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Exploring calibration strategies of the SEDD model in two olive orchard catchments

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ABSTRACT

To optimize soil conservation strategies in catchments, it is required an accurate diagnosis of the areas contributing to soil erosion by using models such as SEDD (Sediment Delivery Distributed model). In this study, different calibration strategies of the SEDD model were explored to adapt its use in two olive catchments with different environmental features and managements. A data series of rainfall–runoff–sediment load, collected in the catchments for 6 years was used: i) to evaluate calibration strategies for different management and flow conditions through the analysis of the *C* and *R* factors, and ii) to describe the temporal patterns of sediment delivery ratio (*SDR*) at the event and annual scales. Different results and calibration approaches were derived from contrasting soil features and sediment dynamics in the catchments. A good model performance with simple calibration procedure was obtained for the catchment with clayey soil and a very active gully, whereas the model parameterisation was adapted to event features in the catchment with sandy soil where the importance of concentrated flow was minor.

Mean annual values of *SDR* at the watershed scale (SDR_w) were 110.1% for the catchment with clayey soil and 64.1% for that with sandy soils. SDR_w values greater than 100% occurred in very humid years with precipitations 30% above the mean annual values. At the event scale, similar behaviours of *SDR* were observed. $SDR > 100\%$ were associated with the gully exporting sediments out from the clayey catchment, whereas this was done by rills and an ephemeral gully in the sandy catchment.

1. Introduction

Olive plantations on sloping areas are a major factor of soil erosion in Southern Spain that also interacts with intense rainfall events, a low soil cover fraction and unsuitable soil managements (Gómez et al., 2014a). Vanwalleghem et al. (2011) reconstructed the temporal variation of soil management and its erosion rates in olive trees located in mountainous areas, and found soil losses of 8 to 124 t ha^{-1} year^{-1} for water erosion similar to values obtained by Gómez et al. (2009) and 3 to 42 t ha^{-1} year^{-1} for tillage management. A number of experimental studies quantified soil losses in olive orchards and evaluated the impact of different managements using runoff plots with a maximum size of 200 m^2 (Kosmas et al., 1997; Pastor et al., 1999; Gómez et al., 2003, 2004, 2009, 2014a; Licciardello et al., 2013). Gómez et al. (2009) indicated how the soil management of olive orchards with bare soil resulted in unsustainable water erosion rates. At the hillslope scale, erosive processes are mainly splash, inter-rill and rill erosion; however, on commercial farms, erosion can also be from concentrated flow in larger rills or gullies. In Southern Spain, Taguas and Gómez (2015) measured total soil losses of > 10 t ha^{-1} year^{-1} in a hilly olive catchment with an ephemeral stream and rill erosion processes for hydrological years with annual precipitation close to the long-term average (700 mm). Studies of soil losses at the catchment scale (Taguas et al., 2009, 2010; Gómez et al., 2014b) can provide information more relevant to the challenges faced by farmers in implementing suitable management measures to ensure the sustainability of resources and safeguard their incomes.

In order to optimize soil conservation strategies, an accurate diagnosis of the main sediment sources contributing to soil erosion is required (Giri et al., 2015), as well as identifying the areas where the measures should be implemented more urgently. Locating and determining the morphological origins of the sediment will help us to predict which areas are more prone to soil loss and which type of soil conservation measure is more suitable; for example, vegetation strips (Kapil et al., 2010; Al-wadaey et al., 2012), check dams (Xu et al., 2004; Nyssen et al., 2010) and afforestation in rivers (Huang and Zhang,

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2004; Zhao et al., 2013).

Research carried out over the last 50 years has developed erosion models which can predict sediment production at different spatial and temporal scales, as well as completing the information derived from monitoring and supporting taking-decision processes about sustainability (e.g. Merrit et al., 2003). Erosion models can help us to understand hydrological processes, and simple parametric approximations such as USLE (Universal Soil Loss Equation; Wischmeier and Smith, 1978) or its revised version RUSLE (Renard et al., 1997), calibrated from physical parameters, are commonly used to evaluate risk of soil erosion all around the world.

SEDD (Ferro and Minacapilli, 1995) is a Sediment Delivery Distributed model based on the USLE whose main features are its applicability at the scale of the morphological units into which a basin is divided, and the ability to predict sediment delivery ratio (*SDR*) at the morphological unit and catchment scale (Ferro and Porto, 2000). Using the USLE as a starting point, the model has been calibrated under different environments (from studies in the Mediterranean basin, the Pyrenees and Northwest USA) and soil managements such as eucalyptus forests (Ferro and Porto, 2000), coniferous forests with croplands (Fernández et al., 2003; Fu et al., 2006; López-Vicente et al., 2011), olive catchment (Taguas et al., 2011) and naturally-colonized abandoned farms (López-Vicente et al., 2013). It has been also validated with Cs^{137} in forested areas with eucalyptus trees at the mean annual temporal scale (Di Stefano et al., 2005a, 2005b). These studies showed the good performance of SEDD on different land use types; however, possible adaptations to erosive processes or to specific features of catchments were not studied. Such analyses can be helpful in areas with highly variable soil types or rainfall regime such as the Mediterranean Basin where olive crop is mainly located. The present work aims to shed light on erosion studies in olive catchments, by adapting tools to evaluate soil degradation risks. In this study, the model was applied at both morphological unit and basin scales (Di Stefano et al., 2005a, 2005b). The SEDD model was chosen for this study because: (1) it allows for discretization of a catchment into morphological units which is useful to evaluate the contribution degree of each unit to total sediment load; (2) it predicts *SDR* values at the morphological unit and basin scales; (3) it is based on the RUSLE, a model used under Mediterranean olive catchments with favourable results (Gómez et al., 2003; Vanwalleghem et al., 2011); (4) it is easy to couple within GIS (López-Vicente and Navas, 2010) and (5) previous studies performed in olive catchments in south Spain support its application and reliability (Taguas et al., 2011).

