairs. Often cultivated for its aromatic oil (Polunin and Smythies, 1973; Davis, 1982, p.76).

P. calabrica (L. fil) DC, is a Rubiaceae of Mediterranean region which is a prostrate shrublet with leathery leaves and dense heads of long-tubed pink flowers. Flowers about 1.5 cm long, with 4 spreading lobes; stamens projecting. Leaves opposite, shining, inrolled. Rocks in hills and mountains (Polunin and Smythies, 1973). In the Mediterranean area *R. officinalis* and *P. calabrica* are frequently used to improve the soil, and adaptation in stony hillsides.

We studied the ability of *R. officinalis* and *P. calabrica* to protect soil against water erosion processes in experimental field plots during the period 1995-1997. Their effects on erosion rates were compared with each other and bare soil.

MATERIALS AND METHODS

Study area

The study was conducted in the Experimental Farm of Cukurova University, Adana (Southern Turkey). The climate of the region is Mediterranean. The long term annual mean temperature and relative humidity are 18-19 ºC and 66% respectively. The annual precipitation is about 650 mm, of which about 75% falls during the seasons of winter and spring. The mean potential evapotranspiration reaches 1500

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Table 1. Some properties of the soils in the experimental plots.

Soil properties	Plots		
Particle size distribution (<2 mm)	***Rosmarinus officinalis* (L.) Benth**	***Putoria calabrica* (L.fil).**	**Bare soil**
Sand (%)	34.3	27.8	24.5
Silt (%)	29.9	35.2	39.1
Clay (%)	35.8	37.0	36.4
Textural class	CL	CL	CL
Organic matter (%)	2.5	2.2	2.5
Aggregate stability (%)	32.8	34.0	33.1
$CaCO_3$ (%)	34.5	49.5	55.6
pH	7.7	7.7	7.8
Cation exchange capacity (meq/100 g soil)	31.1	22.3	20.9
Na^{+} (me/100 g soil)	0.22	0.10	0.14
K^{+} (me/100 g soil)	0.26	0.19	0.15
$Ca^{++}+Mg^{++}$ (me/100 g soil)	30.6	22.0	20.6

mm yr^{-1} (Aydin and Huwe, 1993). The soil of the experimental sites is classified as a Fluventic Xerochrept (Soil Survey Staff, 1994).

Some selected chemical and physical properties of the soils are given in Table 1. Twenty soil surface samples representing the uppermost 0-30 cm of each plot were taken for analysis. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1951), organic matter was determined by the modified Lichterfelder method (Schlicting and Blume, 1966), cation exchange capacity was analyzed by extraction with 1 M ammonium acetate solution (Rhoades, 1986). Aggregate stability was determined by the Yoder's wet-sieving procedure (U.S Salinity Staff, 1954) and calculated by Kemper's (1965). The Scheibler calcimeter method (Schlicting and Blume, 1966) was used for determining total carbonate.

Experimental details

The study area has a 30% slope, which has been for free grazing throughout the year and relatively eroded. Native vegetation species (*Oryzopsis miliacea*, *Pinus brutia, Pistacia atlantica, Erica arborea, Hyparrhenia hirta, Thymus spicata, Quercus coccifera, Themeda triandra*, etc.) of the study area were removed from the plots by hoeing the experimental site several times one year before the experiment. In order to protect the site from animal grazing, the study area was enclosed with barbed-wire fence.

Three plots were laid out at an altitude of 140 m, with a mean slope of 30%. Each plot was 7.0 m long x 3.0 m wide, and wide enough to minimize edge effects and large enough for downslope rills to develop. The experiments were conducted on three plots, which were aligned next to each other at 50 cm distances. Each plot was enclosed by 45 cm wide waterproof planks of which 20 cm was inserted into the ground and 25 cm remained above the surface.

To measure runoff and soil loss each plot had an installation consisting of a metal gutter at the lower end of plot, a coarse sediment tank, a sedimentation box and a collection tank. The metal runoff collection apron intercepted runoff and directed it to the collection tank (Fig. 1). The sedimentation box also acted as a multi-pipe divisor with 5 pipes. Only the middle pipe was connected to the runoff collection tank through a 13.0 mm diameter plastic hose, thus allowing only (in theory) 1/5 of the runoff to be collected during each rainfall event. The actual amount going into the tank was determined using a calibration curve.

