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Temporal variability of soil management effects on soil hydrological properties, runoff and erosion at the field scale in a hillslope vineyard, North-West Italy

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ABSTRACT

Soil management in vineyard inter-rows has a great influence on soil hydraulic conductivity and bulk density, and, consequently, on runoff and soil erosion processes at the field scale. The maintenance of bare soil in vineyard inter-rows with tillage, as well as the tractor traffic, are known to expose the soil to compaction, reduction of soil water holding capacity and increase of runoff and erosion. The use of grass cover is one of the most common and effective practices in order to reduce such threats. It is therefore important to relate rainfall characteristics, soil properties and response in terms of runoff and soil erosion, from yearly to seasonal and to single event temporal scales. The objective of this work is to quantify the temporal variability of the effects of two different kind of inter-row management on soil hydrological properties, runoff and erosion in vineyards. For this reason two vineyard field-scale plots in the Alto Monferrato vine-growing area (Piedmont, NW Italy) were monitored in two years. The inter-rows were managed with conventional tillage (CT) and grass cover (GC), respectively. Fifteen series of infiltration tests were carried out during a 2-year period of observation (October 2012 to November 2014). In order to take into account the effect of tractors traffic, the tests were done on the track, and outside the track. Furthermore, a dataset of 29 rainfall-runoff events covering a wide range of topsoil characteristics was collected in the two plots, along with soil water content and runoff discharge monitoring, and determination of sediment yield in case of erosive events. An optical disdrometer installed in the plots provided also 1-min rainfall intensity data. In summer, just one month after tillage, CT soil showed very low hydraulic conductivity, so storms were able to cause Hortonian runoff and soil losses up to 5.7 Mg ha^{-1}. In autumn and winter very high saturation-excess runoff was observed in CT, that reached 83% of the precipitation. Runoff in the grass cover plot was mainly due to saturation of the topsoil, and the annual reduction of runoff in the GC plot was about 63%. Soil erosion up to 1.2 Mg ha^{-1} in a single event was observed in the GC vineyard in winter. In each year of observation, most of the erosion occurred during a single event, while the total annual erosion was up to 9 times higher in the CT treatment than in the GC.

1. Introduction

Grapevine cultivation represents one of the land uses for which higher runoff rates and sediment losses are observed in Europe, especially in the Mediterranean area (Tropeano, 1983; Kosmas et al., 1997; Cerdà and Doerr, 2007; García-Ruiz, 2010; García-Ruiz et al., 2015). Analysis of data collected throughout Europe showed that in the Mediterranean region runoff higher than 9% of annual precipitation (Maetens et al., 2012) and the highest erosion rates

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(17.4 Mg ha^{-1} $year^{-1}$) are related to vineyard land use (Cerdan et al., 2010).

Some typical features of the vine-growing system, such as location on hillslopes and disposition of rows along the slope, make runoff and erosion stronger (Corti et al., 2011). Furthermore, some practices usually adopted in vineyards' installation (land levelling works and deep tillage) and vineyards' management (maintenance of bare soil by mechanical or chemical weeding, intense tractor traffic along fixed paths) are favoring runoff, erosion and further threats as compaction, nutrient losses and reduction of soil water holding capacity (Tropeano, 1984; Ramos and Martínez-Casasnovas, 2004; Ferrero et al., 2005; Ramos and Martínez-Casasnovas, 2007; Arnaez et al., 2007). The effects of the inter-rows soil management on runoff and soil erosion in vineyards of southern Europe was evaluated in several studies under natural rainfall, at different spatial scales (from plot to catchment) and from event to multi-year temporal scales (Tropeano, 1983; Kosmas et al., 1997; Arnaez et al., 2007; Brenot et al., 2008; Casalí et al., 2008; Raclot et al., 2009; Ruiz-Colmenero et al., 2011; Novara et al., 2011; Corti et al., 2011; Biddoccu et al., 2016). The use of grass cover in the inter-rows is one of the most common and effective soil management practices adopted in order to reduce runoff and soil erosion in vineyards (Blavet et al., 2009; Novara et al., 2011; Ruiz-Colmenero et al., 2011; Prosdocimi et al., 2016) and other land uses which are especially subjected to erosion as olive groves (Gómez et al., 2009). Under the indication of the CAP agro-environmental requirements, some Rural Development Programmes (i.e., Regione Piemonte, NW-Italy) introduced during the period 2007–2013 specific subsidies to encourage the adoption of grass cover in vineyards and orchards in order to protect soil from degradation. However, tillage is still used in vineyards growing on low-permeability soils as a practice to remove grass in summer and improve water infiltration, particularly during autumn and winter time. In fact, growers are often worried that competition for soil resources, namely water and nutrients, between the grass cover and grapevines could affect grape yield and quality.

