Discriminating impacts of geomorphological and human factors on vineyard soil erosion (Burgundy, France)

Emmanuel Chevigné, Amélie Quirques, Christophe Petit, Pierre Curny

UMR CNRS 6298 ARTISHE, Université de Bourgogne, 6 Bd Gabriel, F-21000 Dijon, France

Introduction

Vineyards are known to undergo substantial soil loss in comparison with other types of agricultural land. Hydroic erosion on vineyards is controlled by complex interactions of natural and anthropogenic factors leading to intra-plot spatial heterogeneities of topsoil at a scale of a metre. Studying the relationship between soils and their degradation is crucial in this situation where soil sustainability is threatened. This study explores the relative influences of historical and present-day anthropogenic factors and geomorphological processes controlling soil erosion on vineyard hillslopes. The selected area was located in the Monthelie vineyard (Côte de Beaune, France) where intensive erosion occurred during high intensity rainfall events. Soil erosion quantification was performed at a square-metre scale using dendrogeomorphology. The obtained maps, together with various complementary datasets, such as geological and geomorphological data, but also historical documents (cadastral plans, cadastral matrices and old aerial photographic archives) allow the landscape evolution to be assessed.

Erosion map

Soil erosion quantification was performed at a square-metre scale using dendrogeomorphology. This method is based on the measurement of the unearthing of the stock located on the vine plants, considered as a passive marker of soil-surface vertical displacement since the year of plantation (Brenot et al., 2008).

Two campaigns of measurement were conducted in winter 2004 and in spring 2012. Each vine stock was measured twice, allowing erosion rate and spatial distribution variation to be detected.

Factors controlling erosion

Lithology was mapped by processing the geophysical data acquired in 2012 using the Automatic Resistivity Profiling method (ARP®, Qubis, 2008). The change in soil apparent resistivity from 30 to 70 °C (Area B) shows a change in lithology that matched a limestone bed in a marly formation. This area is correlated with a NW-SE trend on the erosion map, observed in Area A. Mean SUM (2004) and mean topsoil values are respectively:

- 4.8 cm and 62 % on the limestone bed area
- 6.3 cm and 62 % on the alluvial slope area
- 1.0 cm and 42 % downslope area

Electrical resistivity map performed at a square-metre scale on a 0.50 cm investigation depth. Resistivity variations highlight changes of lithology.

The use of historical documents as cadastral plans, cadastral matrices and aerial photography allows to identify factors controlling erosion patterns on the plot.

It appears that erosion patterns are still influenced by historical landscape structures. Some landscape structures:

- As historical gullies or paths present favorable conditions for erosion formation
- As damantelled dry-stone walls, present favorable conditions to preserve soil from erosion

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Discussion and Conclusion

This study shows that erosion in a vineyard context is controlled by complex interactions between geomorphological processes and historical and present-day anthropogenic factors. More specifically, this work highlights the role of historical anthropogenic structures, such as landscape architecture, with regard to erosion in a vineyard context. Historical landscape structure has an impact on erosion intensity and spatial distribution. Some historical structures, such as dry-stone walls, decrease erosion, whereas historical gullies increase erosion. Our study also shows that the impact of historical landscape structure generally declines over time. However, in a step slope context, erosion dilutes the effects of both historical and present-day anthropogenic factors. Conversely, the effects of historical landscape structure are partially preserved when the slope is mowed.

This study demonstrates that it is crucial to take into account the pre-plantation history of plots in order to assess the spatial distribution of erosion, especially on vineyard hilltops where soil losses have major economic and environmental consequences. The SUM appears to be useful method to quantify the effects of management practice changes on soil erosion on the long term.

References


Evolution of erosion patterns over the last decade

In this anthropogenic context, where soils are continually perturbed by vineyard management practices, we evaluate the evolution of erosion patterns and intensity over the last decade (2004 to 2012). The map of differential SUM, presented thereafter, was calculated by subtracting for each vine stocks the 2004 SUM to the 2012 SUM.

On the 1 ha plot:
- 9,384 vine stock were measured in 2004
- 7,316 vine stocks were measured in 2012

The difference between the two periods is caused by erosion increase or disease.

For both maps, it is possible to identify three areas by their erosion patterns (A, B and C):

- Area A is characterised by low erosion values detected and by high erosion values upslope.
- Area B displays linear erosion patterns with NW orientation.
- Area C presents linear erosion patterns with NNW-SEE orientation.

All of these erosion patterns are uncorrelated to the mean slope direction (NW-SE).

Soils and erosion values are grouped in four classes that correspond to:

- Low erosion values (less than 4 cm)
- Medium erosion values (between 4 and 8 cm)
- High erosion values (between 8 and 12 cm)
- Very high erosion values (greater than 12 cm)

SUM and erosion rates calculated for each area with specific erosion patterns from the 2004 and 2012 datasets.

We propose that the increase of erosion rate between the two periods could be related to the change in weed management practices from chemical weeding and no tillage (NT) to surface tillage (ST) in 1992. This hypothesis is consistent with the study performed by Le Bissonnais and Andreu (2007) who demonstrated that erosion rate increased with the change from NT to ST. We assume that erosion increase can be explained by a change of the wheel compacting occurrence on inter rows in vineyard context. In NT, plots the superficial layer remains compact, which reduces the soil particles detachability and limits erosion. Conversely, in ST plots, the soil tilth modifies the superficial soil structure, composed of a loosened soil surface layer overlaying a low permeability compact layer, which favours soil erosion during intense rainfall events.

Erosion is controlled by the combination of two factors, i.e. historical landscape structure (NS orientation) and present-day vineyard management practices (NW orientation).

Factors controlling erosion

Plot reference Area Number of vine stocks measured Mean SUM Period 1 Period 2 Relative increase from period 1 to 2 %

Area 1 3790 3347 2876 3.6 ± 0.13 3.0 ± 0.11 1.1 ± 0.04 0.7 ± 0.13 123
Area 2 2880 2712 1892 6.1 ± 0.18 3.8 ± 0.22 1.9 ± 0.06 4.2 ± 0.06 121
Area 3 3665 3325 2038 4.2 ± 0.12 4.5 ± 0.19 1.3 ± 0.04 1.5 ± 0.07 15