Accumulation of micronutrients (Cu, Zn) in vineyard soils and transport *via* soil erosion

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Introduction / Research Motivation

- Copper and zinc are important micronutrients for plant growth; however, the long-term use of Cu-fungicides and Zn-containing fertilizers can lead to their accumulation in the topsoils of vineyards.
- European vineyards can display elevated levels of Cu and to a lesser extent Zn in their topsoils.
- Soil erosion caused by the overland flow of rainwater is a main problem in sloping vineyards and may result in the relocation (i.e., downstream transport) of Cu- and Zn-bearing soil particles [1].
- The fate of the presumably high soil-bound Cu and Zn in vineyards needs further investigations in so far as soil erosion can significantly affect their distribution in soils.
- Cu and Zn can be significantly enriched compared to the average topsoil in eroded sediments transported by runoff [1, 2].
- Our study conducted in March-May 2019 focused on evaluating Cu and Zn enrichment in the topsoil and eroded sediments in two study vineyards located in the historical winegrowing region of Tokaj (Hungary).

Materials and Methods

The study was conducted in 2019 in a 1,8 ha sloping vineyard at Tokaj (mean slope: 8°) and a 0.4 ha plot near Tállya (mean slope: 18°), both in the historical vinegrowing region of Tokaj-Hegyalja (in northern Hungary). The vineyards at Tokaj have been converted to organic farming, where Cu-based fungicides are repeatedly used in a typical dose of 4 kg/ha/year, supplemented with fertilizers containing micronutrients. The soil samples from the top layers (0-10 cm and 10-20 cm) have been collected using a hand auger form the two vineyards and from local forested sites, the latter accounting for the local geochemical background. Additionally, sediment traps have been deployed for collecting eroded sediment samples.

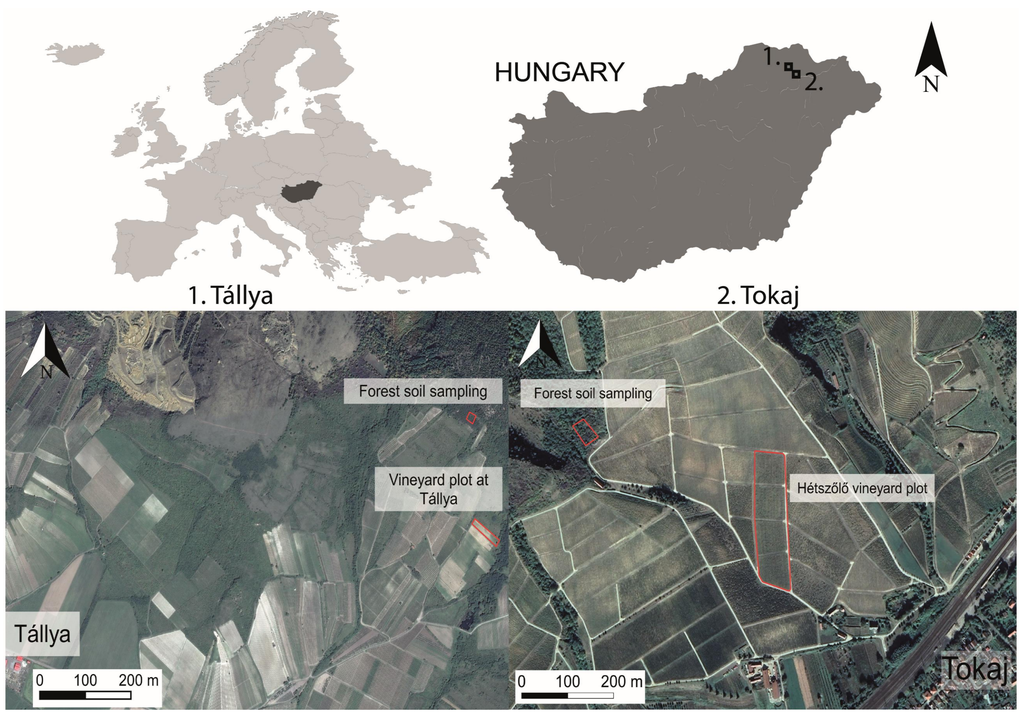

Fig. 1. The study vineyard plots at Tállya (1) and at Tokaj (Hétszőlő vineyard) (2)

- Annual precipitation: 600 mm

1) Tállya:
   - 0.4 ha
   - Soil forming parent material: Rhyolite
   - Mean slope: 18 °
   - Slope lkength: 130 m
   - Soil texture: loam

