Soil erosion rates in Burgundian vineyards

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ABSTRACT

Burgundian vineyards are affected by erosion phenomena that induce sediment transfer along hillslopes. The vineyard under study has occupied the western Bressan rift border for 1000 years, benefiting from marly limestone bedrock and its silt-sand covering. The combined effects of rainstorms and monoculture on slopes reaching 25°, induce a high level of erosion in the arable soil layer. Quantification of erosion rates on a pluri-decennial scale, using vine roots as a palaeo-surface marker, has been performed on three parcels on three sites along the Côtes-de-Nuits and Côtes-de-Beaune. Assessed erosion rates of around 1 $mm.yr^{-1}$ characterise current erosive dynamics involving a critical situation for soil sustainability, and consequently for terroir conservation.

KEY WORDS: *Erosion rate, vineyards, Burgundy.*

RIASSUNTO

Tassi di erosione del suolo nei vigneti del Borgogna.

I vigneti della costa della Borgogna presentano fenomeni di erosione lungo i versanti. Questi vigneti occupano il bordo degli altopiani che sono sospesi sulla pianura della Bresse, caratterizzate da substrati marno-calcarei giurassici e da coperture superficiali limoso-sabbiose. L'effetto combinato di una monocultura su forti pendenze e di forti temporali provoca l'erosione di strati arabili dove sono state piantate le viti.

Una quantificazione dell'erosione è stata realizzata su tre zone della Côte de Nuits e della Côte de Beaune. I tassi d'erosione che raggiungono 1 $mm.an^{-1}$ indicano che la dinamica attuale di tali altopiani è in una situazione critica per la conservazione del suolo e dunque del territorio.

TERMINI CHIAVE: *Tasso di erosione, vigneti, Borgogna.*

INTRODUCTION

The quantification of soil degradation in terms of budget and quality, in the Burgundian vineyards, is crucial for environmental and economic reasons since it has direct consequences for wine-growing (CHAMBRE D'AGRICULTURE DE SAONE-ET-LOIRE, 1988). Erosion processes cause the physical ablation of plots by gullying, and soil exportation by mudflows, during rainstorm events. These processes lead to an ablation of hillslope covers where vineyards are implanted (fig. 1). In order to maintain soils on hillslopes, anthropic earth supply is transferred to these gullies, which modifies soil loss budget. Therefore, sediment distribution in Burgundian vineyards results from slope dynamic processes and agricultural practices.

The purpose of this study is to describe soil losses, and to quantify and compare soil erosion rates, from the survey of three representative plots in the Burgundy vineyards. This study, if extended to the scale of all Burgundian vineyards, should allow the relative importance of natural and anthropic processes to be quantified, leading to further discussion of the sustainability of the Burgundian terroir.

STUDY CONTEXT

Three plots have been studied in the Burgundian vineyards (fig. 2): Vosne-Romanée and Aloxe-Corton located on the Côtes-de-Nuits, and Monthélie on the Côtes-de-Beaune. All these vineyards are located along a fault-scarp relief induced by Bressan rifting that constitutes the eastern border of the limestone plateaux. The slopes are composed of Middle to Upper Jurassic limestones and marls (MÉRIAUX *et alii,* 1981). Lithology of these sites changes from north to south with increasing marly outcrops (fig. 3). Slopes reach 12° in Vosne-Romanée, 17° in Aloxe-Corton and 24.5° in Monthélie. Jurassic bedrock is covered by silty-clayey colluviosol and cryoclastic screes, with a variable sand-gravel ratio, depending on bedrock lithology, but also on stone clearing. These colluviums are at most a few metres thick: for example, the sandy-clayey screes («grèzes litées») reach 3 metres on Comblanchien limestones in Vosne-Romanée. On Aloxe-Corton hillslopes, a 0.5 to 1 metre thick layer covers the Jurassic marls. This surficial sedimentary layer is generally devoid of pedogenetic segregation. Absence of soil development indicates that sediment is removed from this layer by hillslope processes, i.e. erosion on slopes and sedimentation on toes of slopes. Moreover, frequent earthworks, i.e. earthmoving and tilling, prevent soil stabilisation and pedogenesis.

Some hillslopes, characterised by a hundred-metre mean elevation, have been used for wine-growing since the Middle Ages, and some even since Roman times (DION, 1959; LEBEAU, 1986). After the *Phylloxera* crisis at the end of the 19th century, replantation and mechanisation modified the parcellar and row plantation system (LAURENT, 1957). Rows, planted parallel to the slope, induce propitious conditions for rill. The landscape is characterised by monoculture where parcellar limits, walls and paths are the only discontinuities along the slope.

