Agriculture, Ecosystems and Environment 213 (2015) 194–208

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Simulating soil conservation measures to control soil and nutrient losses in a small, vineyard dominated, basin

M.C. Ramos*, C. Benito, J.A. Martínez-Casasnovas

Department of Environment and Soil Science, University of Lleida, Lleida, Spain

ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form 25 June 2015
Accepted 3 August 2015
Available online 15 August 2015

Keywords:
Erosion rates
Mediterranean climate
Rainfall patterns
Runoff
SWAT model
Vegetative filter strips
Vines

ABSTRACT

In recent decades, newly planted vineyards have been adapted for labor–saving mechanization. This has facilitated the use of machinery, but has meant that most of the soil and water conservation measures, which were assets in the original plantations, have had to be eliminated. This work analyses the effects of introducing drainage terraces and vegetative filter strips in a small basin (0.46 km^2) whose main land use is vine cultivation. The basin is located in the municipality of Piera (Barcelona province, NE Spain). Soil and nutrient losses were simulated in scenarios with and without soil conservation measures, using SWAT, for years with different rainfall amounts and characteristics. The model was calibrated and validated using data collected in the basin during the period May 2010–December 2012. The annual rainfall during the study period ranged from 329.8 to 785 mm, with runoff rates of between 4.1 and 21% of total precipitation. In the scenario without conservation measures, annual soil losses ranged from less than 1 Mg ha^{-1}, in the driest year, to 13.9 Mg ha^{-1}, in the wettest. Average annual nutrient losses were around 2.7 kg nitrate (N–NO_3) ha^{-1}, 17 kg organic nitrogen (OrgN) ha^{-1}, 0.5 kg soluble phosphorus (SolP) ha^{-1} and 5.5 kg organic phosphorus (OrgP) ha^{-1}. These results highlight the fact that soil and nutrient losses from vineyards contribute to non-point source pollution and also to economic losses for grape producers. The introduction of drainage terraces produced a reduction in soil losses of up to 20%. Introducing filter strips further reduced these soil losses by up to 57%, while nutrient losses were significantly reduced by the introduction of both measures.

1. Introduction

In recent decades, land use and management practices have undergone significant changes in rural areas of Europe (Verburg et al., 2010) and particularly in the Mediterranean region. As a consequence of the EU's Common Agricultural Policy, the cultivation of certain crops has been intensified (Lambin et al., 2001). In most cases, this has required the leveling and transformation of agricultural land and the reorganization of existing plots. These transformations have had an impact not only on the landscape, but also on soil degradation (Martínez-Casasnovas and Sánchez-Bosch, 2000; Borselli et al., 2006; Bazzoffi et al., 2006). Soil profiles have been altered and the resulting cultivated soils present spatial variability in soil depth. In general, these soils also have low organic matter contents, poor structures and low infiltration capacities; these are all characteristics that favor erosion processes.

Most of the soil and water conservation measures that were assets of the original plantations have since been eliminated. This has favored soil erosion processes and has led to a reduction in water storage within the soil profile. The Anoia-Penedès region (NE Spain), which is part of the Mediterranean region with a long viticulture tradition, provides a clear example of such transformations. Some of the research carried out in this area has pointed to the magnitude of the ongoing erosion processes in these vineyards, which cause high soil and nutrient losses (Martínez-Casasnovas et al., 2002; Ramos and Martínez-Casasnovas, 2006a). Soil erosion not only causes economic losses for farmers (Martínez-Casasnovas and Ramos, 2006); it also entails the loss of soil and water quality. Soil losses exceed the soil loss tolerance level, resulting in continuous soil degradation. Other studies conducted in this area have highlighted the influence of land transformations on soil hydrological properties, with reduced infiltration rates and water retention capacities and an increasing susceptibility to surface sealing (Ramos, 2006; Ramos and Martínez-Casasnovas, 2006b) and to surface runoff resulting in the loss of soil and crop productivity (Ramos and Martínez-Casasnovas, 2010a, 2010b).

* corresponding author at: Department of Environment and Soil Science, University of Lleida, Av Rovira Roure 191, E25198 Lleida, Spain. Fax: +34 973 702 613.
E-mail address: cramos@macs.udl.es (M.C. Ramos).

http://dx.doi.org/10.1016/j.agee.2015.08.004
0167-8809/

In the Anoia-Penedès region, the most frequently used traditional soil conservation measures used to be drainage terraces, known locally as " *rases* ". These present a great diversity of designs, which include different geometrical shapes (such as triangular or trapezoidal bases), and have different depths, lengths and slopes (Ramos and Porta, 1997). In the past, this type of terrace seems to have been effective in reducing water velocity and retaining soil displaced by runoff, thereby preventing its removal from the fields (Martínez-Casasnovas et al., 2005). However, in most cases these terraces have not been maintained in new vineyards. The elimination of these traditional forms of conservation has been mainly driven by the need to plant longer vine rows in order to facilitate the circulation of machinery within the fields and to increase the density of planting. However, the high soil losses subsequently recorded in these vineyards show the need to apply new conservation measures.

Green vegetation cover has been successfully used in vineyards to increase infiltration rates and reduce soil losses. Thus, Garcia-Estringana et al., (2010) found that infiltration rates were 7.9 times greater in vineyards with herbaceous cover than in those with bare soil. The same authors also reported reductions in soil loss from 61.4 $g\,m^{-2}$ to 4.5 $g\,m^{-2}$. Similarly, working in Sicilian vineyards, Novara et al., (2011) observed reductions in soil losses ranging from 39.6 to 69.8% for different cover crops.

