Disturbed nutrient cycling as a key limitation for spontaneous restoration: study on metalliferous post-mining sites in Serbia

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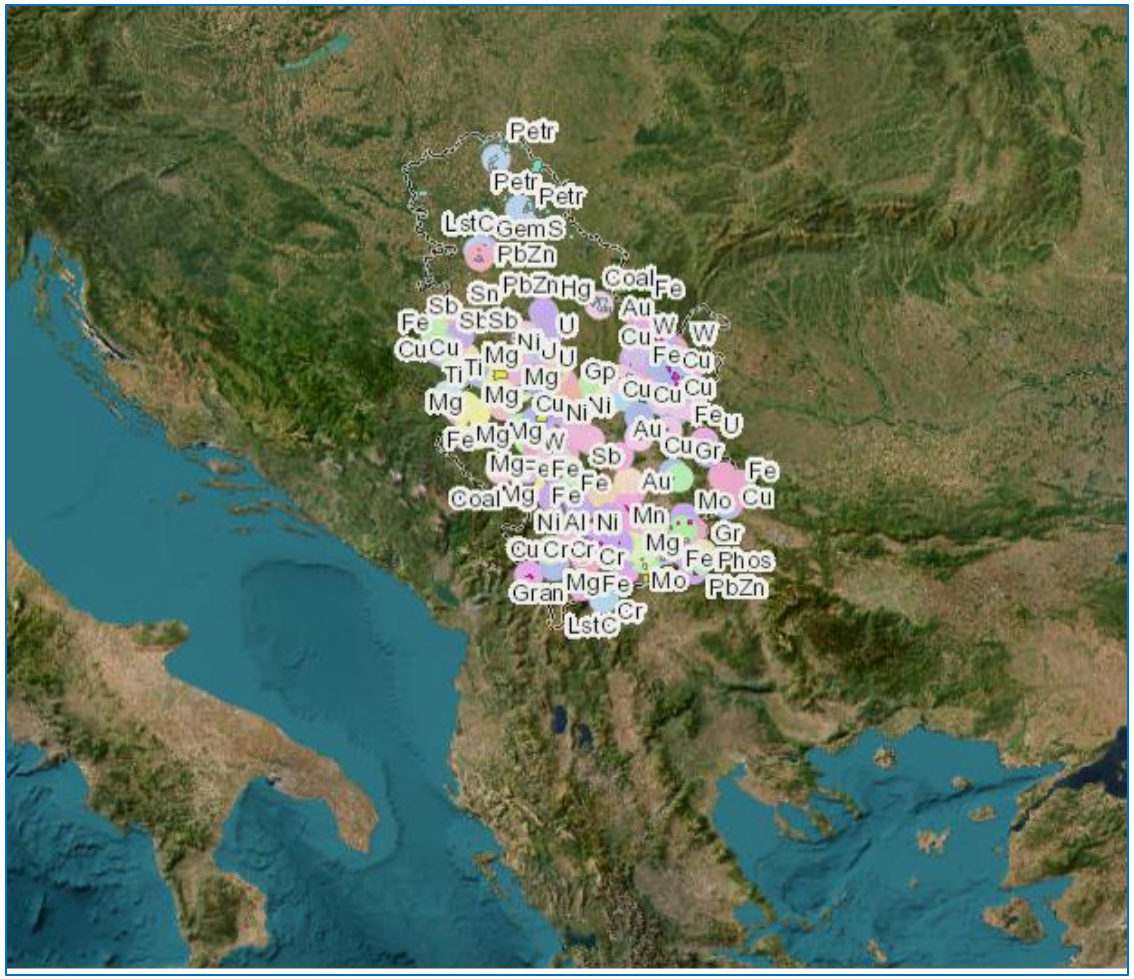
Serbia: a mining country with low environmental concerns



(Source: Serbian Ministry of Mining and Energy)