The main objectives of our work were:

1) To calibrate the model in two different olive catchments in areas with contrasting environmental characteristics in terms of soils and importance of concentrated flow, monitored over six years;
2) To study different calibration strategies and parameterisation in order to facilitate the use of the SEDD model in contrasting conditions of olive crop land use; and.
3) To evaluate the temporal variability of *SDR* values at each event and annual scales, identify the areas which contribute most to the soil losses, and decide where the conservation measures should be concentrated.

2. Study area and data

2.1. Study area

Two olive catchments were selected for this study (Fig. 1). The Setenil catchment is located in the province of Cadiz (36.88°N, 5.13°W; Fig. 2A,C). The drainage area is 6.7 ha, and the mean slope is 9.5%. The catchment presents a Luvisol (FAO–IUSS, 2007) with an average depth of 1.5 m and sandy texture (74% sand, 6% silt and 20% clay on average). The average surface organic matter content is 0.9% (Taguas and Gómez, 2015). Data for six hydrological years (2005–2011) under different soil management techniques were analysed. In 2005–2007, the soil management applied was no tillage (NT), with bare soil and using herbicide; conventional tillage (CT) was used in 2007–2010; and conservation measures (CM) with mulching were applied in 2010–2011 (Taguas and Gómez, 2015).

The Conchuela catchment (37°N, 4°W, Fig. 2B,D) is located 10 km west of Cordoba. The drainage area is 8 ha, with a mean elevation of 142 m and mean slope of 9%. The catchment presents a Vertisol (FAO–IUSS, 2007) with an average depth of 2.2 m. These soils are highly plastic when wet and cracked as they dry due to their high content of smectite clay. The average surface organic carbon is 0.59% in Horizon A (see Gómez et al., 2014a for details). The soil management technique used was growing natural weed vegetation in the lanes, applying glyphosate and occasional mowing in some areas. At the same time, surface tillage was sometimes used, but only to cover rills or small gullies so that tractors could pass (Gómez et al., 2014a). A total of five hydrological years between 2005 and 2011 were considered in the analysis.

2.2. Data

Data for 121 runoff events were collected in the Setenil catchment for the period 2005–2011, of which 60 were analysed. Data for 195 events were collected in Conchuela from 2006 to 2011, 95 of which were analysed. Only complete events in terms of peak flow, runoff and sediment load at the basin outlet were included into the analyses. An event was defined as a rainfall pulse series that generated runoff, separated by time intervals of at least 6 h without rainfall. A full description of the data series was provided by Gómez et al. (2014a) and Taguas and Gómez (2015).

For the model application and the determination of morphological units, a 1 × 1 m resolution digital elevation model (DEM) was used for each catchment following the procedure of Pedrera-Parrilla et al. (2014). A Real Time Kinematic (RTK) GPS system was used (AgGPS 432 and Ag RTK Base 430, Trimble Navigation Ltd., Sunnyvale, CA, USA), with the antenna mounted on a sled for accurate geo-referencing. RTK operation is based on a mobile GPS measurement, which is corrected in real time by a reference station, enabling centimetre precision. The sled is pulled by an all-terrain vehicle, which is equipped with a guidance system and a TK 6000 field computer (Juniper Systems, Logan, UT) that runs HGIS9 software (HGIS – Starpal Inc., CO) to log coordinates.

3. Methods

Firstly, the main parameters of the SEDD model were calculated based on the RUSLE. Then, a sensitivity analysis was applied to identify the impact of the *C* and *R* factors. Finally, the best model adjustment was determined after different strategies were compared.

3.1. SEDD model

The SEDD (Sediment Delivery Distributed) is a distributed model developed to calculate sediment yield based on the USLE (or its revised version RUSLE) and *SDR* calculations for each morphological unit *i* (SDR_i) and at the watershed scale (SDR_w). *SDR* depends on the travel time of eroded particles along the hydraulic path until they reach the nearest channel, after which *SDR* becomes a variable subrogated to travel time (Ferro and Minacapilli, 1995):

$$SDR_i = \exp(-\beta \cdot t_{p,i}) \quad (1)$$

where $t_{p,i}t_{p,i}$ is defined by the model developers (Ferro and Minacapilli, 1995) as the travel time, although its unit is meters for the hydrological path *p* in the *i*-th morphological unit, and β (m^{-1}) is a coefficient (assumed constant for the basin) according to the calculated linear