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Effects of rows arrangement, soil management, and rainfall characteristics on water and soil losses in Italian sloping vineyards☆

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ABSTRACT

Erosional processes are highly affected by seasonal climatic fluctuations and soil management practices. Controlled grass cover is one of the most used soil conservation practices adopted in temperate climates, even if the protective effect of grass cover may decrease according to seasonal pattern. This technique is effective and, thus, widely adopted in the inter-rows of orchards such as olives, citrus or vineyards. This study reports the erosive events recorded in two different rain-fed hillslope vineyards with different rows orientation located in the Monferrato region, NW Italy. The study is addressed at compare the effects of different inter-row managements and rainfall characteristics on runoff and soil loss in hillslope vineyards (average slope from 15% to 35%). Rainfall, runoff and erosion variables were monitored in hydraulically bounded vineyard plots, where the inter-rows were managed with tillage and grass cover. Seventy-two erosive events were recorded in the period 1992–1996 in two vineyard plots with rows along the contour lines while 86 erosive events were recorded in two plots with rows up-and-down the slope from 2000 to 2014 (158 erosive events and four plots in total). Events were classified according to rainfall characteristics as "long-lasting", "intense" and "normal". In plots with rows along the contour lines, "intense" events were responsible for the highest mean soil loss in tilled plots (0.7 Mg ha^{-1}) with very high erosion rates (12.3 Mg ha^{-1}) observed during a single storm. In plots with rows up-and-down the slope the highest erosion rates, 21.2 and 3.4 Mg ha^{-1}, were recorded during fall "long-lasting" events in the tilled and grass cover plots respectively. The grass cover proved to be effective in decreasing runoff and soil losses during most of the events (at least 68% and 61% of the occurrences, respectively) reducing soil losses especially during summer storms when most of the "intense" events occured. Furthermore, the results show the fundamental role of contour-slope row orientation in reducing runoff and soil losses, disregarding the inter-rows soil management that is adopted.

1. Introduction

In 2016, vineyards covered over 7.5 million ha (OIV, 2017) representing about 0.5% of the agricultural area at global scale. Furtermore, in the same year, wine market moved around 29 billion of dollars in the world (OIV, 2017), bringing their products at the top of the agricultural market. In Europe, vineyards cover 3.3 million ha and Italy, with 690.000 ha, is ranked at third position, after Spain and France (OIV, 2017). Piedmont (NW Italy) has a vineyard surface of 43.500 ha, nearly totally devoted to wine production, including 17 PGI (Protected Geographical Indication) and 42 PDO (Protected Designation of Origin) wines (Regione Piemonte, 2017a, 2017b). In 2014 *The Vineyard Landscape of Piedmont: Langhe, Roero and Monferrato* was recognized as UNESCO World Heritage Site for the outstanding landscapes and the importance of vinegrowing and winemaking in the Region (UNESCO, 2014). Vineyards are mostly located in the southern part of the region and more than 88% of the Piedmont vineyard surface is on hilly areas while over 8% is on mountain areas (Regione Piemonte, 2017c). At the same time more than 40% of the hilly areas of the Piedmont region are characterized by soils with erosion rates higher than 15 t ha^{-1} yr^{-1} (IPLA, 2009).

In the last decade, much attention has been paid to environmental impacts of agricultural activities, especially regarding soil degradation. The Soil Thematic Strategy from the European Union (EU) in 2006 (CEC, 2006a, 2006b) identified soil erosion as one of the major threats that affect European agricultural soils. Soil erosion processes in

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vineyards have been studied across Europe in order to assess runoff and soil water erosion rates in this agricultural system (Rodrigo-Comino and Cerdà, 2018; Martínez-Casasnovas et al., 2016; Novara et al., 2015; Corti et al., 2011) using different methodologies and obtaining erosion rates ranging from 0.02 t ha^{-1} yr^{-1}, measured by runoff plots over a 2-year period in Spain by Ruiz-Colmenero et al. (2011), to 15.7 t ha^{-1} yr^{-1}, estimated on a 44-years period using the technique of botanical benchmark in a mountain vineyard in North-Italy (Biddoccu et al., 2017b). Panagos et al. (2015b) estimated soil loss in Europe for the reference year 2010 by the application of a modified version of the Revised Universal Soil Loss Equation model (RUSLE2015): the mean soil loss rate in the European Union's erosion-prone lands (agricultural, forests and semi-natural areas) was found to be 2.46 t ha^{-1} yr^{-1}, resulting in a total soil loss of 970 Mt annually. Permanent crops, including vineyards, showed the highest soil erosion rate among agricultural land uses (9.47 t ha^{-1} yr^{-1}), accounting for 10% of the total soil losses in the 28 European Union countries. Furthermore, measured data (Maetens et al., 2012) showed that in the Mediterranean region runoff coefficients higher than 9% are related to vineyard land use.

Under the same land use, climate, topography, soil texture and soil management are recognized as the factors primarily affecting soil erosion (Biddoccu et al., 2016; Prosdocimi et al., 2016a; Novara et al., 2011; Cerdan et al., 2010). With regard to climate, many studies have been carried out to investigate the effects of rainfall characteristics on runoff and soil erosion (Biddoccu et al., 2017a; Gómez et al., 2014; Taguas et al., 2010). Many experiments focusing on soil erosion in vineyards are located in hillslope areas, with a slope gradient up to 35% (Rodrigo-Comino et al., 2017a, 2017b), as this is the typical landscape hosting vineyards in the European area. Specifically, a large number of studies investigates the effect on runoff and erosive processes of different soil managements and cover solutions in vineyards (Gómez, 2017; Prosdocimi et al., 2016b; Novara et al., 2011).

