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Vulnerability of olive orchards under the current CAP (Common Agricultural Policy) regulations on soil erosion: a study case in Southern Spain

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ABSTRACT

To measure the erosive processes taking place under conditions close to those experienced by farmers and land managers; analyses on spatial units adapted to the size of the farm must be carried out; in a non-isolated way in the case of conventional plots. The objective of this study was to describe and understand the current state – in terms of high soil losses and degradation risk – of a commercial olive farm following the CAP agro-environmental requirements as well as the interaction between soil management decisions and rainfall variability. In this work, rainfall and runoff soil loss for 6.4 hydrological years (2005–2011) were monitored in the outlet of an olive orchard microcatchment of 6.7 ha. The equipment used was a flume with an ultrasonic sensor to measure flow height, a rainfall gauge and a sediment sampler. Management systems and olive yields were described for the study period. Different management operations (no-tillage, conventional tillage, no herbicides with tillage and mulch) were applied in the field as a result of the farmer adapting to yearly conditions and to recommendations on good agricultural practice.

Our results indicate that the interaction between the factors of annual climatological features and management determined the hydrology, soil loss and olive yield. On the annual scale, cumulative rainfall and rainfall erosivity varied between 600 and 1000 mm and 600 and 1500 MJ Mm ha^{-1} h^{-1}, respectively. The average annual runoff coefficient was equal to 15 ± 10%, while total sediment loss ranged from <1 t ha^{-1} $year^{-1}$ to >20 t ha^{-1} $year^{-1}$. Olive yield ranged between 5000 kg ha^{-1} $year^{-1}$ and 10,000 kg ha^{-1} $year^{-1}$. Above average annual rainfall values were associated with both high yields and soil losses >10 t ha^{-1} $year^{-1}$.

For the study period, frequent events with a low return period resulted in soil losses >10 t ha^{-1}, despite the use of different soil management techniques and the compliance of CAP agro environmental regulations. The high risk of soil degradation evaluated might mean that the criterion based on slopes >10% is not suitable for the application of agro-environmental requirements of CAP. On the other hand, further research on conservation technologies such as a more efficient use of cover crops, mulches and plant barriers, controlled traffic farming and/or changes in land use is needed.

Introduction

The environmental impact of agriculture has been a major concern to experts and policymakers for several decades, particularly with regard to the use of water and food production (e.g. Fereres et al., 2011; Foley et al., 2011; Baveye, 2012). This concern may be related to production systems in fragile areas due to the scarcity/variability of water resources or to their susceptibility to desertification, as is the case of olive cultivation in the Mediterranean area. Over 95% of the world's olive oil is produced in Mediterranean countries (FAOSTAT, 2011), which illustrates its social economic and environmental importance. Nowadays, the main challenge consists of achieving suitable productivity and incomes for rural communities in a context of high rainfall variability, serious risk of soil degradation and incentives associated with olive yield.

Since the latest reform of the Common Agricultural Policy of the European Union (European Commission, 2004; Spanish Ministery of Agriculture, 2004; CAP, 2005, 2009), compulsory agro-environmental requirements have been implemented in order to pursue a sustainable agricultural yield, balancing the social and

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economic requirements of their members and environmental protection. Cross-compliance is the mechanism tying European Union support for farmers to compliance with standards of environmental care and public health, animal and plant health and welfare. It penalizes farmers who infringe EU law on environmental, public and animal health, animal welfare or land management – by reducing or cancelling the EU support they receive (European Commission, 2014). It includes compulsory directives and regulations known as "statutory management requirements" and "good agricultural and environmental conditions". The rules on good agricultural and environmental conditions are aimed specifically at farmers receiving CAP payments, and are designed to: (1) prevent soil erosion; (2) maintain soil organic matter and soil structure; (3) ensure a minimum level of maintenance; (4) avoid the deterioration of habitat; and (5) protect and manage water (European Commission, 2014).

In Table 1, the main requirements affecting olive orchards derived from cross compliance are presented. The criterion of mean slopes in the fields is significant in determining the establishment of ground cover for values over 10% and the ban on ploughing in areas with values equal or larger than 15%. Proper design and evaluation of these measures in olive cultivation is of major importance to countries such as Spain, particularly in Andalusia (in Southern Spain) with an olive orchard area of 1.5 Mha (CAP, 2010). It is worth noting that about 60% of its olive cultivation farms are located in areas with a mean slope over 10% (CAP, 2003). Cross-compliance derived from the new Common Agricultural Policy for the period 2014–2020 (CAP 2014–2020) will take effect in 2015, and broadly promotes crop diversification on farms larger than 3 ha, the keeping of permanent pastures and the establishment of ecological areas of at least 7% of the surface (European Commission, 2013). However, these new measures of diversification and the keeping of permanent pastures do not affect olive orchards and other permanent crops (FEGA, 2014).

