**Comments on “Is soil erosion in olive groves as bad as often claimed?” by L.
Fleskens and L. Stroosnijder**

Gómez, J.A.^{1,*}, Giráldez, J.V.^{1,2}, Vanwallegghem, T.^{2,3}

¹ Institute for Sustainable Agriculture, C.S.I.C.. Apartado 4084. 14080. Cordoba. Spain

² Department of Agronomy, University of Cordoba, Spain

³ EU Marie Curie Fellow

* corresponding author, ag2gocaj@uco.es. Phone: +34-957-499210

1. Introduction

Olive groves are frequently reported as being highly susceptible to soil erosion. Early research efforts established average soil erosion rates for olive groves in some regions of between 40-100 t ha⁻¹ year⁻¹ based on USLE model predictions (López-Cuervo, 1990; ICONA, 1991; Kok et al., 1995). In their recent paper, Fleskens and Stroosnijder (2007) have presented experiment data inferring that actual figures are probably much lower than the alarming regional averages reported above. They have cited seven factors explaining the overestimation of these USLE model predictions.

Given the importance, and our limited knowledge, of soil erosion rates of this particular, although widespread in Mediterranean countries, land use type, we welcomed the recent paper by Fleskens and Stroosnijder (2007). Their challenging of the above-mentioned

average erosion rates is worthy of appreciation because, like what happened with an average soil erosion rate for Europe (Boardman, 1998), these figures are often uncritically adopted (Boardman, 1998). We believe, however, that their discussion omits some important aspects of the interpretation and extrapolation of model predictions, and that their experiment results are too inadequate to support their conclusions. In our opinion, further discussion and clarification of this important issue are therefore required.

2. Discussion

2.1. Length of measurement versus infrequent, high-intensity events

The first point requiring attention concerns the original data that Fleskens and Stroosnijder (2007) used to conclude that average erosion rates in olive groves are unlikely to exceed $10 \text{ t ha}^{-1} \text{ year}^{-1}$. Their figure is basically derived from rainfall simulation data, runoff plots and field measurement of rills in three areas. Rainfall simulator experiments have obviously been designed to evaluate processes under controlled conditions and are hardly suitable for evaluating long-term, regional estimates. The latter were actually the objective of previous rainfall simulation studies in olive orchards reviewed by Fleskens and Stroosnijder in Table 1 of their paper. Next, the original runoff plot studies presented by them do not provide the appropriate time scale to capture the full variability in rainfall (300 mm of cumulative rainfall for the plots in Portugal and 4 months in Italy). These authors do admit this, and underline that, especially in a Mediterranean climate, erosion mainly results from infrequent high-intensity events. Unfortunately, this definition is rather vague and does not determine

for how long an experiment should be continued to secure these events. Some previous studies cited in Table 1 of Fleskens and Stroosnijder (2007), e.g. Gómez et al. (2003) or Bruggeman et al. (2005), provide some insight, and suggest that, although annual erosion rates can greatly vary, it is not uncommon to detect and describe, at least partially, this variability in experiments lasting only three or four hydrological years. However, they used their own plot data, during a period of a few months, uncritically, even though these were contradicted by results of previous runoff plot measurements, carried out over longer time spans. Fleskens and Stroosnijder have striven to make a comprehensive overview of the available literature, but we feel that it would have been desirable to concentrate on and discuss further the results from their Table 1.

2.2. Plot length and management

We have re-analyzed the runoff plot data taken from the literature and summarized by Fleskens and Stroosnijder in Table 1 (section 3). Where necessary, we completed them using the original publications or contacting the authors for additional information. The runoff plot data currently available and depicted in Figure 1 show a clear dependence on spatial scale and soil management. The data shown in Figure 1 are those of Fleskens and Stroosnijder in Table 1. Only at one site, under conventional tillage, were much lower soil losses ($3 \text{ t ha}^{-1} \text{ year}^{-1}$) measured than were to be expected on the basis of the slope length of the runoff plot (60 m). This can probably be attributed to the low slope gradient (4 %) at this particular site. In any case, a two-way analysis of variance shows that soil loss is significantly dependent on soil management (CT conventional tillage and CC cover crop) and plot size (large $> 10 \text{ m}$ and small $\leq 10 \text{ m}$) at $P=0.05$ (Table 1). The small number of plots with no-tillage (NT) prevented making a correct statistical

analysis of this treatment. Nevertheless, its trend was visually similar to that observed for CT and did not contradict our observations. This dependence on slope length or management is not surprising given the well known effect of slope length and ground cover modification by soil management on erosion rates currently included in erosion models on a hillslope scale (e.g. RUSLE, WEPP). Note that in our data analysis, presented in Figure 1, the results presented by Kosmas et al. (1997) were classified as CC instead of CT, because these authors described their olive plots as being 90% covered by annual vegetation and plant residues, which is not the case in tilled olive orchards.

