Impact of land-use change on soil degradation by establishment of terraces with subtropical orchards in sloping areas (Granada, SE Spain)

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ABSTRACT

In the coast of Granada, an intensive irrigated agriculture based on subtropical crops has been established. These trees have been planted in highly sloped areas, by the construction of terraces. In this fragile Mediterranean agroecosystem, the removal of native spontaneous vegetation cover and substitution by orchards, increase the susceptibility to soil degradation and eventually brings up the destruction of these structures by rainfall events. To study this net change, we monitored the soil loss and runoff over a two-year period in the taluses of terraces with a mature mango (*Mangifera indica* L.) orchard. The studied treatments were bare soil (BS) and spontaneous vegetation (NSV), each twice replicated. The erosion plots were 4 m x 4 m in area and were located in the taluses of orchard terraces (65º slope). The average annual soil loss by erosion for BS and NSV was 2.5 and 0.3 Mg ha^{-1} yr^{-1}, and for runoff 34.1 and 6.8 mm yr^{-1}, respectively. Therefore, soil erosion and runoff from BS plot were 8- and 5-times higher than in NSV, showing the importance of plant covers in the taluses of terraces in reducing this impact. Thus, the removal of plant cover from the taluses under these conditions, represent a high risk of slump and collapse, causing serious environmental and economic problems for farmers of subtropical crops.

INTRODUCTION

Erosion is one of the most important soil problems in area with Mediterranean climate. In this zone, climatic variations and the impact of human activities for centuries have resulted in progressive soil degradation, especially in arid and semiarid areas (Imeson, 1990; Eswaran et al., 1999). Natural vegetation protect the soil because the canopy and litter intercept raindrops, reducing the kinetic energy, and the organic carbon provided increases the formation of soil aggregates (Andreu, 1998; Casermeiro, 2004; Durán et al., 2006a; Rodríguez et al., 2009). In the coast of Granada (SE Spain), hillsides have been terraced to establish an intensive irrigated agriculture based on subtropical crops including avocado (*Persea americana* Mill.), mango (*Mangifera indica* L.), loquat (*Eriobotrya japonica* L.), custard apple (*Annona cherimola* Mill.), litchi (*Litchi chinensis* Sonn.) and others (Durán et al., 2003; 2006b). The common practice by farmers in the study area is to maintain the taluses with bare soil by spraying herbicides. Also, the detached soil from the talus accumulates on the platform of the terrace below, hindering manual fruit harvesting and orchard maintenance. In this sense, talus erosion, making terrace reconstruction necessary, poses a serious economic challenge for farmers. The objective of the present study was to determine the impact of land-use on soil erosion in subtropical orchard terraces, evaluating its environmental effect under this new scenario of intense fruit production in southeast Spain.

METHODS

The study was performed on a south-facing terrace of a mango orchard located some 7 km north of the Mediterranean coast at Almuñécar (Granada, SE Spain) at the experimental farm 'El Zahorı´' (36º48´00´´N, 3º38´0´´W) and at elevation of 180 m a.s.l. The platform had a single row of bearing mango trees (*Mangifera indica* L. cv. Osteen) spaced 3 m apart (Fig. 1)

Figure 1. Mango plantation in a single row on terraces

Local temperatures are subtropical to semi-hot within the Mediterranean subtropical climatic category (Elias and Ruiz, 1977). The average annual rainfall in the study zone is 449.0 mm. The soils of the zone are Typical Xerorthent (Soil Survey Staff, 1999). Four erosion plots (4 x 4 m each) were laid on the taluses of the terraces, two with bare soil (BS) and two with natural spontaneous vegetation (NSV). The soil loss and runoff from the plots were collected and measured after each rainfall event. The rainfall data were collected from a local meteorological station (<100 m from the plots) at the experimental farm 'El Zahorí". By analysis of variance (ANOVA), the means for soil loss and runoff were compared, and differences between individual means were tested using the LSD test at $P < 0.05$.

RESULTS AND DISCUSSION

Annual runoff for the study period was 34.1 and 6.8 mm yr^{-1} for BS and NSV, respectively. Therefore, NSV reduced 5-times total runoff. Figure 2 shows the average monthly runoff for the two treatments. From the experimental results the runoff was much greater during December and February, coinciding with the highest rainfall amounts (34.7 and 40.3 mm, respectively). These results are lower than those obtained by Durán et al. (2005) for the same area in BS plots (100 mm yr^{-1}).

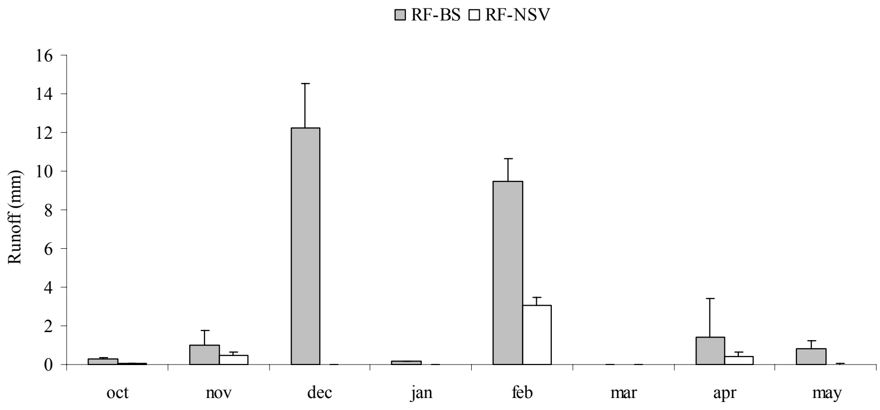

Figure 2. Monthly mean runoff for the study period. Vertical bars are standard deviation. RF-BS, runoff in bare soil, RF-NVS, runoff in natural spontaneous vegetation

On the other hand, annual soil losses rates for BS and NVS were 2.5 and 0.3 Mg ha^{-1} yr^{-1}, respectively. NSV reduced soil erosion in 98%. The analysis of variance concerning the effect of NSV when comparing with BS on the average soil loss is presented in Table 1.

Table 1. Statistical summary for the soil loss during the study period

	Soil loss (g m^{-2})	
	BS	NSV
Average	16.7a	2.2b
Stand. Dev.	14.4	3.2
Max.	72.9	14.5
Min.	0.1	0
Total	249.9	32.9
n	15	15

Values with different letters between the columns for the average values are statistically different at level 0.05 (LSD).

Average soil loss in BS was 7.6-times the soil loss in NSV, differing significantly from each other (P < 0.05). The plant architecture of the mixture of diverse plants existing in the NSV plot was decisive factor in discouraging runoff and soil loss, and favouring the infiltration of rainwater into the soil matrix.

CONCLUSIONS

The main conclusion that may be drawn from this study is that the inappropriate removal of plant cover and the intense farming systems of steep land areas endanger land conservation, raising an urgent need to implement appropriate land management. Particularly, terrace reconstruction can require nearly as much labour and investment as the initial terrace, costs that could be at least partially offset by the use of plant covers on taluses, as was shown in the present study avoiding slumping and promoting stability. Thus, under this new scenario originated by land-use change with agricultural purposes, the combination of orchard terraces with native spontaneous vegetation provided a viable option to conserve soil in the taluses with opportunities to increase overall land productivity as well as sustainable agro-environmental measures.

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