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Assessing the impact of terraces on soil erosion

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Introduction

Tuscany countryside (central Italy) is characterized by a hilly landscape that over the centuries, has been shaped by farmers in search of new arable land, leading them to realize terraces (Agnoletti et al., 2015). However, from the 1960s, the development of agricultural mechanization has led to an expansion of up and down the slope cultivated fields and to a progressive abandonment of terraced surfaces (Landi, 1989; Agnoletti et al., 2015, Napoli et al., 2016). Our study was focused on the "Alta Val di Pesa" in the Municipality of Radda in Chianti. The aims of this study were: 1) to evaluate the effectiveness of the land setting practices such as diversion ditch and stonewall terraces on reducing soil loss by water erosion in the vineyard and olive groves; 2) to compare erosion rates from fields with non-degraded (standing) and degraded (fully or partly collapsed) stonewall terraces.

Materials and Methods

The study was conducted in the "Alta Val di Pesa" area, Tuscany, Italy (Figure 1) across the period 2016–2020. The climate was typical of the European Mediterranean area, with average annual rainfall height (RH) ranging between 700 to 800 mm. Vineyard and olive groves selection was based on the proximity to roads and the permission given by the farm owners. The soil losses associated with land setting practices were studied: 1) Level ditching with a distance between successive diversion ditch (DDD) higher than 80 m (DDD>80); 2) Level ditching with DDD lower than 80 m (DDD<80); 3) degraded stonewall terracing, 4) standing stonewall terraces. Soil loss (SL, t ha^{-1} y^{-1}) measurements were carried out over nine years, from 2016 to 2020, in 161 fields. A total of 10 undisturbed soil core samples were taken from each field to determine the bulk density (ρd) ($kg \cdot m^{-3}$). The yearly volume of soil loss (V, $m^3 \cdot y^{-1}$) by water erosion was determined as proposed in Napoli et al. (2016) and briefly described here. All trees of the same plantation were considered planted with the same aboveground height of the root collar. Therefore, the erosion and deposition effect may be highlighted by average yearly changes in surface level with respect to the root collar (Δh, m y^{-1}). The initial root collar aboveground height (di, mm) and number of years from plantation founding (Δy, y) were provided by the plantation owners. The average exposed aboveground height of the root collar (hm, m) was measured along a cross-section between two adjacent trees, perpendicularly to the slope and considering the root collar as the initial soil height. To compensate for errors due to changes in bulk density and the initial aboveground root collar height, hm were determined on about 10% percent of the plants in each plantation. Finally, the SL was calculated for each plantation as follows (Eq. 1):

$$SL = F \times \rho d \times (hm - di) \times \Delta y^{-1} \qquad (1)$$

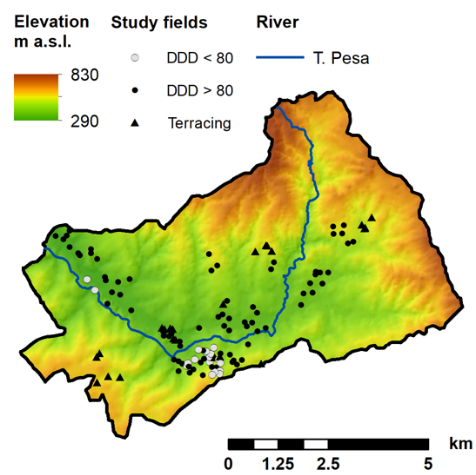

Figure 1. Digital elevation model of the "Alta Val di Pesa" area, with the position of the study fields.

Where F was the conversion constant from meters to metric tons per hectare (10 $m^3 \cdot ha^{-1} \cdot m^{-1}$).
On stonewall terraced fields, the SL measurements were carried out on 50% of the terrace bed and then averaged over the whole field surface. The Kruskal–Wallis (K-W) test was applied to check the SL difference between land settings at significance level $p < 0.05$. Pairwise multiple comparisons for detected significant differences were analyzed by applying the Dunn's post-hoc tests with Bonferroni's p-value adjustment method. The SL values were also compared with the (OECD, 2008) tolerable average annual SL limit (T, 6 $t \cdot ha^{-1} \cdot y^{-1}$) to evaluate the land settings effectiveness in reducing the soil losses.

Results

The average measured SL were consistent with those found in other sites in the European Mediterranean area. The average measured SL in DDD<80 was 27.6% lower (p>0.05) than that measured in DDD >80. The average soil loss measured in degraded terraces was significantly lower than that measured in DDD >80, while no significant difference was detected with respect to DDD<80. The average SL from standing terraced vineyards resulted in 10.7, 7.8, and 5.8 times lower than that measured in DDD >80, DDD <80, and degraded stonewall terraces, respectively. The average SL values in DDD >80, DDD <80, and degraded stonewall terraces, were found to be 5.5, 4, and 2.9 times higher than T, respectively. On the contrary, the average annual soil losses from standing stonewall terraced fields did not exceed the tolerable average annual soil loss limit (OECD, 2008). These results indicated that the contour ditching was not sufficient to control the erosion process in steep hillslope Further, soil loss values measured at standing and degraded stonewall terraced fields indicated that terraces maintenance could reduce soil erosion by about 82.5%, with respect the terraces abandonment.

Table 1. Average and standard errors (in brackets) of yearly measured soil losses. Dara is reported as a function of the type of land settings. Lowercase letters indicate significant differences in average soil loss between land settings according to the Dunn post hoc test (p<0.05).

n° of fields	Land setting	Average yearly soil loss (t ha^{-1} y^{-1})
17	DDD < 80	23.8 (4.2) ab
78	DDD > 80	32.8 (3.2) a
43	Degraded stonewall terraces	17.7 (1.9) b
23	Standing stonewall terraces	3.1 (0.4) c

Conclusions

Diversion ditches were not sufficient to contain the erosive process within the tolerable limits in the olive groves and vineyards. Similarly, soil loss measured on degraded terraces exceeds the tolerable limits by 2.9 times. On the opposite, standing stonewall terraces have instead shown their value as land settings capable of reducing the erosive process.

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