As gullies grow to greater proportions, a critical situation arises when bedrock is reached, particularly on lime-

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stones, as is exemplified in the Aloxe-Corton plots (fig. 1). Most of the time, erosion effects are counterbalanced by anthropic earth supply, stored in toe of plot, following a traditional practice dating at least from the Middle Ages (1393 A.D.; BECK, 1996). Non-grassed inter-rows, slope-oriented rows and superficial tilling are the dominant agricultural practices. Such conditions are met in the three parcels selected for the study.

METHOD

To quantify erosion rate for each plot, we first calculate an eroded volume corresponding to the net exported material since the vinestock plantation year. This volume is estimated by using a biological marker, i.e. the vinestock. Traditionally, the vinestock must be planted with the grafting level 1 cm above the surface, with a variation of ±1 cm depending on soil roughness and planting technique (NEBOIT, 1983; GALET, 1993). By measuring the gap between the grafting level and the current surface, net soil loss at each vinestock can be calculated. Another agricultural practice defined by wine-growing rules is vinestock density, imposing 10,000 vinestocks per hectare. Each measurement on a given plot will thus show mean soil loss at a metre scale resolution. The initial soil surface level, based on the position of the vinestock, can therefore be reconstructed (fig. 4). The net soil

Fig. 1 - Gullies developed in colluviums on calcareous bedrock (top, En Charlemagne, Aloxe-Corton) and on marly bedrock (bottom, Monthélie, Le Cloud des Chênes).
– Solchi di erosione sviluppati nel colluvium su substrato calcareo (sopra, En Charlemagne, Aloxe-Corton) e su substrato marmoreo (sotto, Monthélie, Le Cloud des Chênes).

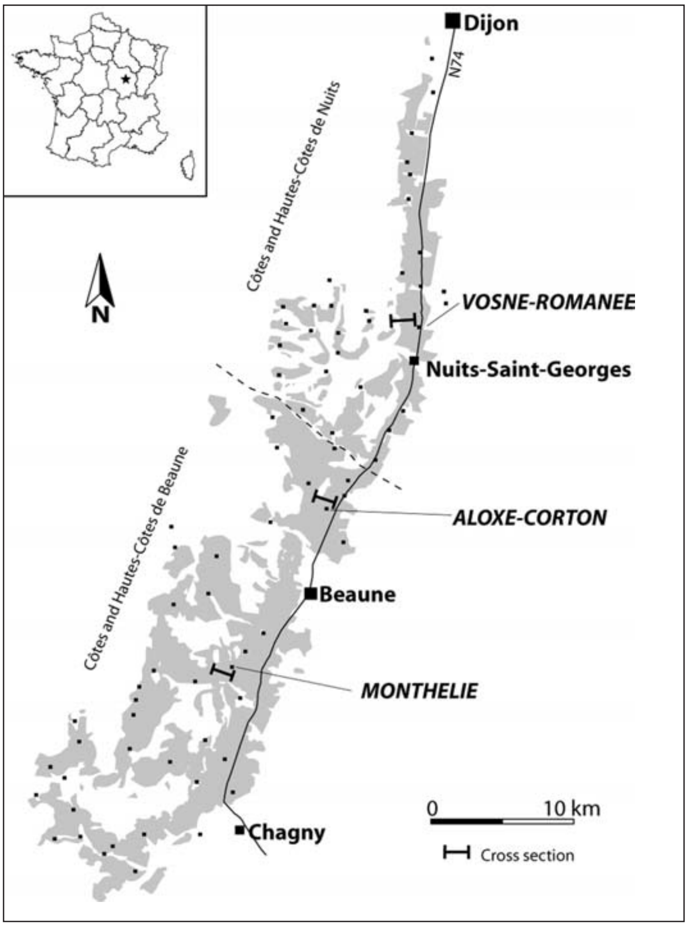

Fig. 2 - Vineyard extent in Côte-d'Or, and studied sites location.
– Estensione dei vitigni in Côte-d'Or, e ubicazione dei siti studiati.

