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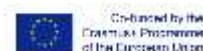
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Estimating erosion control performance of soil management practices in Douro viticulture

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Abstract

Conventional soil management (sm) in Douro viticulture, Portugal, comprise several weed control tillage operations along the crop cycle. Alternative sm practices reduce or exclude tillage, keeping ground cover for large part of the wetter seasons. Aiming at comparing the relative performance in erosion control of alternative sm practices, this study used long term records from a Douro vineyard as vine and ground vegetation evolution, crop management operations and detailed rainfall data. The USLE C factor was calculated combining vine row cover and inter-row ground cover effects in the typical vine cycle. With rainfall erosivity temporal distribution, erosion control by ground vegetation management options, representing different sm practices, was assessed for conventional and alternative (imposing different ground vegetation density, removal date and residues level after weed control). Results compare relative soil protection performance of alternative sm practices with conventional sm. Leaving residues over ground after weed control works better (54% increase in erosion control for 80% residue cover), than delaying weed control date (37% increase for a delay to mid-July), while increasing sown ground vegetation density is not so effective (17% increase for 80% cover). The methodological approach and results of this study are expected to contribute to better adjust sm practices for erosion control in Douro viticulture.

Keywords: Soil management, Erosion control, Universal Soil Loss Equation, Vineyards, Douro Region.

Introduction

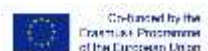
Douro viticulture, Portugal, is an exemplary case of ancestral concern with soil protection, a scarce resource in quality and suitability in this Region (Figueiredo, 2015). The topography with very steep slopes, the dominance of schist-derived soils with fine earth high erodibility, the climatic regime with increasing aridity towards east, all together determine a very severe potential erosion risk. This is, however, mitigated by the high soil stoniness and heavily reduced by traditional soil conservation structures, such as walled terraces, which justified the UNESCO's World Heritage status granted to this humanized landscape (Figueiredo, 1989; Figueiredo, 2015).

Conventional soil management (SM) in Douro viticulture comprises tillage operations for weed control throughout the crop cycle (Magalhães, 2008). Alternative SM practices aim to reduce or exclude tillage, keeping the soil covered by herbaceous vegetation, adventitious or sown, for most of the year, with positive effects, among others, on reducing erosion, and on improving nutrient and water cycles (Morlat and Jacquet, 2003; Celette et al., 2005; Vrsic et al., 2011). Its ongoing implementation is still limited in the Region (Martins et al., 2014; Martins, 2015). The adoption of alternative SM practices is particularly necessary in vineyards planted against the contour, “vinha ao alto” (Figure 1), a system installed in the Region from the 1970s onwards, currently not allowed in new plantations above 40% slope gradient (Bianchi-de-Aguiar, Bianchi-de-Aguiar, 2002, Portugal, 2003, Figueiredo, 2015). Despite the long-term records from erosion plots at Quinta de Santa Bárbara, Pinhão, have demonstrated a low impact of this system in the Douro, due to the high stony soils, “vinha ao alto” is, however, the one with the highest potential risk of water erosion as compared to the other vine planting systems in the Region (Figueiredo, 2001, Figueiredo, 2015).

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The study compares the relative performance in erosion control of alternative SM practices, simulated with Universal Soil Loss Equation (USLE) C factor, supported by long term erosion plot records that were taken as representative of the Conventional SM in “vinha ao alto” in the Douro Region.



Figure 1 – Vineyards planted against the contour (“vinha ao alto”) in Douro Region, at the end of June: left – no inter-row cover; right – dense residue cover in inter-row.

Materials and Methods

The base data for this exercise included the Quinta de Santa Bárbara, Pinhão, Douro (41°10'N, 7°33'W and 130m elevation) 10-year records of 5 erosion plots (5.2m width, 32.1m long, 45% slope), set to evaluate the erosive response of “vinha ao alto” with 3 planting densities (ca. 3600, 4800 and 6000 vine plants ha⁻¹) (Figueiredo, 2001).

In addition to soil and runoff water losses, records include information on vegetation (residues, weeds and vines) and crop management (traditional tillage operations as described by Magalhães, 2008). Their interpretation, together with field assessments, allowed to establish the normal pattern of temporal variations in plots vegetation cover (Figure 2).

