

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

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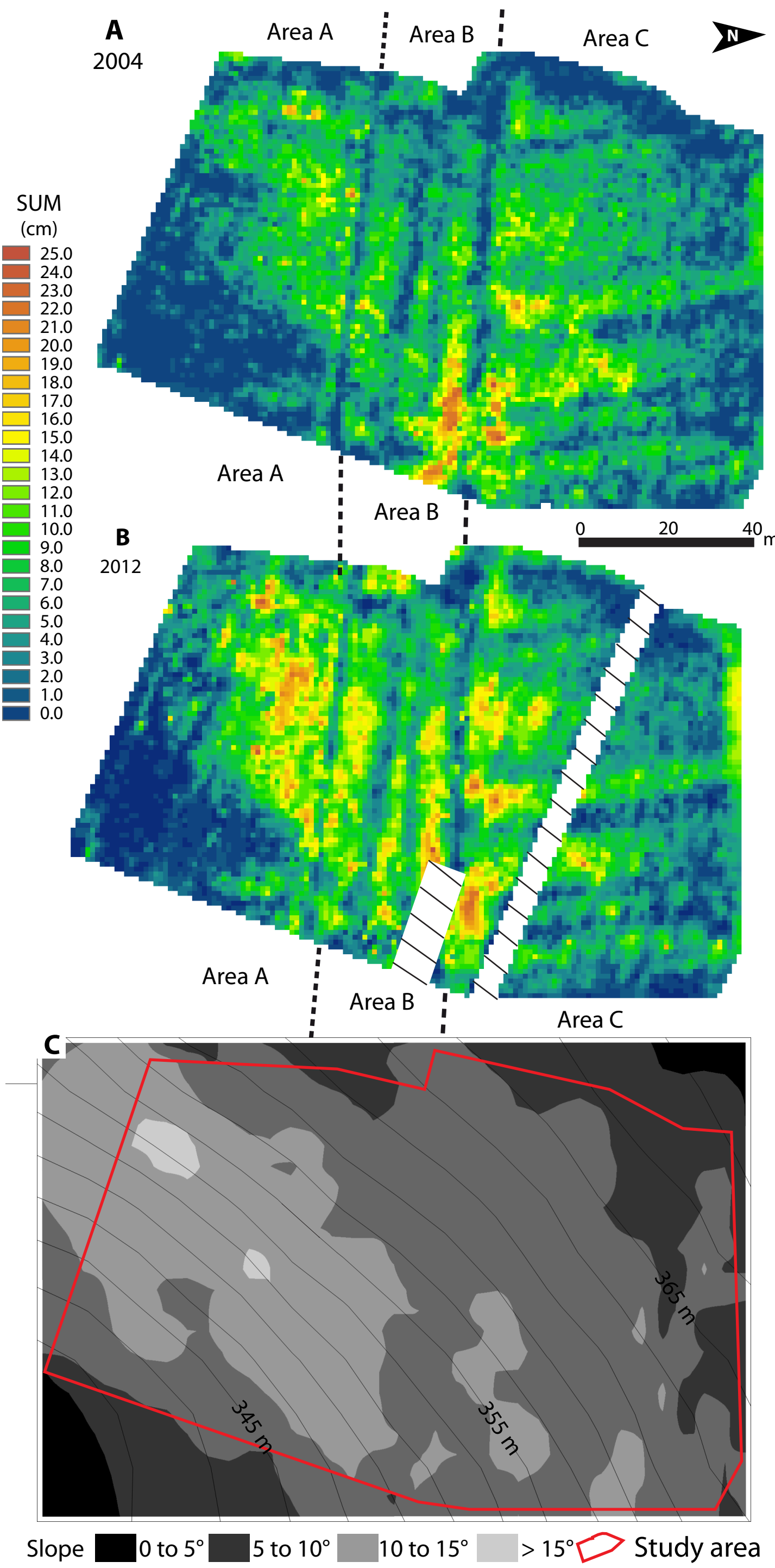
Introduction

Vineyards are known to undergo substantial soil loss in comparison with other types of agricultural land. Hydric 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The obtained maps, together with various complementary datasets, such as geological and geomorphological data, but also historical documents (cadastral plans, cadastral matrices and old aerial photographs) allow landscape evolution to be assessed.