The box and tank were shielded from direct rainfall and animal trampling by an iron sheet cover. Each plot was kept clear of up-slope runoff by a run-on barrier and an interceptor drain at the upper end of the plot.

R. officinalis was transplanted to the first plot, *P. calabrica* was transplanted to the second plot and the third plot was left bare (not planted). The plants used for this study were collected from natural grazing lands in Adana province. In October 1995, one well developed clone from each type of plant was selected and transported to the parcels with a 50 x 50 cm intra and inter row spacing and total of 77 plants were planted. These plants were irrigated 4 times until the first rainfall. Development of the vegetation in height and percent surface cover (Lal, 1988) were measured 4 times at 6-month intervals.

Sediment and water samples

Sediment and water samples were collected as soon as possible after each rainfall event that produced runoff in at least one treatment. A rainfall event, which resulted in runoff and soil losses from the relevant plot, was identified as erosive rainfall event for a particular treatment. For example, during the experimental period of three years, 57 out of 92

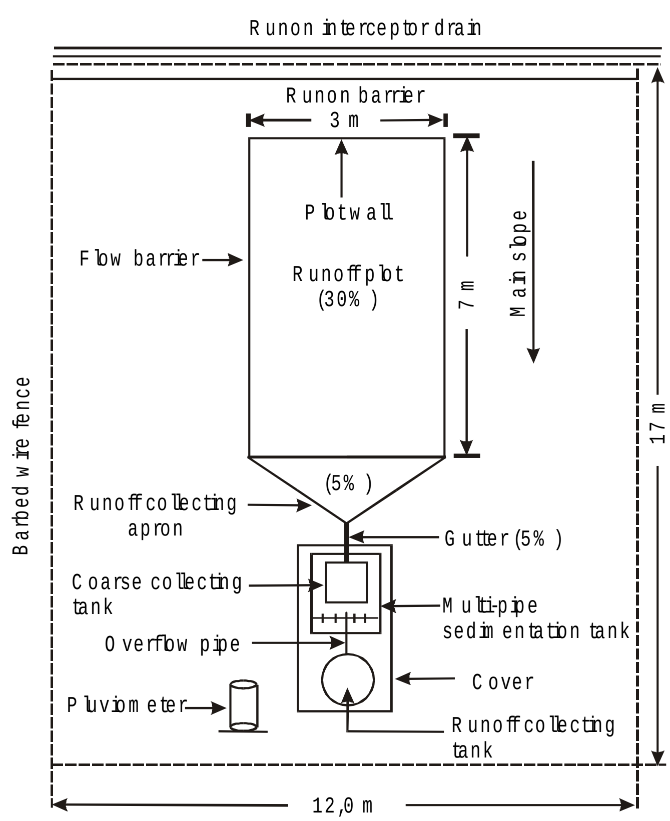

Figure 1. Experimental plot with a runoff and sediment collection system (Celik, 1998).

rainfall events were erosive for the bare soil plot. Thus, for each erosive rainfall event from 1995 to 1997, the total runoff and soil loss were collected from plots of *R. officinalis*, *P. calabrica* and bare soil. A representative sample was collected from the sedimentation box and the overflow tank after stirring the mixture vigorously. Concentration of suspended material was determined using the filtration method (Heron, 1990; Hudson, 1993, p.139).

With the filtration method, the sample was filtered through a filter paper (of known weight) that retained particles >1.2 µm, dried at 105ºC for 24 hours and weighed. Soil loss was calculated by subsample sediment concentration X total runoff volume. The weight of soil was converted to sediment yield in kg/ha (Hudson, 1993).

always higher than the *P. calabrica* during the experiment period as shown in Table 2 after plantation.

Table 2. Mean values of vegetative cover and height development of the plants.

Period	Plots			
	Rosmarinus officinalis *(L.) Benth*		***Putoria calabrica* (L.fil) DC**	
	Cover (%)	**Height (cm)**	**Cover (%)**	**Height (cm)**
Initially	10.2	14.6	10.1	14.3
I$^{\#}$	17.6	44.1	11.3	17.6
II$^{\#}$	31.3	51.8	19.9	18.8
III$^{\#}$	61.4	66.6	25.6	22.7
IV$^{\#}$	87.5	75.9	35.1	29.5

I$^{\#}$: 6 months after transplanted of the plants to the plots.
II$^{\#}$: 12 months after transplanted of the plants to the plots.
III$^{\#}$: 18 months after transplanted of the plants to the plots.
IV$^{\#}$: 24 months after transplanted of the plants to the plots.