2) Tokaj-Hétszőlő:
   - 1.8 ha
   - Soil forming material: loess
   - Regosol
   - Mean slope: 8°
   - Slope length: 270 m
   - Soil texture: sandy loam-loam

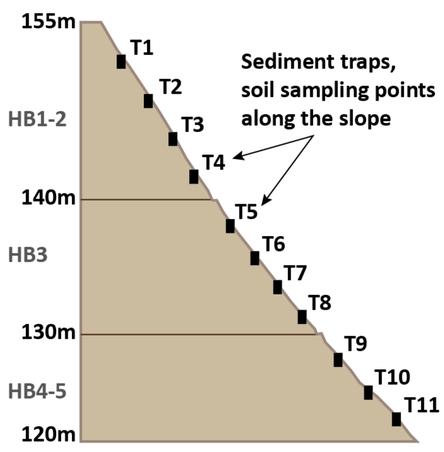

Fig. 2. The location of sediment traps and soil sampling points along the main slope of the experimental plot at Tokaj-Hétszőlő

Sample treatment and analyses:
- pH (in H_2O) (MSZ-08-0206/2:1978) (±3 %)
- organic matter content (MSZ-68 21470/52-83) (±15 %)
- dried and powdered (<200 µm) soil samples (0.5 g) were digested in aqua regia (hydrochloric acid : nitric acid = 3 : 1) in closed vessels in a microwave oven (Anton Paar Multiwave 3000)
- Cu and Zn analysis with an inductively coupled plasma optical emission spectrometer (ICP-OES) (Perkin Elmer ICP-OES Optima 7000 DV)

Results

The soils are characterized by a slightly acidic pH(d.w.) of 6.36±0.27 at Tállya and a moderately alkaline pH(d.w.) of 8.03±0.04 at Tokaj. The differing pH is due to the soil forming parent rocks, that are loess at Tokaj and rhyolite at Tállya. The topsoils (0-20 cm) bear a low to medium organic matter (OM) content (1.5±0.5% OM at Tállya and 1.4±0.2% OM at Tokaj) and a low carbonate content at Tállya (3.1±0.2%), while a low to medium carbonate content at Tokaj (4.4±1.5%).

	pH (H_2O)	$CaCO_3$ (%)	OM content (%)
	Tokaj-Hétszőlő		
Mean	8.03	4.35	1.37
Median	8.02	4.98	1.39
Standard deviation	0.04	1.46	0.20
	Local forested site (control)		
	7.60	2.89	1.67
	Tállya		
Mean	6,36	3,08	1,48
Median	6,28	2,94	1,46
Standard deviation	0,27	0,24	0,46
	Local forested soil (control)		
	4.66	3.78	4.00

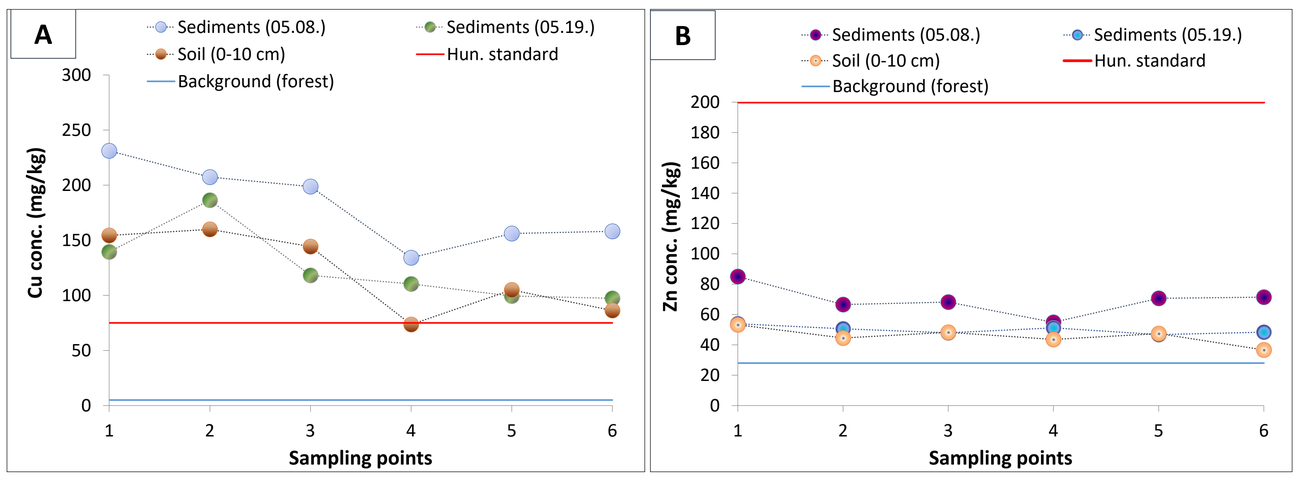

Fig. 3. Cu (A) and Zn (B) concentrations of eroded sediments and soils (0-10 cm) along the slope at Tállya, Hun. Standards stand for the contamination limit according to the Hungarian standards (6/2009. [IV. 14.] KvVM-EüM-FVM)

