Ecological Indicators 85 (2018) 509–517

Contents lists available at ScienceDirect

Ecological Indicators

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

Research paper

Improving stock unearthing method to measure soil erosion rates in vineyards

Jesús Rodrigo-Comino[a,b,*], Artemi Cerdà[c]

[a] Instituto de Geomorfología y Suelos, Department of Geograpy, University of Málaga, 29071, Málaga, Spain
[b] Physical Geography, Trier University, 54286 Trier, Germany
[c] Soil erosion and Degradation Research Group, Department of Geography. University of Valencia, 46010 Valencia, Spain

ARTICLE INFO

Keywords:
Vineyards
Soil erosion indicator
Improved stock unearthing method
Connectivity

ABSTRACT

Vineyard soils experience high erosion rates compared to soils from other agricultural land uses. The high soil losses in vineyards limits the sustainability of traditional production schemes and warrants comprehensive research aimed at thwarting the main erosion processes affecting vineyard systems. However, long-term measurements, which include spatial variability of soil erosion rates at the plot scale, are uncommon, as most of the measurements have taken place either at the hillslope or watershed scales. Against this background, the stock unearthing method (SUM) can be considered a useful methodology. However, the current method falls short because it assumes that the topography between the vine lines (inter-rows) remains planar. Therefore, we propose a new methodology (ISUM: improved stock unearthing method) that includes three measurements between in the inter-row areas. By taking inter-row measurements, we hypothesized that the spatial patterns of sediment detachment, transport and deposition features in the inter-rows would be detected. The ISUM costs 20% more time to conduct than the SUM, but greatly improved the utility of the field survey. ISUM allowed for: i) the creation of maps that identified linear soil erosion features and accumulation sites; ii) measures the amount of soil accumulated under the vines; iii) estimation of soil erosion rates with higher accuracy at long-term periods in a specific moment. This study compared the ISUM with the SUM in a vineyard in Spain. Soil erosion rates with ISUM were -2.5 Mg ha yr^{-1} while the SUM calculated rates of $+4.9$ Mg ha yr^{-1}.Results showed that the traditional method underestimated soil rates a -25.7%. Maps created with the ISUM technique could also be used to provide insights about sediment connectivity.

1. Introduction

Many vineyards have exceeded their ecological limits as they often occupy lands with critical natural conditions such as steep slopes, shallow and rocky soils and dry climatic conditions, factors that may induce high soil erosion rates (Molinero Hernando, 2012; Prosdocimi et al., 2016; Vaudour et al., 2017). The high erosion rates found in vineyards threaten the goods and services that soils offer to humans (Mol and Keesstra, 2012; Brevik et al., 2015) and undermine the United Nations goals of reaching sustainability (Keesstra et al., 2016a). However, viticulture areas remain economically and socially relevant and are often highly appreciated for their cultural heritage (Koch et al., 2013; Lourenço-Gomes et al., 2015). They are often targeted as landscape which should be protected (Leeuwen van et al., 2004; Martínez-Casasnovas et al., 2010).

Soil erosion on vineyards threatens the sustainability of the vine production system (Martínez Casasnovas and Ramos, 2006). Verheijen et al. (2009) defined tolerable erosion rates in the fields where degradation or loss of "one or more soil functions does not occur", meaning in Europe from 0.3 to 1.4 Mg ha^{-1} yr^{-1}. However, in vineyards, this limit is widely surpassed. For example, Martínez-Casasnovas et al. (2003) summarized total average net erosion of 576 Mg ha^{-1} yr^{-1} within their study period (1975–95) in a gully close to a vine plantation. Cerdan et al. (2010) using a *meta*-analysis quantified a total average net erosion for European vineyards of 8.62 Mg ha^{-1} yr^{-1}. In Italy, in Sicilian vineyards, Novara et al. (2011) using the pin erosion method measured erosion rates of as high as 102 Mg ha^{-1} yr^{-1}.