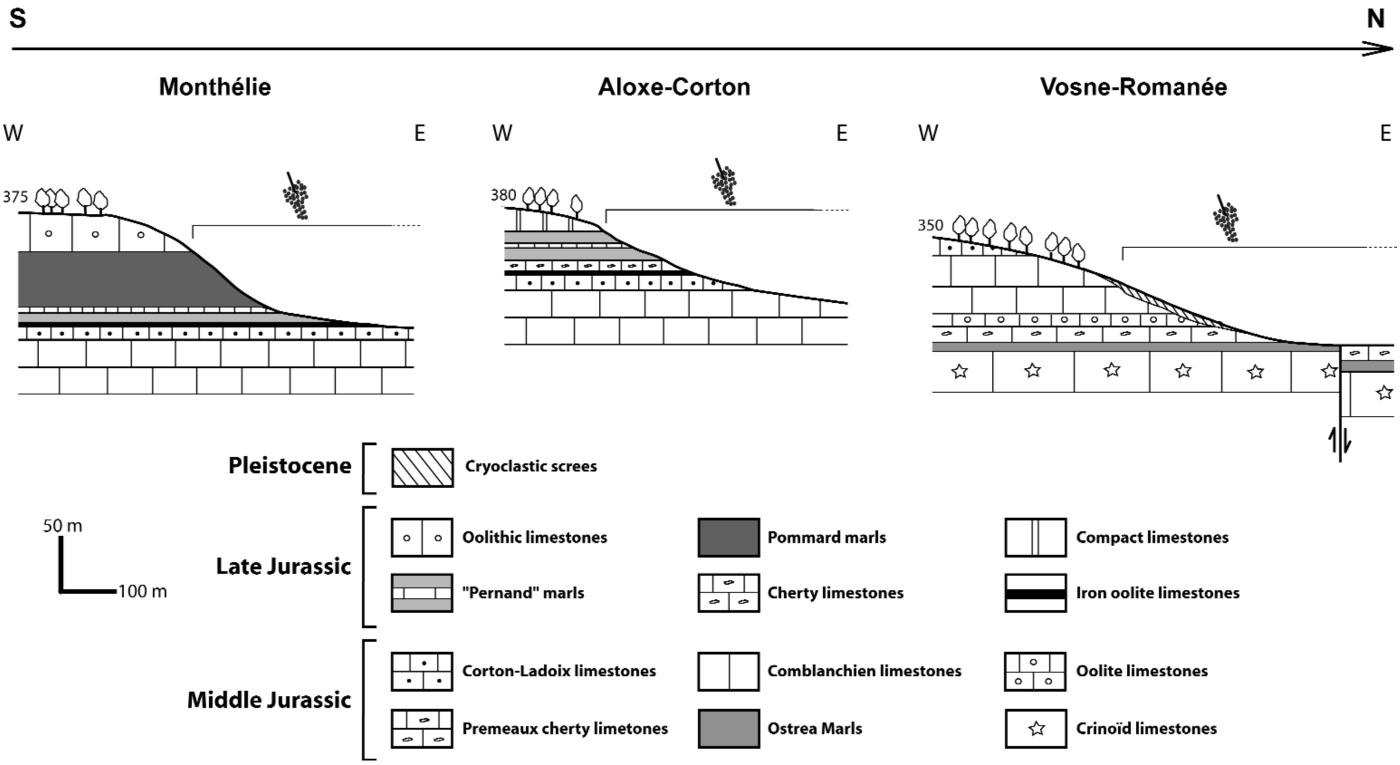

Fig. 3 - Simplified geological cross sections of Vosne-Romanée, Aloxe-Corton and Monthélie vineyards hillslopes.
– *Profili geologici semplificati attraverso i versanti a vigneto di Vosne-Romanée, Aloxe-Corton e Monthélie.*

loss is estimated by calculating the difference in volume between this palaeo-surface and the current one. All calculi have been performed with a triangulated grid from field data, and computed with Surfer™. In order to obtain an erosion rate, volumes are divided by plot surface and by vinestock age as attested by wine-growers.

This method was applied to the three plots in Vosne-Romanée, Aloxe-Corton and Monthélie, with slopes ranging from 10.5° to 10.7° (tab. 1). Respective figures for each plot are 5435, 3334 and 9384 vinestocks, for surfaces of 8783, 4135 and 11383 m^2. Erosion rates are given in mm.yr^{-1}, corresponding to exportation rates of t.ha^{-1}.yr^{-1}, with a factor of mean bulk density of 1.2-1.5 kg.dm^{-3}, from field data collected by densitometer.