Erosion map

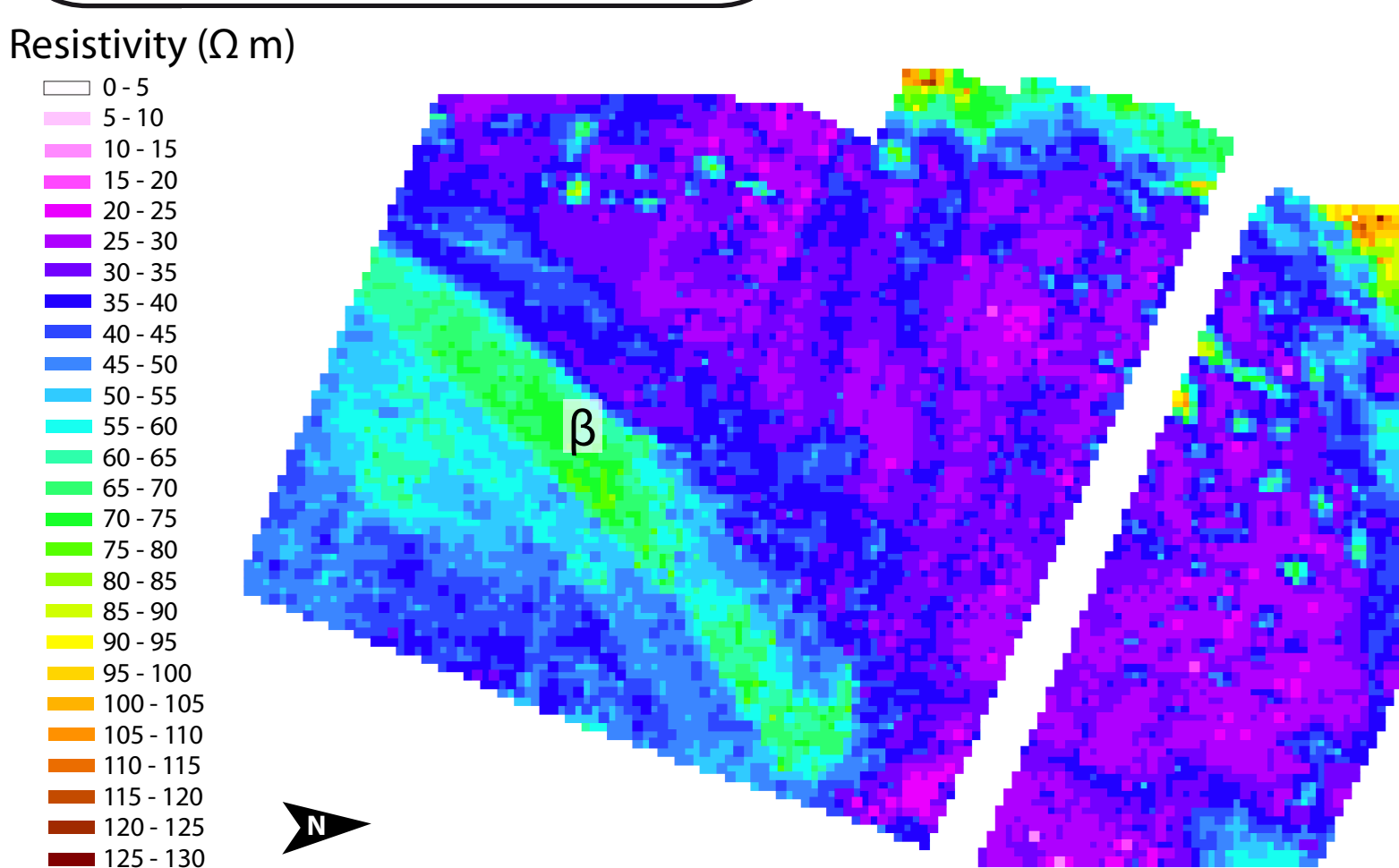
Soil erosion quantification was performed at a square-metre scale using dendrogeomorphology. This method is based on the measurement of the unearthing of the stock located on the vine plants, considered as a passive marker of soil-surface vertical displacement since the year of plantation (Brenot et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



Erosion maps performed on 2004 (A) and 2012 (B) with slope map (C). White bands on the 2012 map highlight uprooted rows in 2010.