Most studies on runoff and erosion in vineyards consider topographic features, soil properties, rainfall characteristics, and soil management techniques in relation to the hydrological and erosive response of the vineyard at yearly or multi-annual scales (Prosdocimi et al., 2016). Nevertheless, annual runoff and soil losses could be strongly conditioned by few rainfall events (Gómez et al., 2014; González-Hidalgo et al., 2009). The adopted soil management influences strongly the temporal and spatial variations of the soil surface characteristics (soil cover, topsoil structure and soil crusting) and soil hydrological characteristics, which drive the partition of rainfall between runoff and infiltration at the field-scale (Leonard and Andrieux, 1998; Pare et al., 2011). There is still a gap in knowledge about the effect of the temporal variations of topsoil conditions on the triggering of runoff and soil water erosion throughout the year. A better understanding of the field response to rainfall events, taking into account the variability of the soil conditions during the year, could be useful for water balance and erosion modelling purposes (Celette et al., 2010) and to support soil management decisions in vineyards, in order to reduce runoff and erosion.

This study presents the results of a 2-year experiment monitoring topsoil hydrological properties and recording runoff and soil erosion in two vineyard field-scale plots with different inter-row soil management, conventional tillage and grass cover, respectively. The objectives were: (i) to evaluate the effects of soil management, at different temporal scales, namely at yearly, seasonal and single event ones; (ii) to identify in each event the prevalent runoff mechanism (either infiltration or saturation excess) in relation to soil management, soil hydraulic conductivity and bulk density, soil moisture and precipitation characteristics.

2. Materials and methods

2.1. Study site

The study was carried out within the "Tenuta Cannona Experimental Vine and Wine Centre of Regione Piemonte" (44°40′N, 8°37′E, 296 m asl), which is located in the Alto Monferrato hilly area of Piemonte, North-West Italy. The climate is sublitoranean, (average annual precipitation of 965 mm at the Ovada station, in the period 1951–1990), mainly concentrated in October, November and March. The driest month was July. The mean annual temperature measured at Alessandria during the same period of observation was 12.6 °C (Biancotti et al., 1998). At the study site, the average annual precipitation in the period 2000–2014 was 905 mm and the mean annual air temperature was 14.5 °C. The Cannona vineyards lie on Pleistocenic fluvial terraces in the Tertiary Piedmont Basin, including highly altered gravel, sand and silty-clay deposits, with red alteration products. The soils derived from reworked Pleistocene alluvium, and they have a clay to clay-loam texture.

The experiment was conducted in two vineyard plots, which are part of a larger vineyard, lying on a hillslope with SE aspect and average 15% slope. Each plot is 1221 m^2 (74 m long and 16.5 m wide) and includes 7 vine rows aligned along the slope, where the vines are spaced 1.0 m along the row and 2.75 m between the rows. The soil has been managed with different techniques since 2000. The first plot has been managed with conventional tillage (CT, cultivated with chisel to a depth of about 0.25 m), while in the second plot grass cover has been adopted (GC, with spontaneous grass controlled with mulcher during the year). The mulcher mows and chips the grass, and residues are left on the soil surface. Soil tillage (in CT) and grass mulching (in GC) were usually carried out twice a year, in spring and autumn. In autumn 2011, the inter-rows of the GC plot were tilled and a grass mixture was sown, to renew the grass cover. The grass mixture was composed of: *Lolium perenne* 20%, *Festuca rubra* 60%, *Poa nemoralis* 15%, *Poa trivialis* 5%. Weeds under the rows of the two plots were controlled with Glyphosate in spring, 0.6 m across the vine row. Most of the farming operations in the vineyard were carried out using tracked or tyred tractors, with intensification from spring to the grape harvest time. During the period of the present study, soil tillage (in CT) and grass mulching (in GC) were carried out five times (on: 24/10/2012, 05/06/2013, 11/11/2013, 16/05/2014, 24/10/2014). The soil is classified as *Typic Ustorthents, fine-loamy, mixed, calcareous, mesic* (Soil Survey Staff, 2010) or *Dystric Cambisols* (FAO/ISRIC/ISSS, 1998). Soil textural composition obtained from soil samples taken in 2014, at 0–10 cm depth, indicated a silty clay loam soil in the GC plot, with 15% sand, 53% silt and 32% clay content; and a silt loam soil in the CT plot, with 28% sand, 54% silt and 18% clay content.

2.2. Measurements

The experiment was conducted from October 2012 to November 2014. A monitoring system provided continuous measurements of rainfall, runoff and topsoil water content for the two experimental plots. Runoff samples were also collected to obtain sediment yield for erosive events. Periodic measurements were carried out to obtain values of saturated hydraulic conductivity (K_{fs}), bulk density (BD) and initial soil water content (SWC_i) in the two plots, in order to detect the temporal variability of the field-saturated soil hydraulic conductivity at the surface of the vineyard inter-rows, with different conditions depending on soil management. Measurements were carried out both in the no-track (indicated as NT) and in the track position (indicated as T), which is the portion of soil affected by the passage of tractor wheels or tracks.