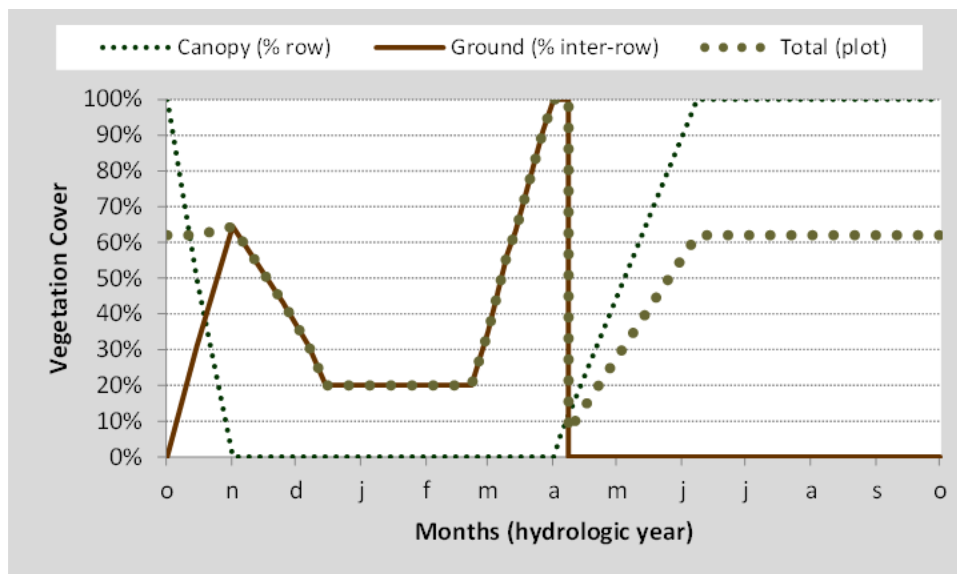


Figure 2 – Typical variation throughout the hydrologic year of plot cover by vegetation components in Douro Region vineyards (“vinha ao alto”), based on 10-year records at Quinta de Santa Bárbara (from Figueiredo, 2001).

Continuous rainfall data records (pluviograph) allowed calculation of EI30 erosivity index (Wischmeier and Smith, 1978). The cumulative yearly curves of EI30 were computed on a weekly base for the 10-year series. Hence, average, 10% and 90% percentile curves of cumulative erosivity were obtained (Figure 3).

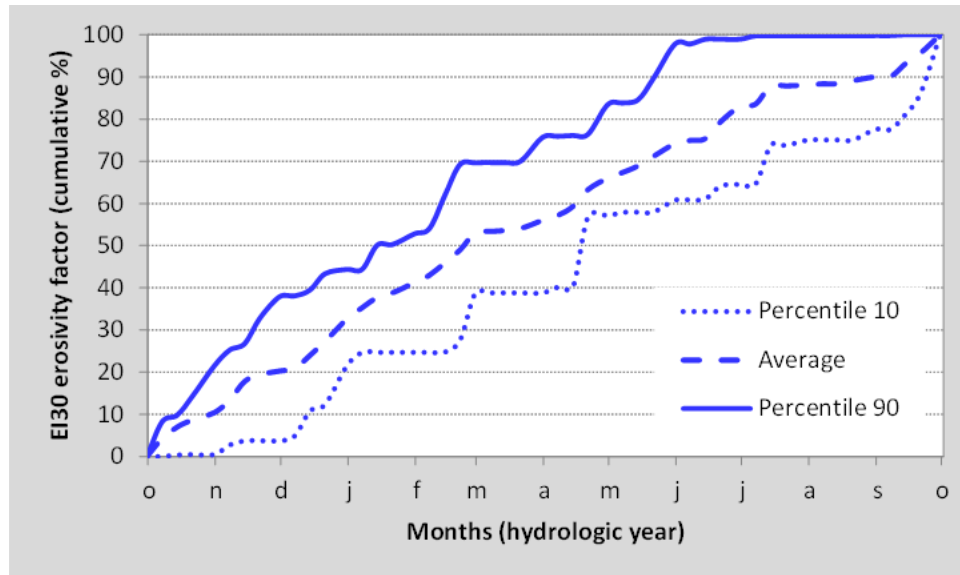


Figure 3 – Percent cumulative rainfall erosivity along the hydrologic year: average, low erosivity (percentile 10) and high erosivity years (percentile 90), based on 10-year records at Quinta de Santa Bárbara (from Figueiredo, 2001).