2.3. A realistic average soil loss value for olive orchards?

By averaging the soil loss measured in conventionally-tilled treatments in large runoff plots, defined as being longer than 10 m, a figure of $23.2 \text{ t ha}^{-1} \text{ year}^{-1}$ was obtained, with a maximum value of above $40 \text{ t ha}^{-1} \text{ year}^{-1}$. These CT large plots had an average length of 64 m and an average slope steepness of 20%. Given that this slope gradient and length is representative of many olive orchards in the Mediterranean, and that tillage still is the most commonly-used management system in olive orchards, we consider that available runoff plot data contradict the statement that “erosion rates are not likely to surpass $10 \text{ t ha}^{-1} \text{ year}^{-1}$ ”, always referred on a hillslope scale. Additionally, to deduce this average erosion rate of below $10 \text{ t ha}^{-1} \text{ year}^{-1}$, Fleskens and Stroosnijder seem to discard their own field measurements of rill erosion, yielding higher average erosion rates ($44 \text{ t ha}^{-1} \text{ year}^{-1}$), and the field measurements made by Laguna and Giráldez (1990) and presented in their Table 1 reporting even higher long-term estimates. The reason given for this omission is that these figures do not consider within-field sedimentation.

However, some of the runoff plot experiments in the literature review of Fleskens and Stroosnijder (2007) had a slope length similar to their fields (e.g. 74 m in Raglione et al., 1999; or 60 m in Gómez et al. 2005) and suggest that their field erosion rates are feasible and that the within-field sedimentation effect on annual erosion rates cannot be very great on the field scale considered in their paper (50 m long). On the other hand, however, these field data permit to take into account other erosion processes. As the authors indicate in their paper, rill erosion, for example, can be very serious in olive groves, but it was not observed in their microplots and runoff plots. Erosion rills coalesce in gullies that are conspicuous in many olive cropping areas and have not been taken into account either. For instance, they are not uncommon in Southern Spain, where 1.5 of the 9.2 Mha of olive in the Mediterranean basin (FAO, 2008) is cultivated. Poesen et al. (2002) reported that gullies in Mediterranean areas possibly explain up to 83 % of the total soil loss. One solution, as suggested by Fleskens and Stroosnijder, could be to take the measurements at the outlet of (sub)catchments. In any case, failure to consider their available field data might have contributed to the relatively low estimate of erosion rates on a hillslope scale compared to other measurements available in Table 1.

2.4. Model prediction of erosion in olive orchards

Another issue demanding attention is how Fleskens and Stroosnijder explain the overestimation of average erosion rates in olive orchards by model predictions, which are basically USLE-based. Unfortunately, their discussion is solely focused on the up-scaling of experiment results. In our opinion, the discrepancy between experiment and simulated erosion rates can be better understood and explained, at least partly, by an

incorrect use of these models. It is surprising that this discussion is missing since a number of studies (Gómez et al., 2003; 2005) have already pointed to the fact that inappropriate calibration and application to spatial scales for which these models were not intended are also responsible for distorted erosion estimates in olive orchards. Part of the error comes from the use of slope lengths that are unrealistic, mainly due to the employment of digital elevation models with an excessively coarse resolution. An extra careful calibration of model parameters, by taking into account stone cover and by using a differentiated C value rather than a homogeneous one, further improves model predictions (Gómez et al., 2005). When this is closely examined, predictions are obtained in the range of the hillslope erosion rates measured (Álvarez et al., 2007). Nevertheless, this does not mean that, as in any other crop, large doubts do not persist on the accuracy of erosion rate predictions (Nearing et al., 2000).