Table 3. Total precipitation, runoff and soil losses collected after erosive rainfall events during 1995-1997.

Year	Precipitation (mm)	Plots	Erosive rainfalls		Runoff (mm)	Soil loss (kg/ha)
			Number	**Amount (mm)**		
		Rosmarinus officinalis	6	201.7	22.0	11166.2
1995	247.6†	Putoria calabrica	8	240.2	47.9	29474.9
		Bare soil	8	240.2	54.6	43842.8
		Rosmarinus officinalis	20	767.0	54.8	12343.6
1996	896.0	*Putoria calabrica*	25	830.5	148.0	29814.4
		Bare soil	27	848.5	197.1	59834.0
		Rosmarinus officinalis	12	531.8	36.2	6616.4
1997	715.3	*Putoria calabrica*	19	617.5	176.6	32463.0
		Bare soil	22	657.0	235.9	90507.7

†The precipitation falling after October 1995.

RESULTS AND DISCUSSION

The growth of *R. officinalis* and *P. calabrica* during the studied period is presented for both in Table 2. The *R. officinalis* growing rate was The surface cover percentage of the *R. officinalis* has increased 207% from the beginning of plantation to the end of the first year, and reached up to 31.3% of total ground cover. However, at the same period the surface cover of the *Putoria calabrica* has increased only 97%, and reached up to 19.9% of the ground cover. This was also same for the height development of the two plant species. The *R. officinalis* height measured at the end of the year was 51.8 cm, which was 255% higher than the beginning, but the *P. calabrica* height has increased only 31.5% and reached to 18.8 cm.

The experimental results showed that the development of *R. officinalis* was much more significant than *P. calabrica. R. officinalis*'s surface cover percentage and height were 87.5% and 75.9 cm, however values of the *P. calabrica* were 35.1% and 29.5 cm, respectively at the end of this three-year experiment.

The number of erosive rainfalls causing runoff and soil losses along with the amount of losses during the research are given in the Table 3. The most intensive rainfalls were recorded in 1996 and consecutively the highest surface running and soil losses were also observed in the same year. As it can be seen from Table 3; 57, 52, and 38 rainfall events during the research period caused surface runoff and soil losses from the bare soil, *P. calabrica* and *R. officinalis* plots, respectively. At the end of erosive rainfalls, 113 mm runoff and 30126 kg/ha soil loss were measured in the *R. officinalis* plot, 373 mm runoff and 91752 kg/ha soil losses have recorded in the *P. calabrica* plot for the entire period under consideration. Also, 488 mm runoff and 194185 kg/ha soil losses have determined in the bare (not planted) plot.

In general, total soil losses from the plots were less than the expected for soil of this type on a >20% slope (Gachene et al., 1997). This situation may be attributed to the relatively high organic matter content and aggregate stability of the soils in all plots (see Table 1). Organic matter most probably increased the resistance of soils to the erosion (Pierson and Mulla, 1990).

The runoff and soil losses measured after each erosive rainfall event are shown in Figures 2, 3 and 4 for 1995, 1996 and 1997, respectively. It can be seen that losses from all plots were very close to each other from the beginning of the experiment until the first half of 1996 (Fig. 2, 3), but when the plants started to cover the soil surface, runoff and soil losses were significantly different on bare soil than planted