Taking as reference of “vinha ao alto” in Douro viticulture the Quinta de Santa Bárbara conditions, the USLE C factor was applied (Wischmeier and Smith, 1978), combining the effects of vine row cover and of inter-row cover by herbaceous vegetation and residues, along the typical crop cycle, and considering the temporal distribution of rainfall erosivity:

$$C_i = CC_i SC_i = (1 - FC_i e^{-0.34H_i}) e^{-3.5RC_i} \quad (\text{eq. 1})$$

$$C_{\text{year}} = \sum R_i C_i \quad (\text{eq. 2})$$

C – Crop Factor; CC – canopy effect (vine plants, maximum cover is 62% of plot area); SC - soil cover effect (residues and weeds); FC – canopy cover; H – canopy height; RC – residue or weed cover; R - proportion of annual erosivity (percentile 90 curve in this case); i – crop period or calculation interval in the year (week in this case); FC, RC and R, [0-1]; H, m.

The C_{year} indirectly estimates the performance of SM practices in erosion control, either for conventional (represented by the reference conditions of Quinta de Santa Bárbara) or for alternative simulated SM practices. Performance was actually assessed by (1 – C), and the relative performance of the alternatives by:

$$C \text{ factor: } C_{\text{relative}} = C_{\text{alternative}} / C_{\text{conventional}} - 1 \quad (\text{eq. 3})$$

$$\text{Performance: } (1 - C)_{\text{relative}} = (1 - C)_{\text{alternative}} / (1 - C)_{\text{conventional}} - 1 \quad (\text{eq. 4})$$

Alternative SM practices were simulated and the respective C_{year} calculated, in each case keeping all other parameters as for the reference condition (conventional) and changing the pertinent ones as follows:

- (i) Density of herbaceous vegetation cover in the inter-row (adventitious or sown) generating maximum winter cover at 50% for dense cover and 80% for very dense cover (conventional, 20% cover).
- (ii) Weed control dates in spring by herbaceous vegetation removal in the inter-row, with progressive delay in the operation: conventional – at vines vegetative start (early to mid-April), 1 month (early to mid-May), 2 months – at maximum vine vegetative development (early to mid-June).
- (iii) Residue cover left in the inter-row after spring weed control made at vine vegetative start: conventional – full removal, low cover – 20%, very high cover – 80%.

Results and Discussion

It is estimated that conventional SM in “vinha ao alto”, under conditions considered to be representative of Douro viticulture, have average performance in erosion control of 58%, meaning average soil loss equivalent to 42% of that in bare soil. The critical period of soil exposure is spring, after weed control and before the driest season, although in Winter months soil protection is also lower than the average (Figure 4). This low average performance confirms that vineyards are not generally a protective crop, ranking among the largest soil loss records in Europe (Cerdan et al., 2006). On the other hand, the erosive events of higher magnitude in 10 years of records in Quinta de Santa Bárbara occurred in late spring and early summer, confirming this period as critical (Figueiredo, 2001).

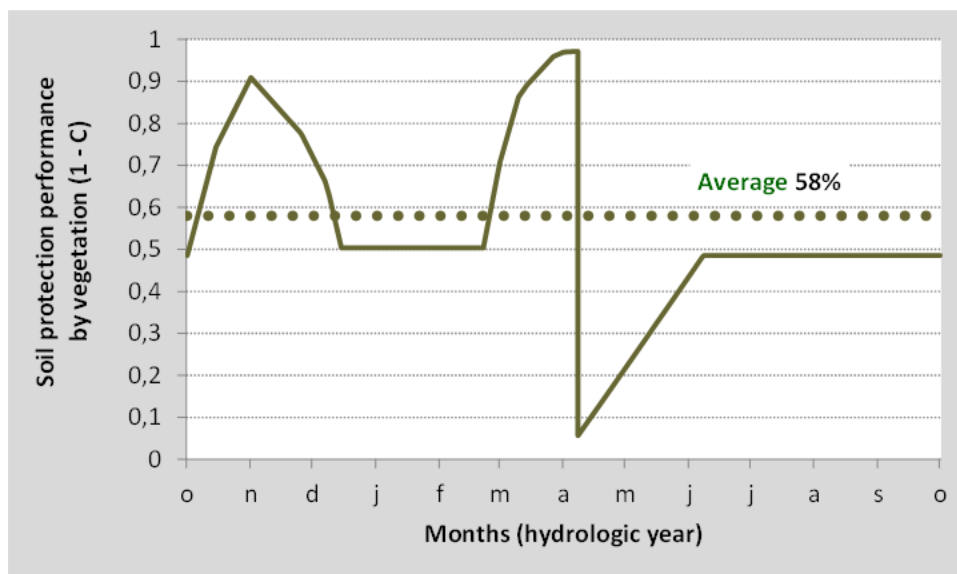


Figure 4 – Typical variations along the hydrologic year of the performance in erosion control of a “vinha ao alto” vineyard plot under conventional soil management.