Changing from conventional to minimum tillage has also produced satisfactory results. Ruiz-Colmenero et al. (2013) reported reductions in soil losses from 5.88 $Mg\,ha^{-1}\,yr^{-1}$ in vineyards with conventional tillage to 0.78 $Mg\,ha^{-1}\,yr^{-1}$ in those with permanent herbaceous cover. Similarly, Bienes et al. (2012) reported a reduction in soil loss from an average of 20 $Mg\,ha^{-1}\,yr^{-1}$ with bare soil to 1.76 $Mg\,ha^{-1}\,yr^{-1}$ when spontaneous vegetation was grown. The effectiveness of filter strips between rows in vineyards has been also shown (Ohliger and Schulz, 2010; Novara et al., 2013). Even so, soil cover has not been traditionally applied in the study area in order to avoid competition for water. More recently, this practice has been encouraged by the Department of Agriculture of the Catalan Government (DAR, 2010), but it has not been extensively applied or accepted by farmers for the same reason.

The Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) has been used to estimate the effects of applying terraces and vegetative filter strips to limit soil and nutrient losses (White and Arnold, 2009; Moriasi et al., 2011; Park et al., 2011; Aouissi et al., 2014). This model, which is widely used to predict soil, water and agricultural chemical exportations in basins and at different scales (Jayakrishnan et al., 2005; Akhavan et al., 2010; Lam et al., 2010; Roebeling et al., 2014), makes it possible to consider different management practices and changes in land cover.

The objective of the present study was to analyse the implications of introducing drainage terraces in a small basin (0.46 km^2) in which vines are the main land use and where high magnitude erosion processes have been recorded. The additional effects of introducing vegetative filter strips were also analysed. The SWAT model was used for this purpose and the results were analysed in terms of reductions in soil and nutrient losses associated with conservation measures.

2. Material and methods

2.1. Study area

The study area is located in the Anoia region, about 40 km northwest of Barcelona (1°46′11″ E, 41°31′52″ N, 340 m a.s.l.). The

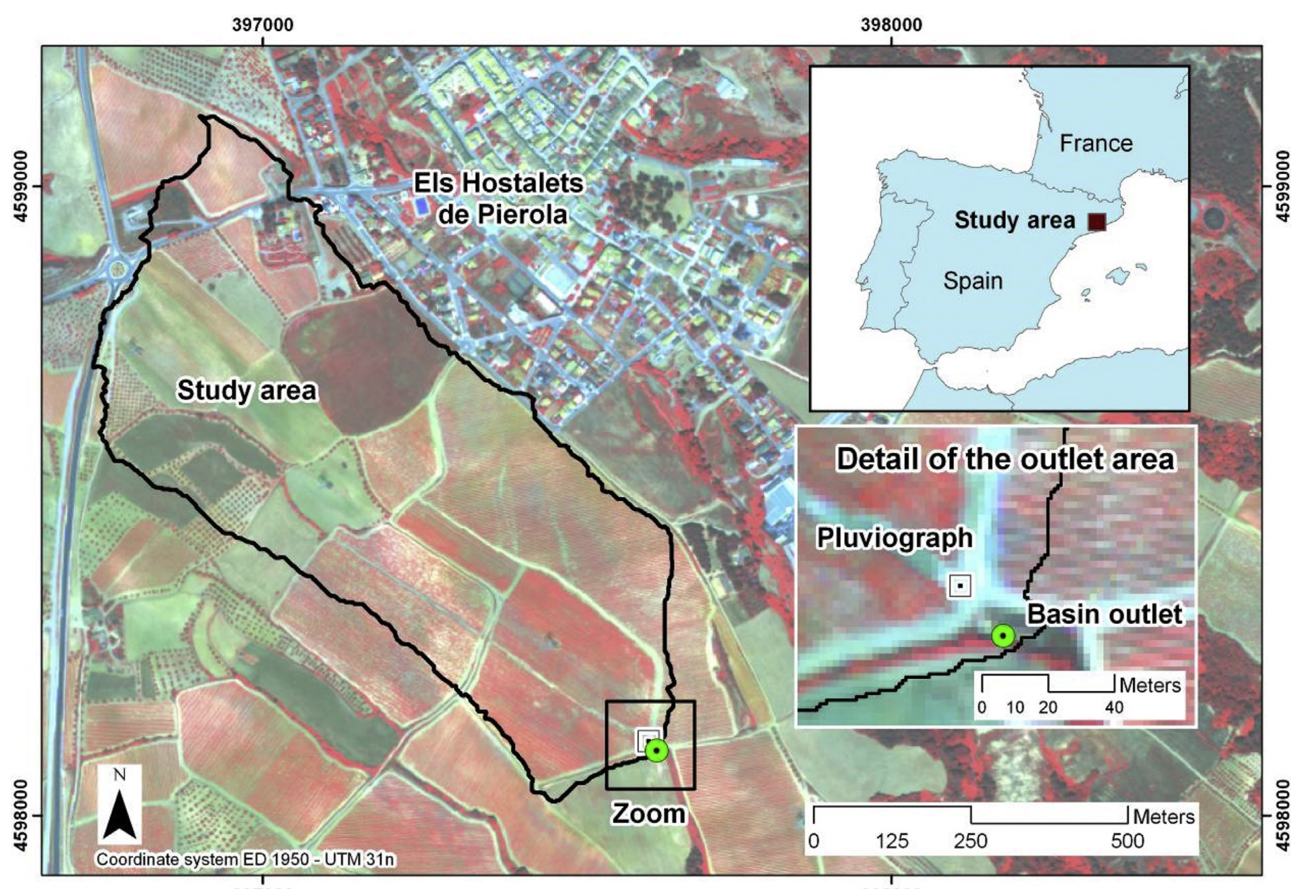

Fig. 1. Location of the study area. Basin delimitation over a false color composite of a World view-2 multi-spectral image (RGB NIR, Red, Green).