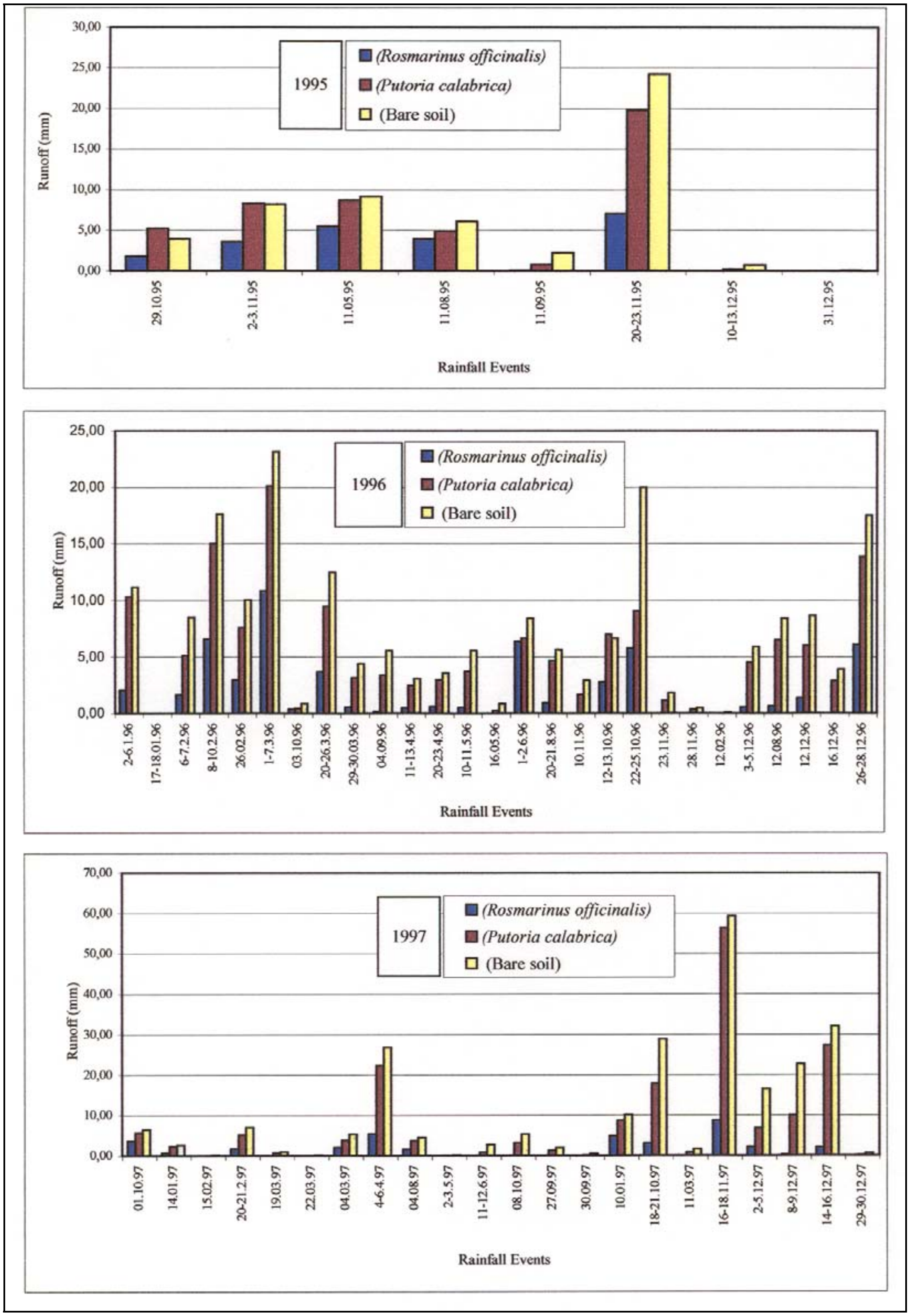

Figure 2. Runoff and soil losses from the experimental plots in 1995.

