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Evaluating the Arc-SWAT2009 in predicting runoff, sediment, and nutrient yields from a vineyard and an olive orchard in Central Italy

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ABSTRACT

The ArcSWAT2009 model with an improved sub-model (SWAT-GC) was used to assess plant growth to evaluate sediment and nutrient runoff yields from an alternating grass-covered/tilled inter-row vineyard (VP) and from disk harrowing (DH) and grass cover (GC) management techniques in an olive orchard in Castelfiorentino (Florence), Tuscany, Italy. The model was calibrated for field plots (0.11 to 0.12 ha) using runoff volume and composition measured from January 2010 to December 2010 and validated using measured data from January 2011 to August 2013. The results obtained with the SWAT-GC were compared with those obtained with the standard model (SWAT) calibrated in situ. Daily performance of the calibrated SWAT model in simulating runoff, sediment, and nutrient yields for all treatments was good or very good according to the Nash–Sutcliffe model efficiency (NSE), the mean percentage error (M%E), and the median-based root mean square error (RSR). However, based on validation results, daily performance of the SWAT model was unsatisfactory. On the contrary, the SWAT-GC model provided very good predictions of average daily runoff and soil and nutrient loss during both the calibration and validation periods. Moreover, results indicate that SWAT-GC model is capable of adequately modeling differences in nutrient yields between the different tillage practices by calibrating crop growth, runoff, and sediment yields only. In fact, calibration for N and P resulted in identical calibration parameters regardless of tillage practice on olive orchard.

1. Introduction

The vineyard and olive orchard surface areas in Tuscany (central Italy) cover, respectively, about 60,300 and 95,450 ha (ISTAT, 2012), and are frequently located on slopes for reasons related to both tradition and quality of production. In fact, by comparing the CORINE land cover 2006 (CLC2006) map with the Digital Elevation Model (DEM) of Tuscany (20 m of resolution), it was estimated that approximately 76.2 and 51%, respectively, of the olive orchard and vineyards in Tuscany are located on rugged areas.

Because of both the sloping nature of the countryside and conventional soil management techniques, high erosion rates can be expected in agricultural areas planted with vine and olive trees. According to several studies, vineyards are the most erosion-prone lands in the Mediterranean region of Europe (Kosmas et al., 1997; Hooke, 2006; Cerdan et al., 2010). Moreover, olive orchards may also incur high runoff and soil losses as reported by some studies (Kosmas et al., 1996; Theocharopoulos et al., 2003; Gómez et al., 2009).

As soil erosion not only threatens the crop production sustainability (Ramos and Martínez-Casasnovas, 2006), but also the surface water quality (Lenat and Crawford, 1994; Fisher et al., 2000), local planning authorities need to use modeling tools that are able to evaluate the effects of changes in land use, management practices, and climatic variation on non-point source pollution problems at the regional scale.

SWAT is a basin-scale, continuous-time model that operates on a daily time step, and is capable of predicting water, sediment, and chemical yields in ungauged basins (Gassman et al., 2007; Neitsch et al., 2011). A geographic information system (GIS) interface, specifically ArcSWAT, is available to simplify the development of model input files (Di Luzio and Arnold, 2004). Although the SWAT database did not include parameters for either vineyards or olive orchards, the model has been applied to some regions where those trees constituted the main crops (Bruggeman and van der Meijden, 2005; Ouessar et al., 2009; Potter and Hiatt, 2009; Martínez-Casasnovas et al., 2013). Those authors introduced specific cover classes for vineyards and olive orchards, into the land-cover SWAT plant database. In addition, a number of adjustments were made to

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the model. Variables taking into account the growth and dormancy of olive trees, and the USLE C factor to simulate the effects of the ground cover, were introduced.

However, Douglas-Mankin et al. (2010) stated that before the SWAT model could reliably simulate watershed or regional scale impacts of crop practices, in-field studies should be conducted to measure model parameter values needed to accurately simulate those practices.

In this study, a modified version of the ArcSWAT2009 model (SWAT-GC) was used to quantify the effects of vine and olive tree management on daily water runoff, as well as sediment, N, and P runoff yields. The objectives were to (1) calibrate and validate the model to simulate both vine and olive tree growth and management (summer and winter pruning), and (2) determine appropriate parameter values for simulating the impact of tillage on daily sediment, N and P runoff yields. This paper presents the results derived from a 44-month study, field measurements made on a vineyard, and an olive orchard in central Italy in combination with the SWAT-GC model. Moreover, the results obtained with the SWAT-GC were compared with those obtained with the standard model (SWAT) calibrated in situ.

2. Materials and methods

2.1. Study area, plot characteristics, sampling, and analysis

The study area was located in Castelfiorentino in the south-western portion of the province of Florence (Tuscany, Italy) (WGS84 43.6241°N, 10.9792°E) (Fig. 1). The climate is typical of the European Mediterranean area, with a mean annual rainfall of about 550 mm and a mean annual temperature of around 15 °C. The rainfall is usually concentrated mainly in two periods: September to December and March to May. The soil is classified as Typic Calcixerepts, coarse-loamy, mixed, thermic according to the Soil Survey Staff (2010).