Factors controlling erosion



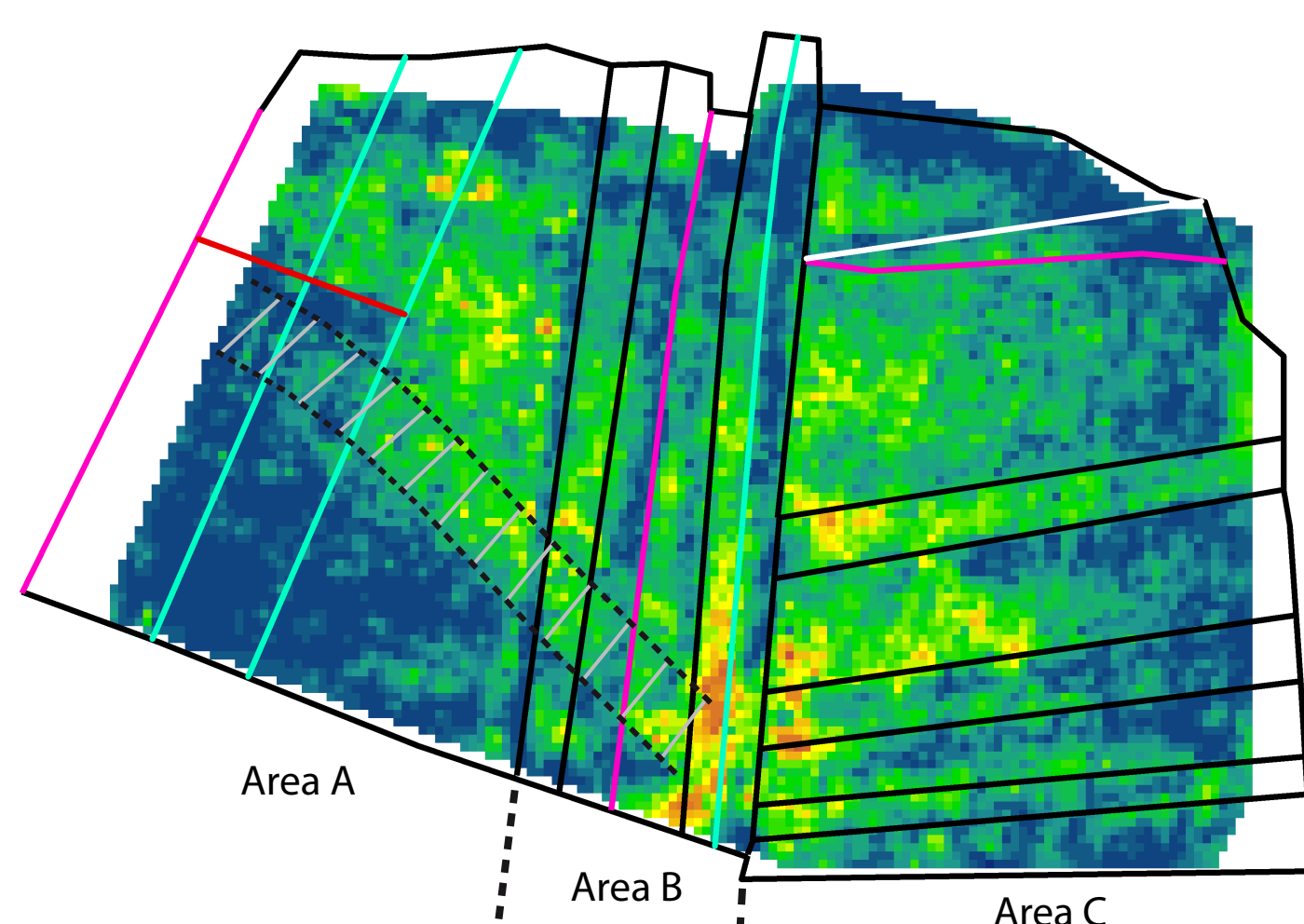
Electrical resistivity map performed at a square metre-scale on a 0-50 cm investigation depth. Resistivity variations highlight changes of lithology.

The use of historical documents as cadastral plans, cadastral matrices and aerial photographs allowed to identify factors controlling erosion patterns on the plot.

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

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

Historical landscape structure still influences the distribution and intensity of erosion, although deep ploughing was performed throughout the area before plantation in 1972.