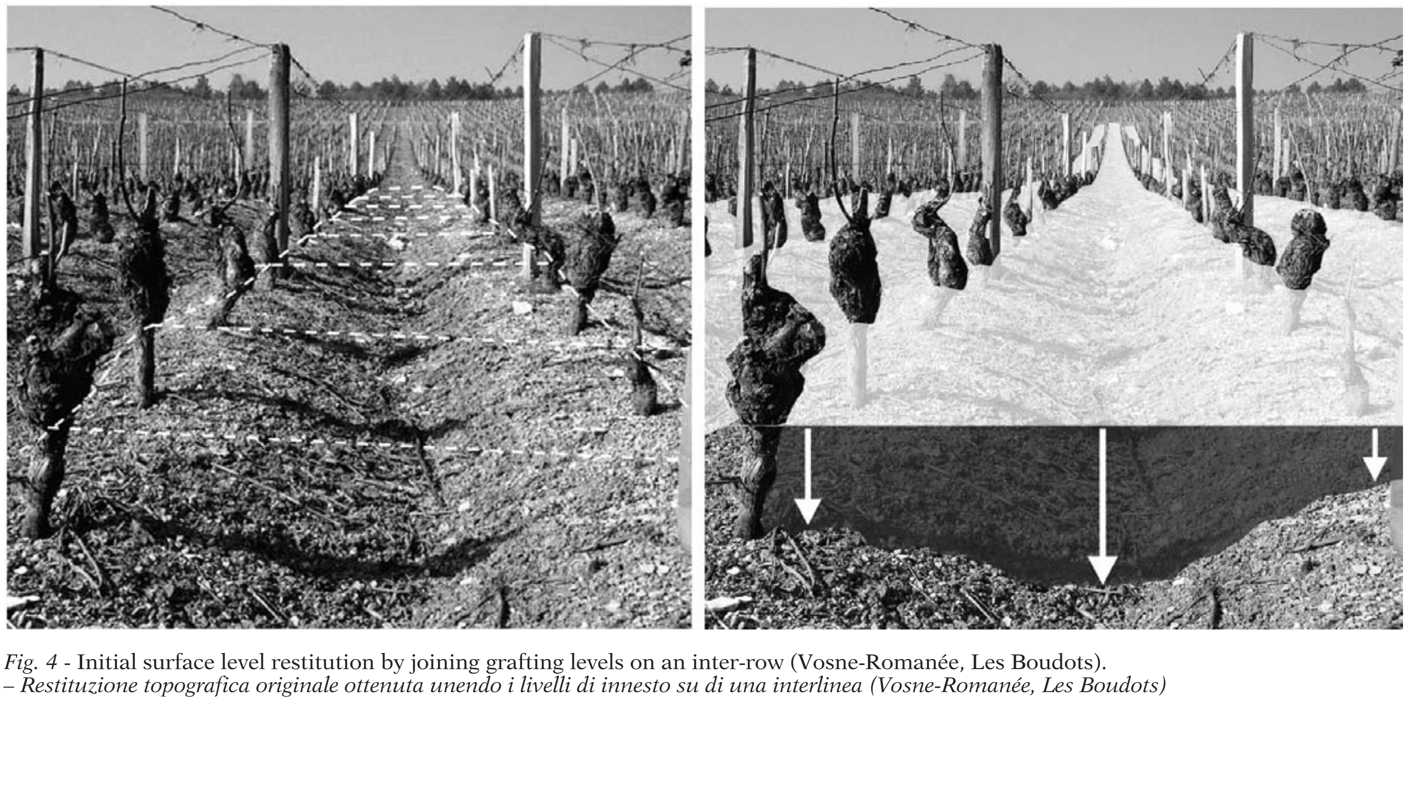

Fig. 4 - Initial surface level restitution by joining grafting levels on an inter-row (Vosne-Romanée, Les Boudots).
– *Restituzione topografica originale ottenuta unendo i livelli di innesto su di una interlinea (Vosne-Romanée, Les Boudots)*

TABLE 1

Slope, surface, length of the studied plots, and number of vineroot measures.
– *Pendenza, superficie e lunghezza delle parcelle studiate e numero delle misure degli apparati radicali.*

PLOT	*Mean Slope (°)*	*Surface (m^2)*	*Plot length (m)*	*Number of samples*
Vosne-Romanée	10.5	8783	130	5435
Aloxe-Corton	10.5	4135	53	3334
Monthélie	10.7	11383	93	9384

TABLE 2

Eroded volume, thickness and erosion rates for the studied plots of Vosne-Romanée, Aloxe-Corton and Monthélie.
– *Volume eroso, spessore e tassi di erosione nelle parcelle studiate in Vosne-Romanée, Aloxe-Corton e Monthélie.*