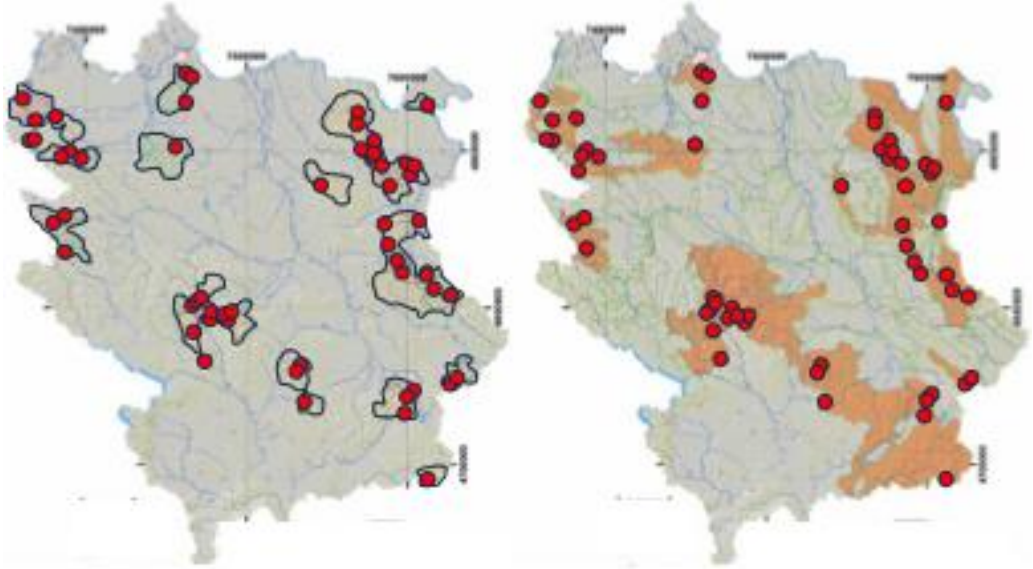
- Inadequate monitoring and information sharing.
- Spontaneous restoration not officially acknowledged.
- Low focus on environmental issues.

  Official data:
  709 sites with soil contamination
  52 recultivation finished
  41 in the process of rehabilitation

Metalliferous post mining sites: restoration priorities

- High risk of metal (and other pollutants) mobilization in a watershed
- Priority: **FAST establishment of vegetation cover**!

Water pollution risk



Surface waters Groundwaters

● Abanandoned metal mines in Central Serbia

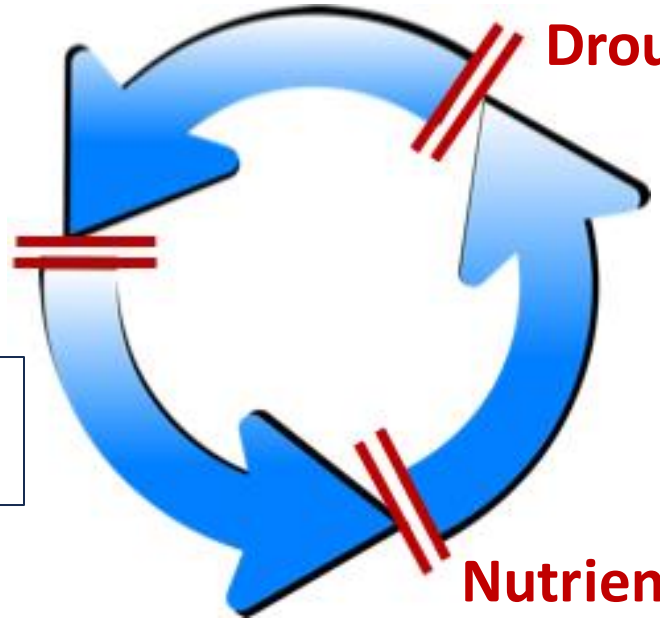
(based on: Atanackovic et al. 2016. Env Earth Sci 75:1152)

Pollutant spread by wind

Sandy flotation waste from Cu mining, deposited in the Timok floodplain, Eastern Serbia

Managing post metal-mining sites: constraints and options

- Small scale (tailing ponds): engineering of pedogenic processes (rehabilitation/reclamation)



Drought ⇦ Irrigation (expensive, rarely applied)

Humid climate increases metal mobility!

Metal toxicity

⇧ Reduce mobility; Metals remain!

Nutrient deficiencies & imbalances ⇦ Fertilization (partly successful)

- **Thesis: natural flooding can eliminate severe drought and restore nutrient cycling!**