Alternative SM practices focused on increasing winter cover by herbaceous vegetation (adventitious or sown) determine a decline in vineyards’ average annual C factor. Conversely, there is an increase in soil protection performance of 13% and 17% for, respectively, 50% and 80% cover, when compared with conventional SM (20% winter cover) (Figure 5).

Keeping herbaceous cover on the ground as long as possible, delaying weed control intervention in the spring may be an alternative SM strategy. This was simulated and results show that it works better than increasing weed coverage in winter. In fact, average annual performance increased 37% for a 2 months delay and 22% for a month delay, as compared to the conventional practice (Figure 5).

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The maintenance of residues over the ground after weed control in spring, meaning minimal incorporation in the soil, simulated at 20% and 80% residue cover, leads to soil protection performance increase of 37% and 54%, respectively, as compared to the conventional, in which the full incorporation of residues by spring tillage is assumed (Figure 5).

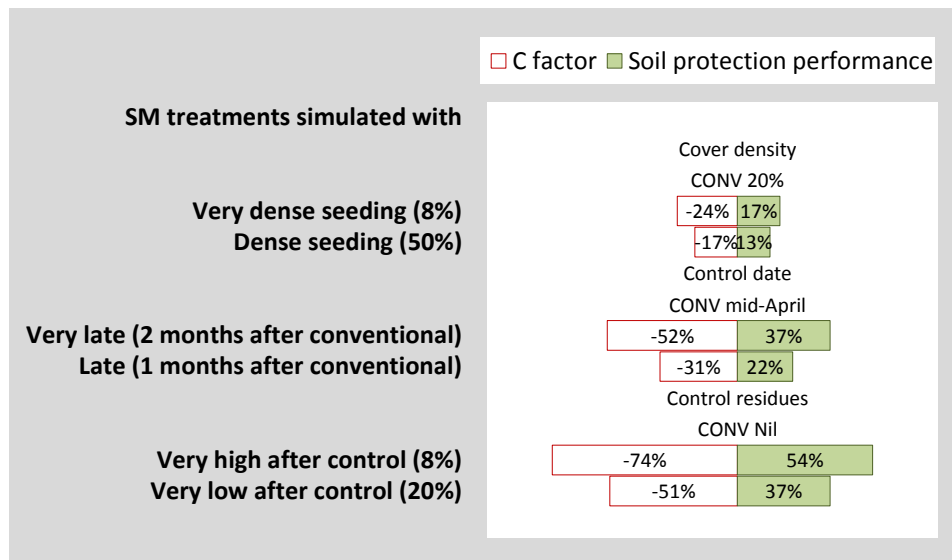


Figure 5 – Relative C factor and relative soil protection performance of alternative SM practices as compared to conventional (CONV): simulations with different inter-row herbaceous cover density in winter, spring weed control dates, residue cover left over the ground after spring weed control.

From the simulated alternatives, the strategy of keeping residues on the soil surface after spring weed control is the most performing, even when the mass of residues is limited. This is a practice consistent with no-tillage and herbicide application or clipping herbaceous vegetation in the inter-row area (Vrsic et al., 2011; Martins et al., 2014; Martins, 2015). Delaying spring weed control has meaningful results when it extends to 2 months, but it entails increased risks of resource competition (water and nutrients) between herbaceous vegetation and crop and of release in soil of viable seeds of weed species more difficult to control afterwards (Celette et al., 2005; Martins et al., 2014; Martins, 2015). Focused on the critical spring period, these alternative SM strategies are more performing than those focused on autumn-winter regulation of herbaceous vegetation cover. This are actually less critical seasons as indicated by the Quinta de Santa Bárbara 10-year records: less than 20% of the total soil loss recorded occurred in these seasons (Figueiredo, 2001; Figueiredo, 2015).

Conclusion

The results allow to conclude that:

- The performance of conventional SM practices in the “vinha ao alto” vineyard plantation system in the Douro Region is limited and points out the need to implement alternative SM practices based on more performing management of herbaceous vegetation cover in the vines inter-row;
- Alternative SM practices focused on the control of herbaceous vegetation in the spring period are more performing than those focused on the fall-winter period;
- The maintenance of residues on the soil surface after spring weed control proved to be the most performing option among the simulated ones and it is fully feasible in a no-tillage farm context.

It is expected that the methodological approach and the results of this study may contribute to fine-tune erosion control practices in Douro viticulture.



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