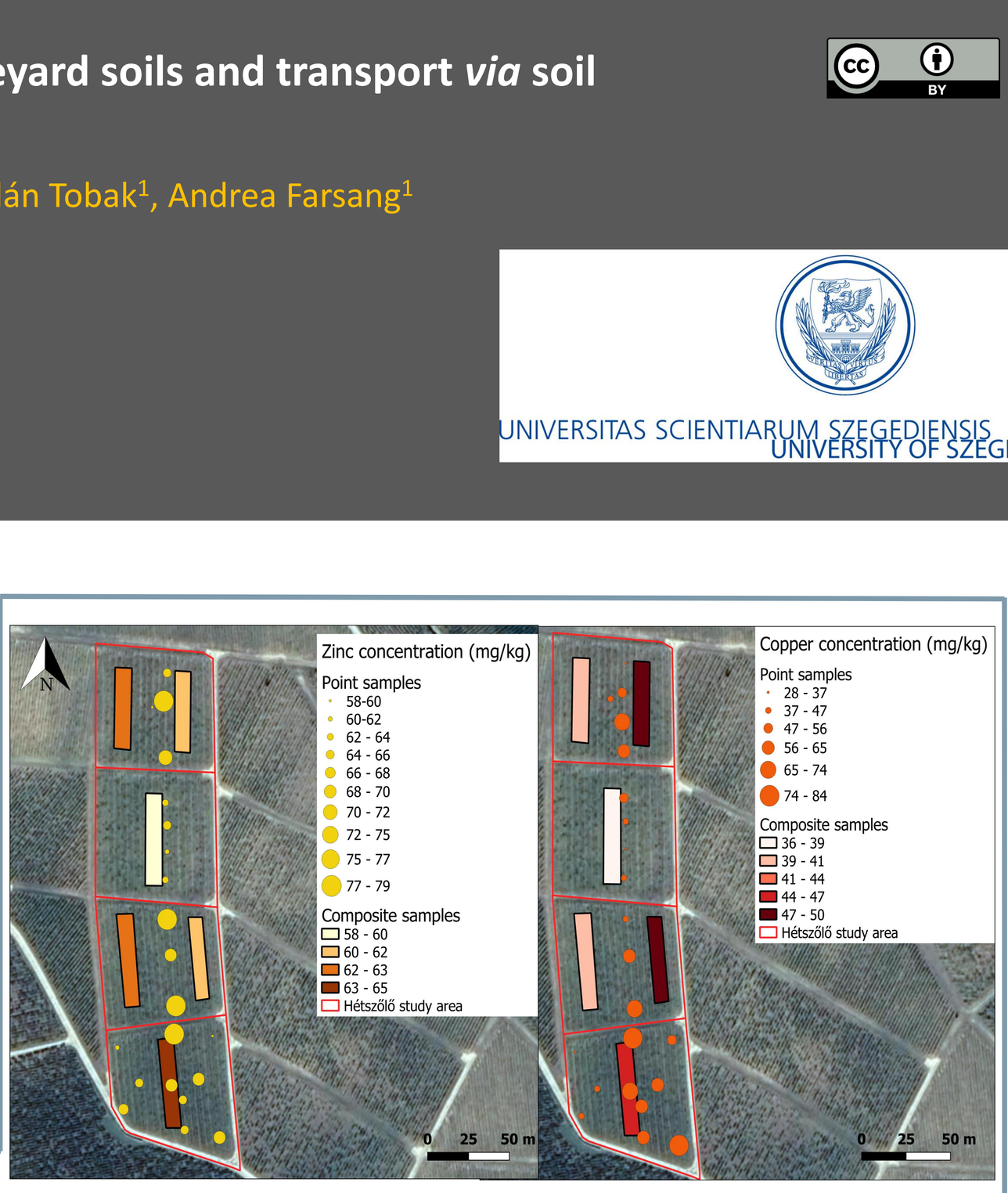

Fig. 4. Zn and Cu concentrations of point and composite soil samples (0-10 cm) in the Hétszőlő experimental vineyard plot (at Tokaj)