Traditional vineyards are commonly planted along contour lines or contain small terraces with moderate slopes, which are supported by long rows of plants (Ramos and Porta, 1997; Sofia and Tarolli, 2017). Both of these systems lead to increased grape and wine productions, but may consequently enhance land and ecosystem degradations due to accelerated soil erosion, intense ploughing, use of pesticides, herbicides and fungicides (López-Piñeiro et al., 2013; Salomé et al.,2016).

* Corresponding author at: Instituto de Geomorfología y Suelos, Department of Geograpy, University of Málaga, 29071, Málaga, Spain.
E-mail address: rodrigo-comino@uma.es (J. Rodrigo-Comino).

http://dx.doi.org/10.1016/j.ecolind.2017.10.042
Received 3 April 2017; Received in revised form 17 October 2017; Accepted 19 October 2017
1470-160X/

Extreme rainfall events are also major drivers that cause high erosion rates. But a lack of vegetation (grass or shrub) and, or litter cover (García-Díaz et al., 2017; Novara et al., 2011; Rodrigo-Comino et al., 2017a) or the use of heavy machinery (Bogunovic et al.. 2017; Ferrero et al., 2005) can also enhance soil erosion processes. In this way, land management strategies in vineyards can be seen as abusive of soil resources, as they increase the risk of catastrophic floods, non-point pollution of chemicals caused by excessive overland flow and decrease of water and nutrient availability for the vines (Calleja-Cervantes et al., 2015; Leonard and Andrieux, 1998). Nowadays, there is a growing awareness of these issues, which has resulted in research aimed to reduce soil losses by means of soil and water conservation strategies (Martínez Casasnovas and Sánchez-Bosch, 2000; Cerdà et al., 2017a). Moreover, recently, new studies quantify and confirm that vineyards are not sustainable since the initial planting due to the impact on soil properties (Cerdà et al., 2017b; Rodrigo-Comino et al., 2017b).

The negative impacts registered at the intra-plot scale in soil erosion (e.g. rills, soil properties, etc.) in vineyards is well known by researchers (Chevigny et al., 2014; Rodrigo-Comino et al., 2016a) and farmers alike (Bramley and Hamilton, 2004; Marques et al., 2015). This has necessitated the development of cheap and easily applied measurement methods that are able to survey spatial and temporal topographical changes in the landscape. Such methods can consequently foresee the development of rills and gullies, which are the principal landscape features leading to the more extreme erosion rates in agriculture lands (Defersha et al., 2011). Most research regarding intra plot variabilities has been focused on short-term (years) time periods. Long-term scale (decades) field measurements, though often claimed to be necessary, are rare, while the information derived from long-term measurements is fundamental to developing and selecting suitable land management plans (Keesstra et al., 2016b) and the sources can be heterogeneous (Smith et al., 2015). Performing long-term topographic measurements of vineyards has proven to be both difficult and costly (De Sy et al., 2013). Therefore, there has been a need to develop long-term measurement techniques to address these demands.

The stock unearthing method (SUM) has been shown to be a reliable method to estimate erosion rates and spatial distribution of the topsoil from pluri-annual to pluri-decennial time scales in vineyards (Brenot et al., 2008; Casalí et al., 2009; Paroissien et al., 2010). This method is similar to a dendro-geomorphological method which is based on the measurement of the distance from the topsoil to the grafted vine stock union. The graft union has been confirmed as a passive indicator of topsoil movements since the initial planting of vine stock. This method is able to estimate erosion rates at temporal scales sufficiently long to evaluate the cumulated effects of tillage practices, but also to show the spatial distribution of the sediment detachment, transport and deposition under natural rainfall events within a specific time frame.