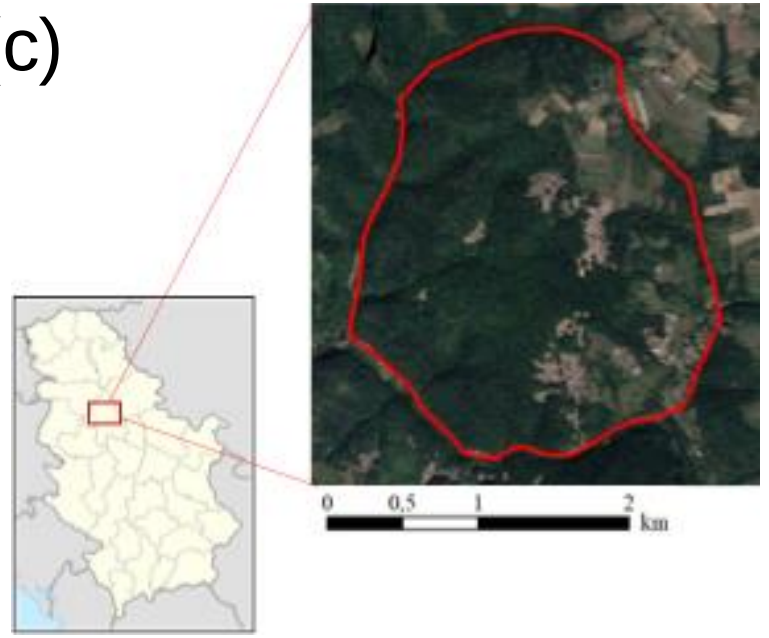
The study sites

- Survey: spontaneous restoration, +/- natural flooding

(a)

(b)

(c)



Metal mining	**(a) Release of Cu-tailings waste**	**(b) Ni (Cr) excavation**	**(c) Pb mining and smelting**
Climate (MAT/∑R)	11.1°C / 646 mm	7.9°C / 974 mm	12.3°C / 696 mm
Pre-mining natural vegetation	*Populus alba – P. nigra* forests	Serpentine grassland	*Q. cerris – Q. frainetto* forests
Surrounding vegetation	Mosaic	Semi-natural	Mosaic
Time since abandonment	> 40 years	> 40 years	Roman era (centuries)

Ancient Pb smelting area, abandoned in the 5th century

Sparse, species-poor herbaceous vegetation

Non-flooded:

Pb_{DTPA}: 987 mg kg^{-1}

pH_{water}: 5.3

C_{org}: 1.1%

P_{Olsen}: 14 mg kg^{-1}

Dense nitrophilous/ruderal vegetation, trees

Flooded:

Pb_{DTPA}: 1150 mg kg^{-1}

pH_{water}: 6.0

C_{org}: 2.3%

P_{Olsen}: 15 mg kg^{-1}

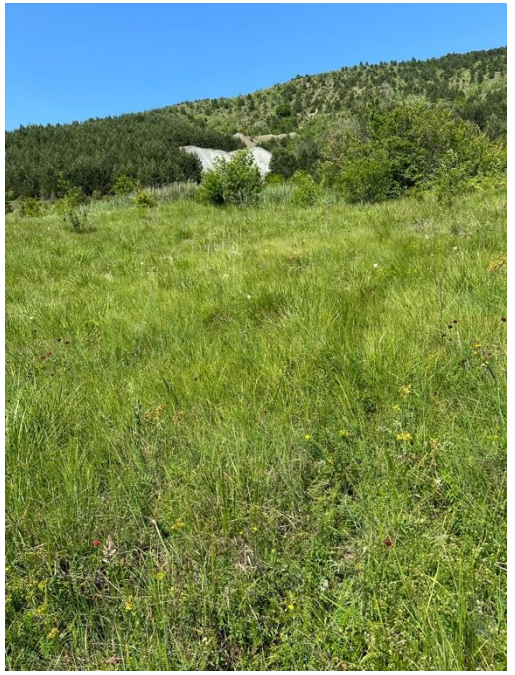
Spontaneous restoration of Cr extraction waste on serpentinite