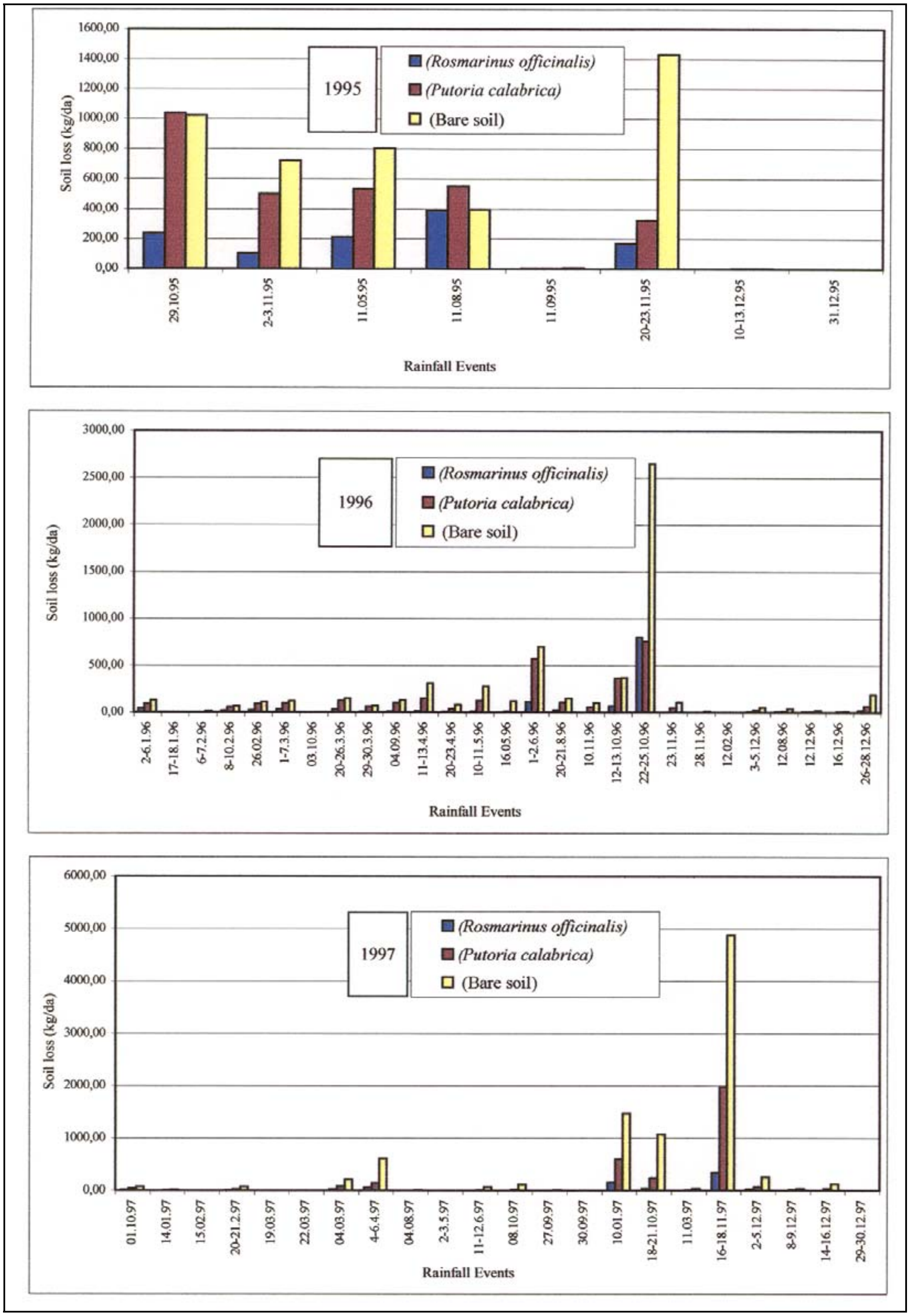

Figure 3. Runoff and soil losses from the experimental plots in 1996.

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Figure 4. Runoff and soil losses from the experimental plots in 1997.
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soils (Fig. 3, 4). These results are significantly related to the rate of surface cover percentage of the plants used in the study. Disruption of soil physical and partly chemical properties also might have an effect on the results.

If the plant cover is destroyed, soil organic matter will be decreased along with aggregate stability of the soil, which will cause erosion in vulnerable lands (Castillo et al., 1997). Vegetative cover reduces the direct impact of raindrops on the soil, increases the flow depth, and reduces the flow velocity (Mwendera et al., 1997).

According to the three-year results, the soil loss from the *Rosmarinus officinalis* plot was 67% less than that of the *Putoria calabrica*. This difference can be attributed to the different soil covering ability of *Rosmarinus officinalis* and *Putoria calabrica*. However, under *Rosmarinus officinalis* vegetation, soil loss and runoff were 84% and 77% less than the bare soil.

Results revealed that *Rosmarinus officinalis* and *Putoria calabrica* plant species can successfully be used for erosion control studies. Though, as it is not as effective as *Rosmarinus officinalis*, the ease in planting of *Putoria calabrica* as well as high amounts of seed production together its value as a forage crop and beneficial effects on erosion suggest that it is an inexpensive and effective soil conservation measure under the Mediterranean conditions.

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