Soil & Tillage Research 168 (2017) 71–80

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Assessment of soil and nutrient losses by runoff under different soil management practices in an Italian hilly vineyard

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ARTICLE INFO

Article history:
Received 30 August 2016
Received in revised form 19 December 2016
Accepted 20 December 2016
Available online 30 December 2016

Keywords:
Soil erosion
Soil tillage
Grass cover
Rainfall

ABSTRACT

Soil erosion is among the major processes that threaten agricultural soils, causing soil and organic matter losses, loss of inherent fertility, and water contamination. In this context, vineyards are the most erosion-prone lands in the Mediterranean region. The adoption of alternative soil management practices, such as the use of permanent grass, can reduce runoff and erosion. Based on an 8-years field study in Tuscany (Central Italy), this research aimed to assess the long-term consequences of permanent grass cover in vineyard plots in terms of both runoff and soil and nutrient losses, and to investigate their relationships with rainfall characteristics. The results showed that permanent grass cover reduced significantly the average yearly runoff (by about 11.7%), in particular during copious and intense rainfalls. Also, grass covered parcels lost on average 68.5% less soil than the inter-rows with harrowed soil. Up to 4.5 and 12.5 kg $ha^{-1}year^{-1}$ of N and up to 6.2 and 5 kg $ha^{-1}year^{-1}$ of P were lost in grassed and harrowed parcels, respectively. Under both soil management practices, the total soil and nutrient losses caused by runoff were significantly correlated with rainfall height and rainfall erosivity.

1. Introduction

Soil erosion affects many agricultural areas, determining degradation of soil fertility, quality, and long-term productivity (Lal, 1995; Gunatilake and Vieth, 2000; Ramos and Martínez-Casasnovas, 2006). Further, soil erosion contributes with significant amounts of nonpoint-source (NPS) pollution to surface waters (Lenat and Crawford, 1994; Fisher et al., 2000; Verstraeten et al., 2003; Chu et al., 2004). 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; Maetens et al., 2012). In fact, soil loss values higher than 1.4 t ha^{-1} $year^{-1}$, which was proposed as the tolerable average annual soil loss limit in Europe (Verheijen et al., 2009), were measured in vineyards during several studies. For example, Tropeano (1983) found soil loss in the Piedmont region of northwest Italy to be between 47 and 70 t ha^{-1} $year^{-1}$; Wicherek (1991) found 35 t ha^{-1} $year^{-1}$ in the north of the Parisian basin in France, and Martínez-Casasnovas et al. (2002) found 207 t ha^{-1} $year^{-1}$ after an extreme rainfall in the Penedès region of northeast Spain. Moreover, during the last decade some studies have been conducted to estimate the loss of nutrient from vineyard (Ramos and Martínez-Casasnovas, 2004, 2006; Velardo et al., 2009). Most of the studies have been focused on N and particularly on P, since already low P concentrations have dramatic effects on development of algae and aquatic microorganisms (Portielje and Van der Molen, 1999). Vineyards area in Tuscany (central Italy) covers about 60300 ha (ISTAT, 2012), and approximately 51% of the vineyards in Tuscany are located on steep slopes (Napoli and Orlandini, 2015; Napoli et al., 2016a) for reasons related to both tradition and quality of production. Due to both the sloping nature of the Tuscany countryside and the conventional soil management techniques adopted, high erosion rates are observed in agricultural areas planted with vine. In this context, the adoption of alternative soil management in vineyards, such as appropriate cover crops, can significantly reduce runoff and the consequent soil erosion (Blavet et al., 2009; Marques et al., 2009; Novara et al., 2011; Biddoccu et al., 2014; Napoli and Orlandini, 2015). Therefore, in recent years, local governments increasingly concerned about the issue of soil fertility, have funded several research projects aimed at the conservation of water resources and limitation of soil erosion. Moreover, the use of permanent grass cover in vineyards and

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Abbreviations: RD, rainy days; HR, harrowed; GR, grass cover; R, rainfall; KE, kinetic energy; SSE, single storm events; OM, organic matter; N, total nitrogen; P, total phosphorous; GC, green cover; RC, runoff coefficient.

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http://dx.doi.org/10.1016/j.still.2016.12.011
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orchards is spreading because it is supported by specific subsidies for environmental measures of the EU Common Agricultural Policy.

The understanding of the long-term effects of the inter-row soil management in vineyards is recommended in order to choose the best soil and water management practices for soil conservation. This study analyses an eight-year dataset of runoff and losses of soil, nitrogen and phosphorous in a hilly vineyard in order to assess the influence of a conventional tillage technique and a permanent grass cover management on erosion processes. In order to contribute to this knowledge, the aims of this paper are i) to assess the long-term consequences of permanent grass cover in field size vineyard plots in terms of both runoff and soil and nutrient losses, and ii) to investigate the relationships between these latter with rainfall eight and erosivity in the study area.

2. Materials and methods

The activity was carried out at Montepaldi, the experimental farm of the University of Florence located in San Casciano Val di Pesa, Italy (43°39′–43°40′ N; 11°08′–11°09′ E; 256 m a.s.l.) (Fig. 1). The site was located in the "Eight Communities of Chianti" territory, where vineyards accounted for the 29% of the farmland (Napoli et al., 2014).