Olive trees are extremely hardy. Olive groves have historically occupied hilly areas with shallow soils, where many other crops fail or produce very little. The rises in world olive oil consumption and agronomical improvements have led to intensive cultivation systems and new plantations on better soils. However, numerous olive groves in the Mediterranean area are found on soils with serious environmental limitations for agricultural use. This is the case of Andalusia, the largest olive-producing region in the world where 60% of olive orchards are located on slopes larger than 10%. The high soil erosion rates, loss of biodiversity, over-exploitation of water resources and water pollution have been highlighted as the main negative environmental impacts that can be associated with this land use by several authors (Beaufoy, 2001; Gómez-Limón et al., 2012; Gómez, 2009). The national government estimates erosion rates of above 50 t ha^{-1} $year^{-1}$ on olive orchards located in mountainous areas in Andalusia (MMA, 2007), which illustrates the severity of the environmental degradation risk.

A significant number of studies have evaluated the effects of soil management on soil erosion, most of which focus on the plot scale (Kosmas et al., 1997; Pastor et al., 1999; Gómez et al., 2003, 2004, 2009a; De la Rosa et al., 2005), comparing the differences among soil management techniques, mainly non tillage, conventional tillage and cover crop. In contrast, studies evaluating current erosion rates on commercial farms and non-isolated spatial units such as the catchment are scarce (De Vente and Poesen, 2005). In particular, it is quite difficult to find analyses with a long enough dataset capturing the wide variability of rainfall magnitude and its impact on erosion in Mediterranean environments (e.g. Renschler et al., 1999; Taguas et al., 2013).

Finally, there is a notable tendency towards the application of new management operations such as the use of pruning residues as mulch (Calatrava and Franco, 2011) or the establishment of spontaneous native grass cover (e.g. Hernández et al., 2005; Taguas et al., 2011a,b), both of which are poorly described in the literature.

This manuscript presents an analysis of the hydrological and erosive response observed in an olive microcatchment located on a commercial farm over a 6 year period (2005/06–2010/11). For the study period, different soil management alternatives (non-tillage, conventional tillage, no herbicides, with tillage and mulch) were adopted by the farmer as a response to different climatological features (mainly quantity and temporal distribution of annual precipitation) and to soil-protection norms outlined in agro-environmental legislation. The objective of this experiment was to reach a better understanding of the current situation on commercial farms by the analysis of: (1) interactions between rainfall variability and the farmers' soil management decisions; (2) relationships of runoff and sediment loss with both olive yield and management in the context of cross-compliance. It is important to highlight that the study site is situated on an administrative zone with a mean slope of 9% and is therefore not obliged to use grass cover or to stop ploughing operations (Table 1). 20% of olive orchards in Andalusia are located in similar areas with a mean slope between 6 and 10%. Thus, our results might provide valuable information for this farm type and might lead to possible future improvements in the planning of agricultural practices.

Study area

The Setenil microcatchment is located in the mountainous areas of the province of Cadiz, Spain (36.88°N, 5.13°W). The drainage area is 6.7 ha (Fig. 1), the mean elevation is 782 m and the mean slope is 9.5%. The climate is of the Mediterranean type with Atlantic influence (subtype Csa Köppen-Geiger classification; Peel et al., 2007) with a mean annual precipitation of 700 mm.

The soil has been classified as Luvisol (FAO classification; FAO, 2007), with an average depth of 1.5 m. The texture is predominantly sandy, with mean values of 74% sand, 6% silt and 20% clay. The average organic matter content in the surface horizon is equal to 0.9%. The microcatchment presents two distinct areas: the first, with young olive trees planted in 2006, is located on the highest ground and has a surface of 1.4 ha; in the second area (5.3 ha), the olive trees were planted in 1995. The mean diameter of the canopy of the youngest olive trees is 1.94 ± 0.29 m whereas 4.23 ± 0.49 m for the oldest olive trees. Tree spacing of 7 m × 7 m is common to both areas (Fig. 1). With the exception of the first year, the same management operations were applied in the catchment.

In this study, the farmer was informed about the options available regarding soil conservation on his farm. However, he alone was responsible for deciding the soil management operations adopted each year (Table 2). Different management types or schedules were applied for the study period. No tillage with the bare soil (NT) was the management type used during the hydrological years 2005–06 and 2006–07. Conventional tillage was applied (CT) during the following three years, 2007–08, 2008–09 and 2009–10. Finally, in the last year, 2010–11, the farmer decided to include several conservation measures (CM). Firstly, he eliminated the usual autumn herbicide treatment in the lanes with glyphosate and oxyfluorfen, in order to allow the spontaneous grass cover to grow. In addition, he applied mulches composed of shredded leaves and branches in the lanes in the spring (after pruning operations). Under NT, there were two weed controls per year (October and March) using herbicides around every tree in the rows, and the tractor with a roller was driven over the soil in May or June to seal it and to reduce the evapotranspiration in the summer (Table 2). For the last year with CM, the chisel plough was driven over the soil at a depth of less than 20 cm (two crossed passes) in April, after the application of the fertilizer treatment. The tillage was mainly applied on the lanes lying most parallel to the maximum slope of the hills. Finally, for