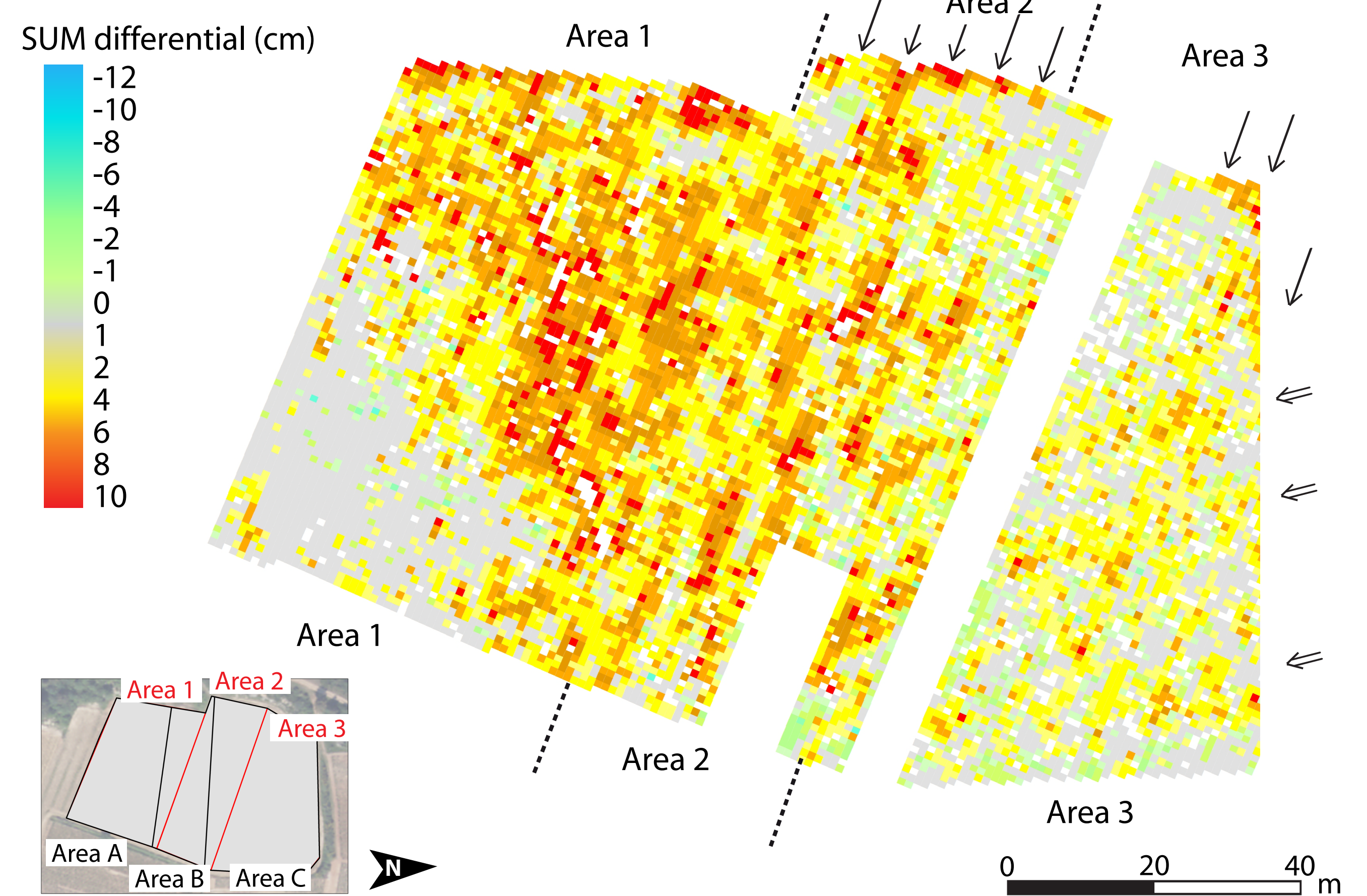
Cadastral (1825 and 1932 plan) and land use limits, overlain on the 2004 erosion map. Erosion patterns are still influenced by historical landscape structures.

References

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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.



Differential SUM ranges from -12 cm (sedimentation) to 10 cm (ablation) and the map highlights three areas with specific patterns of erosion, Areas 1, 2 and 3:

- In Area 1 => limits controlled by geology and topsoil stoniness are preserved
 - => linear patterns of low erosion values have been deleted
 - => relative erosion increase in this area is 236 %
 - => area has the steepest slopes in the study area

Erosion patterns that were controlled by historical human factors are declining, as the impact of topography and lithology increases.

- in Area 2 => linear erosion patterns correlated to historical landscape structure have completely disappeared
 - => alternation of linear erosion patterns parallel to rows appears every six rows and correspond to treatment rows
 - => these rows present important compaction due to 5 to 10 additional passages per year (Lagacherie et al., 2006)
 - => relative erosion increase in this area is 121 %

Erosion is no longer controlled by historical landscape structure and now seems to be governed by present-day vineyard management practices

- In area 3 => two patterns can be observed:
 - linear patterns parallel to rows every six rows
 - linear patterns with a NS orientation
 - => the relative increase of erosion is 15 %
 - => area is characterised by gentle slopes

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

Plot reference	Area (m ²)	Number of vine stocks measured	Erosion rate				
			Mean SUM		Period 1	Period 2	Relative increase from period 1 to 2
			cm		(mm year ⁻¹)		
			2004	2012	72/04	04/12	%
Area 1	3790	3347 2816	3.6 ± 0.13	6.5 ± 0.22	1.1 ± 0.04	3.7 ± 0.13	236
Area 2	2880	2712 1882	6.1 ± 0.18	8.0 ± 0.22	1.9 ± 0.06	4.2 ± 0.06	121
Area 3	3660	3325 2638	4.2 ± 0.12	5.4 ± 0.15	1.3 ± 0.04	1.5 ± 0.07	15

Sum and erosion values are given with their confidence interval

Mean 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 Andrieux (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 compaction occurring 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 tillage modifies the superficial soil structure, composed of a loosened soil surface overlying a low permeability compact layer, which favours soil erosion during intense rainfall events.

Discussion and Conclusions

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 structure, 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 steep slope context, erosion deletes the effects of both historical and present-day anthropogenic factors. Conversely, the effects of historical landscape structure are partially preserved when the slope is moderate.

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 hillslopes 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.