PLOT	*Eroded volume (m^3)*	*Mean eroded thickness (mm)*	*Vine Age in 2004 (yr)*	*Erosion rate ($mm.yr^{-1}$)*	*Erosion rate ($t.ha^{-1}.yr^{-1}$)*
Vosne-Romanée	355	30.5 ±10	54	**0.56±0.16**	**7.61±2.99**
Aloxe-Corton	249	50.1 ±10	50	**1.00±0.2**	**13.52±4.2**
Monthélie	517	35.4 ±10	32	**1.11±0.31**	**14.94±5.88**

TABLE 3

Comparison of soil loss values in different vineyard contexts and different time-scale resolution, from BALLIF (1990), KOSMAS *et alii* (1997), SCHALLER & EMDE (2000), WICHEREK (1991).
– *Confronto dei valori di perdita del suolo in vigneti differenti e considerando intervalli di tempo diversi; da BALLIF (1990), KOSMAS* et alii *(1997), SCHALLER & EMDE (2000), WICHEREK (1991).*

	Location	*Observation timescale (yr)*	*Erosion rate ($t.ha^{-1}.yr^{-1}$)*
KOSMAS *et alii*	Roussillon (France)	5	0.67-4.6
WICHEREK	Aisne (France)	3	35
BALLIF	Champagne (France)	3	0.6
SCHALLER & EMDE	Rheingau (Germany)	1	52
Our study	Vosne-Romanée	54	7.61±2.99
Our study	Aloxe-Corton	50	13.52±4.2
Our study	Monthélie	32	14.94±5.88

RESULTS AND DISCUSSION

Assessed soil loss rates, for Vosne-Romanée and Monthélie respectively, range from 0.56 ±0.16 to 1.11 ±0.31 $mm.yr^{-1}$ (tab. 2), with a mean eroded layer varying from 30.5 ±10 to 35.4 ±10 mm. The Aloxe-Corton plot is eroded at a rate of 1.00 ±0.2 $mm.yr^{-1}$, equivalent to 13.52 ±4.2 $t.ha^{-1}.yr^{-1}$. Information from wine-growers suggests that the lowest value, in Vosne-Romanée, could be explained by earth supplied every two years from downslope areas, to fill the gullies which develop after rainstorms. The highest value, in Monthélie, corresponds to a parcel which has never received earth supply. This example shows that the anthropic parameter influences soil erosion rate and may reduce soil ablation by a factor of two. Moreover, Vosne-Romanée is the only case where a stone wall exists in toe of plot. Such conditions allow sediments to be stored, whereas irreversible sediment exportation, out of the plot, occurs in their absence.

Soil loss rates from the Burgundian vineyards may be compared to rates obtained by geochemical data, e.g. with a ^{137}Cs tracer (QUINE & WALLING, 1991), in which all erosion processes are integrated, also at a decennial scale. Erosion rate values show great disparity depending on time and space resolution, and linked processes (tab. 3). This disparity is especially shown at a short time-scale, from 0.6 to 52 $t.ha^{-1}.yr^{-1}$, whereas the present study reduces the effect of event process variability.

Non-grassed inter-rows, frequent tractor crossing – up to 15 times a year –, decreasing infiltration rate, and summer rainstorms are all factors in erosion dynamics, resulting in homogeneous erosion rates at a human scale, i.e. 20-60 years. This quantification integrates all processes which contribute to root unearthing, including natural processes, but also anthropic processes such as tilling and/or sediment slope transport. From these data, it appears that soil loss rates are close to a value of 1 $mm.yr^{-1}$, corresponding to an exportation rate of 12 to 15 $t.ha^{-1}.yr^{-1}$.

CONCLUSION

Quantification of erosion on a pluri-decennial scale shows homogeneous, high erosion rates of vineyard soils on studied hillslopes. Assessed soil loss rates of more than 10 $t.ha^{-1}.yr^{-1}$ show the existence of disequilibrium on anthropised slopes, in comparison with mean soil production rates, ranging from 0.01 to 0.1 $t.ha^{-1}.yr^{-1}$ (HEIMSATH *et alii*, 1999; MINASMY & MCBRATNEY, 1999). The short term effect of erosion is limited because vinestock growth is not disrupted as long as roots are covered. The long term effect is problematic because it provokes a slow but steady reduction in the surficial sedimentary layer, despite anthropic earth supply. Winegrowers, who are increasingly aware of this problem, are experimenting with various methods at the plot scale, such as inter-row grassing, row length reduction, and wall reconstruction. This study suggest that such practices should be applied to all hillslope plots in Burgundian vineyards.

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