We can observe that soil erosion significantly affects the topsoil Cu and Zn concentrations at Tokaj, as higher Cu and Zn concentrations are found downslope, where the eroded sediments accumulate, compared to the erosion bases upstream (Fig. 4). Meanwhile a different pattern of Cu and Zn concentration pattern can be observed in the topsoils along the slope at Tállya (Fig. 3). At Tállya, our results show a considerable Cu enrichment and a slight Zn enrichment in the topsoil (mean±se: 127±37 mg/kg Cu, 47±4 mg/kg Zn) due to the repeated use of pesticides and fertilizers, compared to a local forested soil displaying 5 mg/kg Cu and 28 mg/kg Zn. The lower Cu enrichment in the vineyard topsoil at Tokaj (49±14 mg/kg in vineyards, 17 mg/kg at the local forested site) is probably due to the more recent plantation of grapevines. The soil-bound Zn also displayed to some degree higher concentrations in the top 20 cm layers in vineyards (64±6 mg/kg) as to the forest soil, exhibiting 41±3 mg/kg Zn. At both sites, eroded sediments tend to display higher Cu and Zn concentrations relative to the vineyard topsoils with mean enrichment factors of 4.2 (Cu) and 1.4 (Zn).

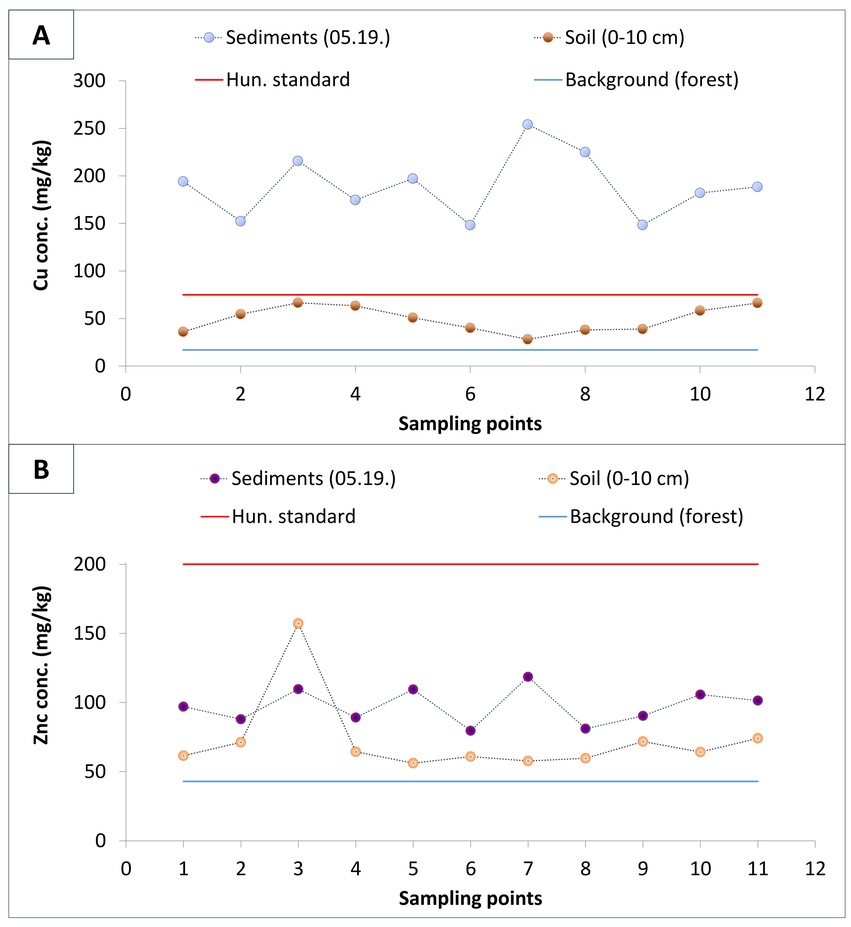

Fig. 6. Cu (A) and Zn (B) concentrations of eroded sediments and soils (0-10 cm) along the slope at Tokaj-Hétszőlő, Hun. Standards stand for the contamination limit according to the Hungarian standards (6/2009. [IV. 14.] KvVM-EüM-FVM)

Conclusions

- Both Cu and Zn are enriched in the surface soil layers in the studied vineyards (Tokaj, Hungary) compared to the deepest sampled layers and the local forested soils due to Cu-based fungicide treatments of grapevines and the application of Zn-containing fertilizers.
- The accumulated Cu is redistributed in the topsoil due to soil erosion processes.
- However, the bioavailability of the redistributed Cu and Zn needs further investigations.
- Eroded sediments tended to display higher Cu and Zn concentrations relative to the vineyard topsoils with median enrichment factors of 3.7 (Cu) and 1.4 (Zn).

References

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