The climate was Mediterranean, the annual average temperature was about 14.9 °C and the annual rainfall was approximately 695.0 mm, with a summer minimum in July and two winter maxima in November and February. The average number of rainy days (RD, rain $\geq$1 mm) was about 86. The experiment lasted 8 years, from January 2005 to December 2012. Runoff and soil loss measurements were carried out in 25-years-old trained vines (*V. vinifera L.)* of Sangiovese red variety. The vine rows were 89.5 m long and ran parallel to the maximum slope degree direction on a S-SW facing convex slope (30% and 4% slope in the lower and in the upper part, respectively). Vines were planted in a 0.8 m × 2.7 m pattern and low-cordon trained. The inter-rows were covered by a mixture of spontaneous grasses: *Bellis perennis* L., *Bromus hordeaceus* L., *Cynodon dactylon* L. (>90%), *Holcus lanatus* L., *Hordeum murinum* L., *Plantago media* L., and *Tussilago farfara* L. According to the U.S. Soil Taxonomy (USDA, 1999), the soil was classified as loamy-skeletal, mixed, mesic, Typic Ustorthents. Soil depth varied within the parcel from about 110–120 cm at the upper part to 160–170 cm at the bottom. The soil colour was light olive brown (2.5 Y 5/4 according to Munsell Soil Colour Chart). The average stone content was about 21%. The principal soil characteristics (0–10 cm) at the beginning of the experiment are reported in Table 1.

Within the vineyard four parcels (490 m^2), each containing two inter-rows, were delimited with an earth bank, with some 0.2 m in height, forming the field boundaries (Napoli et al., 2016b). The space around the vines was kept free of grass by distributing in March a commercial formulation of glyphosate (360 g L^{-1} a.i.) in a 1 m wide strip along each vine row at a dose of 2 L ha^{-1}. Two treatments, harrowed inter-row (HR) and inter-row permanent grass covered (GR), were applied in order to assess soil and nutrient losses and runoff processes. The soil in HR was harrowed once a year in late April using a three-point field cultivator with 9 shanks on two lines, able to till a 2.2 m wide surface. In GR, the inter-row soil remained undisturbed. Grass height, on both HR and GR inter-rows, was kept below 0.15 m height with periodical shredding. Fertilization consisted of one yearly application of 31.5 kg ha^{-1} of ammonium-nitrogen, 28.5 kg ha^{-1} of nitrate-nitrogen, 5.4 kg ha^{-1} of phosphoric anhydride soluble in neutral ammonium citrate, 9.2 kg ha^{-1} of phosphoric anhydride soluble in water, and 30 kg ha^{-1} of potassium oxide. Fertilizer was applied using a distributor of granulated fertilizers attached to the three-point hydraulic system of the tractor.

Each parcel was equipped with devices for measuring runoff and collecting integrated samples for laboratory analysis (Bazzoffi et al., 1989; Caracciolo et al., 2012). Moreover, the site was equipped with a raingauge (Onset RG2 M, Pocasset, MA, U.S.A.) and an electronic meteorological station (SIAP SM3830, Bologna, Italy) for measurement of standard meteorological variables. Rainfall (R) was recorded at 1-min intervals. Single storm events (SSE) were selected by taking into account a rainfall height threshold of 13 mm (Wischmeier and Smith, 1958). Kinetic energy (KE; MJ ha^{-1} mm^{-1}) and rainfall erosivity (EI_{30}; MJ ha^{-1} h^{-1}) were estimated according to Wischmeier and Smith (1978) for each SSE over the period of record (Eqs. (1) and (2)).

$$KE = 0.119 + 0.0873 \log I \quad (1)$$

Where I was the rainfall rate (mm h^{-1}).

$$EI_{30} = KE \cdot I_{30} \quad (2)$$

Where I_{30} was the maximum thirty minute rainfall rate of the SSE (mm h^{-1}).

Six samples of inter-rows surface soil (0–10 cm) were collected in duplicate at equidistant positions along the slope (Fig. 1). Soil samples were lab analysed for determining soil texture (USDA,

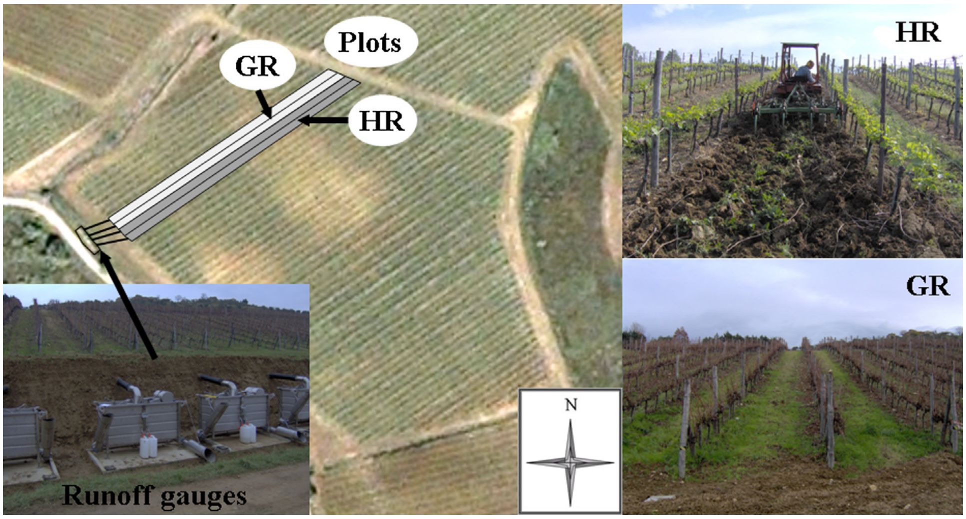

Fig. 1. T s (HR) (top right); permanent grass covered plots (bottom right).