Several studies highlighted that the use of grass cover in the inter-rows is one of the most common and effective soil management practice adopted to reduce runoff and soil erosion in vineyards (Ferreira et al., 2018; Morvan et al., 2014; Gómez et al., 2011), improving also other ecosystem services (Garcia et al., 2018; Winter et al., 2018; Montanaro et al., 2017). Moreover, grass cover in vineyards has been comprised in the most relevant European policies for soil conservation, including the Standards of Good Agricultural and Environmental Condition (GAEC), established by Council Regulation No. 73/2009 (CEC, 2009). Indeed, under European Common Agricultural Policy (CAP), GAEC standards impose a set of requirements aiming at preventing soil erosion such as: (i) minimal soil cover maintenance, (ii) minimum land management reflecting site specific conditions to soil loss, and (iii) maintenance of soil organic matter level. Grass covering measures have been supported also at local level by Rural Development Programmes (RDPs) that are drawn up by Member States and regions addressing common CAP EU priorities that include prevention of soil erosion and improvement of soil management. With regard to Italy and Piedmont region, the measures envisaged during the 2007–2013 RDP for soil erosion prevention were essentially based on the grass covering of orchards and vineyards areas and involved more than 13,000 ha (15.4% of Piedmont's agricultural area utilized for orchards and vineyards) (IPLA, 2016).

Management of the plantations, and in particular the orientation of the rows in relation to the slope lines of the field, is an additional measure able to limit the erosion phenomena. In Piedmont, both orientation of the vine rows, up-and-down the slope and along contour lines, are adopted, depending on the slope angle, to support field mechanization and increase the land productive potential (Corti et al., 2011), because of the influence of orientation on physiological behavior of vines (Hunter et al., 2016). Nevertheless, in many studies, erosion rates are considered without paying attention to the orientation of the vine rows (Prosdocimi et al., 2016a).

Thus, this study aims at comparing the results of two experiments recording runoff and soil losses in two rainfed hillslope vineyards located in the same region, with similar soil management and inclination, but different vine rows orientation. In particular, the objectives of the study are: i) to compare the effects of grass cover with tillage in the vines inter-rows in terms of runoff and soil loss in hillslope vineyards with different row orientation; and ii) to evaluate the influence of event rainfall characteristics in determining the hydrological and erosive response of vineyards with different row orientation.

2. Materials and methods

2.1. Experimental sites

Since 1980, the Institute for Agricultural and Earthmoving Machines (IMAMOTER) of the National Research Council (CNR) of Italy has been carrying out studies on the effect of soil management on runoff and erosion in sloping vineyard. The results presented in this paper refer to soil erosion monitoring activity carried out by IMAMOTER in Piedmont, in two locations on hilly area (Fig. 1): the Vezzolano Experimental Farm (45° 04′ N, 7° 57′ E, 426 m a.s.l., located in the municipality of Albugnano), and the Tenuta Cannona Experimental Vine and Wine Center of Agrion Foundation (44°40′N, 8°37′E, 296 m a.s.l., located in the municipality of Carpeneto). The data have been collected in the two sites over the period 1992–1996 and 2000–2014, respectively. As typical in the Monferrato area, vineyards are arranged with rows along contour lines ("girapoggio") and up-and-down the slope ("rittochino"). In the Albugnano area, vines are traditionally arranged along the contour lines while in the Carpeneto area a significant part, approximately 1/4, of the vineyards in sloping conditions are arranged with rows up-and-down the slope.

2.1.1. Experimental farm of Vezzolano

The farm is located in northern part of the Monferrato area, best known as "Basso Monferrato". The area is characterized by dry summer and cold winter with snowfall events, corresponding to a transitional climate between pre-alpine and sublitoranean (ARPA, 2017). In the period 1962–2004, the mean annual precipitation was 846 mm, mainly concentrated in May, October and November, while the driest month was July. In the same period the mean annual air temperature was 11.8 °C. Soil texture is silt loam (24% clay), and the soil is classified as *Typic Udorthent* (Nigrelli, 1998; Soil Survey Staff, 2010), derived from Miocene silty marls of the Tertiary Piedmontese Basin (Tropeano, 1984).

The runoff and soil erosion data were collected from 1992 to 1996 in two plots, each one part of a vineyard grown along contour lines on a hillslope with south/south-east aspect and average slope of 15%. The monitored plots consisted in two 5200 m^2 portions of the vineyard and include rows at 2.75 m across the hillslope (originally, 15–35% gradient) arranged with slight longitudinal slope (2–10%), terraced at the head of every four rows, to mitigate the hillslope to 12–20% (Fig. 1b-c). Every 20 rows a wider inter-row (linking levelling road) with uphill counterslope collects and diverts the drainage water to the head-rows. Inter-rows were managed according the most common local practices with i) autumn ploughing and summer hoeing (named, from here on out, conventional tillage, CT); ii) grass cover mowed and chopped three times per years (named, from here on out, controlled grass cover, GC).

In the observation period rainfall was recorded with a mechanical weather station. Pluviographs were used to obtain precipitation characteristics and sub-hourly rainfall intensity for erosive rainfall events.

2.1.2. Experimental area of Tenuta Cannona

The farm is located in the southern part of the Monferrato area, known as "Alto Monferrato" (Fig. 1). 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 (Servizio Geologico d'Italia, 1969). The soils have a clay to clay-loam texture. The climate is sublitoranean. According to the