The study was conducted on two experimental fields. The first field was set up in an olive orchard (*Olea europaea* L., cv Frantoio) which covered an area of approximately 1.9 ha. The second field was set up in an up-and-down slope vineyard (*Vitis vinifera* L., Sangiovese red variety), which covered an area of about 1.4 ha. Since 2001, no fertilizers containing either nitrogen or phosphorus had been applied to the fields.

The olive trees were approximately 22 years old at the start of the experiment in January 2010, and had been planted with a 6 m × 6 m tree spacing along the maximum slope degree direction (slope = 18%) (Fig. 1). The trees were about 2.5 m in height and about 4.5 m in a canopy diameter. Four plots of 1200 m^2, each 65 m long, including three olive rows, were selected.

Two soil management systems, disk harrow (DH) and spontaneous grass cover (GC), were applied. The soil in the DH plot was harrowed once a year, during the last week of March, using a trailed tandem disk harrow with a combination of sixteen 610 × 6 mm cutout front blades and smooth rear blades. Blade spacing was 230 mm and the gang angle was set to 27°. The tandem disk weight was 960 kg, thus allowing for a soil penetration up to a depth of 100 mm. In GC plots, soil remained undisturbed. There were three grass height controls per year, both on the DH and GC plots (in early March, June, and in mid-October), and grass height was maintained using a grass shredder. The weed consisted of a mixture of *Bellis perennis* L., *Bromus hordeaceus* L., *Cynodon dactylon* L. (>60%), *Holcus lanatus* L., *Plantago media* L., and *Rubus ulmifolius* S. Winter pruning was carried out in March, just before flowering, and residues (RES_{wp}) were removed, whereas summer pruning (suckering of the

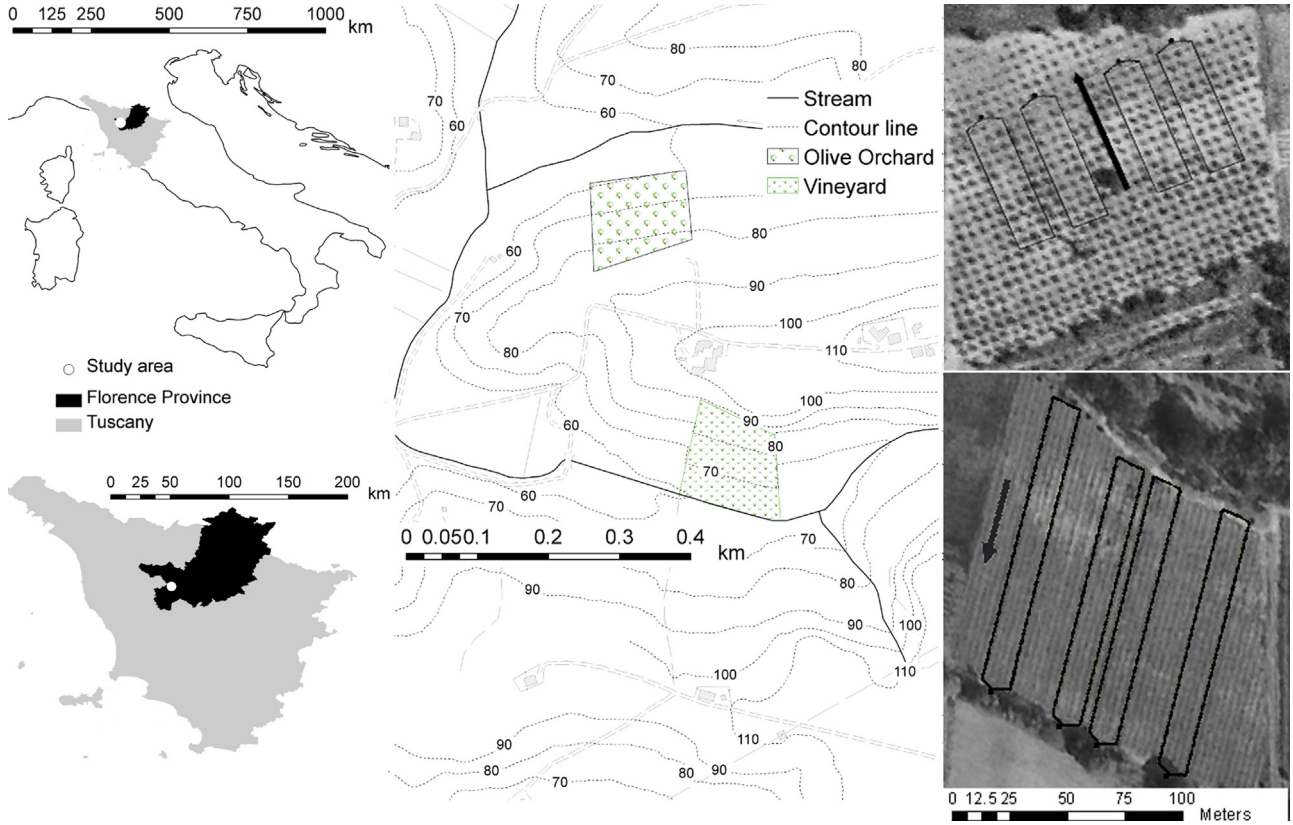

Fig. 1. Position of the study area with respect to Italy (top left) and Tuscany (bottom left); experimental area (center); olive orchard plots (top right); vineyard plots (bottom right).