The authors, instead, have focused on seven factors related to the extrapolation of experiment results. However, their experiment data have been collected not only on an inadequate spatial scale, but also on too short a temporal scale to enable them to challenge these average regional erosion rates on a hillslope scale. In view of the limited experiment data provided by the authors, a more careful discussion would have been an advantage.

2.5. Tillage under olive orchards

Finally, while the influence of some of the factors quoted by Fleskens and Stroosnijder on lowering soil loss is irrefutable and has been demonstrated by previous research (e.g. rock cover, Poesen et al., 1994), other factors require a more meticulous analysis. Their

statement that tillage increases surface roughness and infiltration is well-known (Henderson, 1979). This is one of the reasons why tillage is an efficient agronomical technique in semi-arid climates, although its effect is only temporary. As an example, Nearing et al. (1988) mentioned an increase in the interrill erosion coefficient on a freshly-tilled Vickburg silt loam soil, with respect to the same uncultivated soil, at 5 months after the tillage. Agricultural operations in the olive groves, especially fruit harvesting, accelerate the compaction of the soil, reducing the possible advantages of tillage. Besides, some of the experiment data referred to in their Table 1, (Giráldez et al., 1990), indicated a higher sediment yield in tilled than in no-till soils. Unless tillage is performed continuously, it results in lower infiltration rates than those obtained with a cover crop in olive groves (Romero et al., 2007). Only long-term experiments are able to monitor the interaction of rainfall and tillage effects on runoff and soil loss (e.g. Gómez et al., 2003; Gómez et al. 2007). These have proven that, although a tilled field can show lower runoff and soil losses compared to a cover crop field in a year (or period) of reduced precipitation, in the long term the effect can be the reverse. The fact that tillage effects could be more complex were even noted by Fleskens and Stroosnijder, who reported a case where they measured higher erosion rates in a field with contour tillage. Also, when discussing their Ferrandina site results, the runoff coefficients reported for tilled fields were in some cases higher than their untilled counterparts (slope positions 2 and 3). Therefore, we do not think that the short-term experiment results and summarized literature presented by them are reliable enough to conclude that tillage applied judiciously in selected locations of a grove might reduce erosion in the long-term average or in large rainfall events.

2.6. Irregular slopes

In addition, we consider that it has not been established by the data available that an erosion-modified slope could significantly reduce the erosion process thus increasing the run-on and subsequent infiltration of excess water. When the olive trees were initially planted along contour lines, a practice recommended by the former Spanish Soil Conservation Service, the layout of the plantation favoured the partial trapping of the sediments. Unfortunately, in most olive cropped areas, the fraction of contour-planted trees is very low. In the other cases, the slope profiles do not produce local troughs where the water infiltrates and the sediment settles down, especially in large runoff events, but the erosion goes on removing the soil.

3. Conclusions

To conclude, until historic rates of soil loss are available and additional field experiments are carried out under different conditions and scales, including monitoring sediment budgets for catchments, erosion rates in olive orchards will remain highly uncertain. For the moment, however, our opinion is that data currently available confirm that hillslope erosion in most orchards, cultivated without cover crops or any other type of mulching, can be frequently above $10 \text{ t ha}^{-1} \cdot \text{year}^{-1}$.

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Table 1: Two-way analysis of variance table evaluating the significance of management (cover crops, CC and conventional tillage, CT) and plot length (shorter than 10 m or larger than 10 m) on soil loss collected from runoff plots in olive orchards. Data are from Table 1 in Fleskens and Stroosnijder (2007).

Source	SSE	df	MSE	F	P
Main effects					
Management	1093	1	1093	7.15	0.0136
Plot length	1099	1	1099	7.19	0.0134
Combined	2027	2	1014	6.63	0.0053
Error	3517	23	153		
Total	5544	25	222		

SSE = type III error sum of squares, df = degrees of freedom, MSE = mean square error, P is probability $F > F_{crit}$ for $\alpha = .05$

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297 **Figure 1:** Plot length versus measured average annual soil loss from runoff plots with
298 natural rainfall in olive groves. Three management types are compared: No tillage, with
299 application of herbicides (NT), Conventional tillage (CT) and orchards with cover crops
300 (CC). Data are from table 1 in Fleskens and Stroosnijder (2007).

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