Significant changes in topsoil level caused by the impact of rainfall events and soil tillage practices in traditionally managed vineyards can lead to land degradation processes by decreasing soil quality, nutrient and water losses or pollutant transports (Blavet et al., 2009; García-Díaz et al., 2017). To assess changes in soil level, stock unearthing method (SUM) has been a useful method because: i) it is relatively easy to be applied; ii) it generates accurate data which are representative of long-term periods of soil erosion rates; and, iii) it is an easily reproducible tool which can generate the production of a very high actual DEM resolution (cm) without drones or planes. The papers published by Brenot et al. (2006,2008), Casalí et al. (2009), Paroissien et al. (2010), Chevigny et al. (2014) and Quiquerez et al. (2014) as well as the most recent by Rodrigo-Comino et al. (2016b) and Biddoccu et al. (2017) have not only provided estimates of soil erosion rates and identified the main factors responsible for intra-plot variability, but have generated new information for the education of the stakeholders about the environmental issues.

The most recent studies have tested the SUM accuracy by comparing SUM results with digital elevation models, GPS, orthophotography (Biddoccu et al., 2017; Chevigny et al., 2014; Quiquerez et al., 2014) or with data generated from sediment collectors (Rodrigo-Comino et al., 2016b). However, all of these studies assumed the main limitation of this method: the surface between the vines (inter-row) remains planar. In this way, the effect on soil roughness from tillage, rill development, footpaths, and wheel tracks, plus the consolidation of the soil after tillage or since plantation may have been ignored, as these factors lead to uneven topographical characteristics. Soil is constantly reallocated due to the passing of machinery for various purposes, surface washing of materials as well as consolidation of the soil matrix after the tillage. The SUM method should be enhanced to include measurements which incorporate those factors affecting soil movement in the inter-row areas. Those improvements will contribute to a more accurate soil erosion measurement that will end in a more sustainable management and nature based solutions (Keesstra et al., 2018).

Therefore, the main aim of this methodological approach is to develop an improved SUM. Moreover, we tried to maintain the improved method's ease to apply and of low cost. To achieve this, we intensively measured two vine rows of a vineyard in Eastern Spain by applying the newly developed improved stock unearthing method (ISUM), and compared the results with the results garnered from the traditional method (SUM).

2. Materials and methods

2.1. Study area

We selected a plot from the traditional viticulture region of Terres dels Alforins, in Valencia province (Valencia, Eastern Spain). The experimental area is located in Les Alcusses valley within the Moixent municipality (Fig. 1). The study area is a representative vineyard, located in a colluvial lying area (footslope position) with active erosion processes, including tillage and water soil erosion. The selected rows were considered as representative because they had not been recently tilled and there were clear signals of soil erosion (e.g. rills and sinks).

The plantation belongs to the Celler del Roure winery and is 25-years old, with a framework of 3.0 × 1.4 m. Each row contains approximately 125 and 130 vines (≈175 m). The observed soil profiles reach from 40 to 60 cm depth and are homogeneous due to millennia old practice of tillage. All the rows and inter-rows receive the same agricultural treatment: tillage (three times per year). The soil texture is sandy-loam. At the surface, the rock fragments cover from 25 to 40% and from 10 cm depth, the volume of rock fragments and gravels in the soil profile are lower than 10%.

2.2. Stock unearthing method: improvements from SUM to ISUM

The stock unearthing method (SUM) aims to measure the distance between frontal marks on the graft union of vines and the actual soil surface. The unearthed graft union reflects the initial distance between the vine stock and the actual topsoil level at the date of observation. Before the initial vine plantation under which grafting occurred, soil is levelled and the saplings (30–40 cm tall by 1–2 cm diameter grapevine) roots are used inserted into the soil. When manually planting, the graft union is consistently placed at 2 cm height to allow the vine to avoid complications caused by soil moisture, freezing, and fungi pests. The distance of the graft union to the original soil level has remained constant since the original vine stock does not grow vertically (Brenot et al., 2006; Brenot et al., 2008; Casalí et al., 2009); only the new part corresponding to the new grape variety will grow (Fig. 2a). Therefore, changes from the theoretical initial conditions due to depletion (Fig. 2b) or accumulation (Fig. 2c) of sediments can be estimated. We confirmed with the farmers the unappreciable vertical growth of the graft union after planting and the proof of the initial elevation as constant at a parallel control plot with new vines (initial distance = 2 cm).