Serpentinite grassland

- Flooding

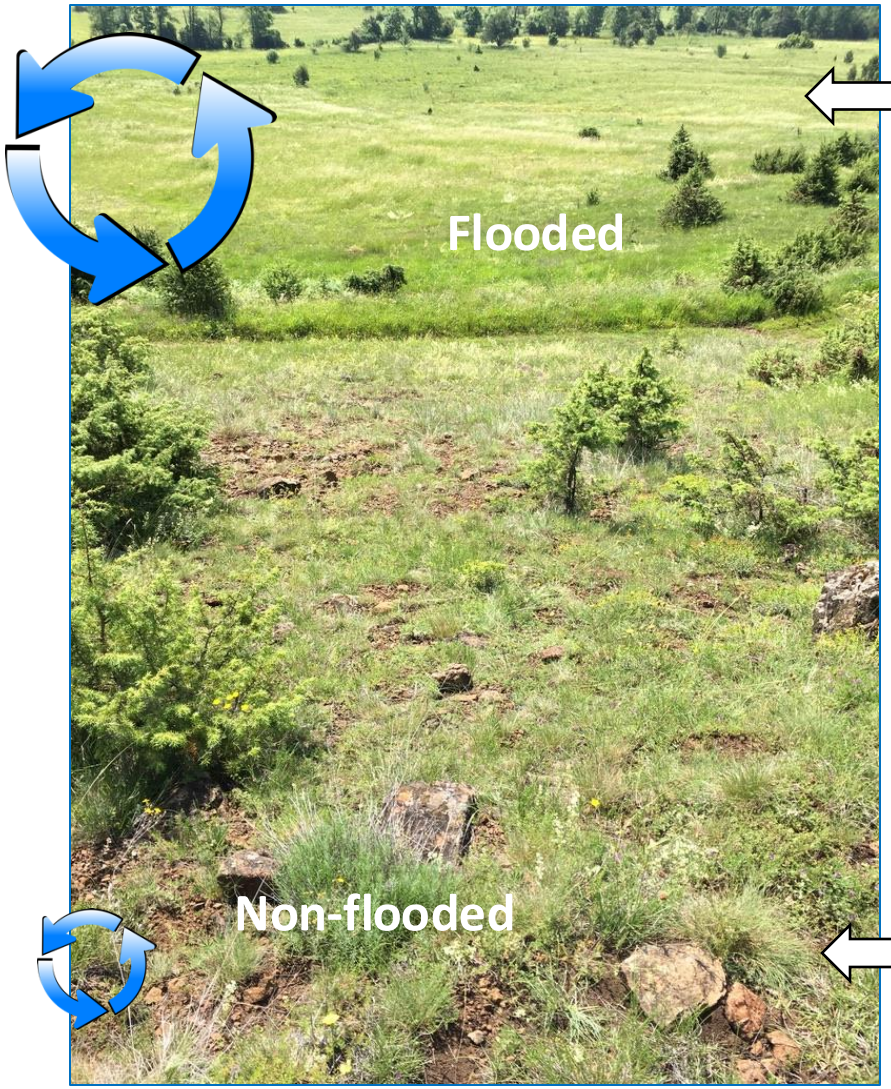
Barren waste deposits

+ Flooding



Non-serpentinite grassland

Cr waste on Ni-rich serpentinite hillside

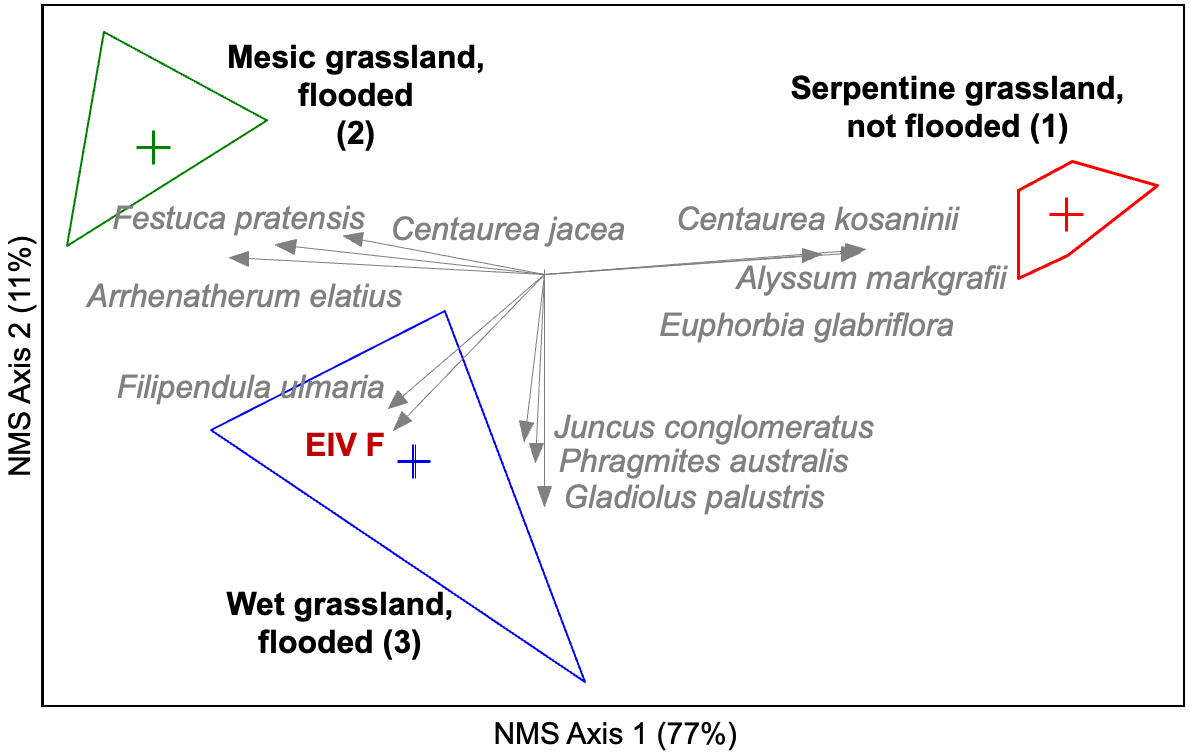


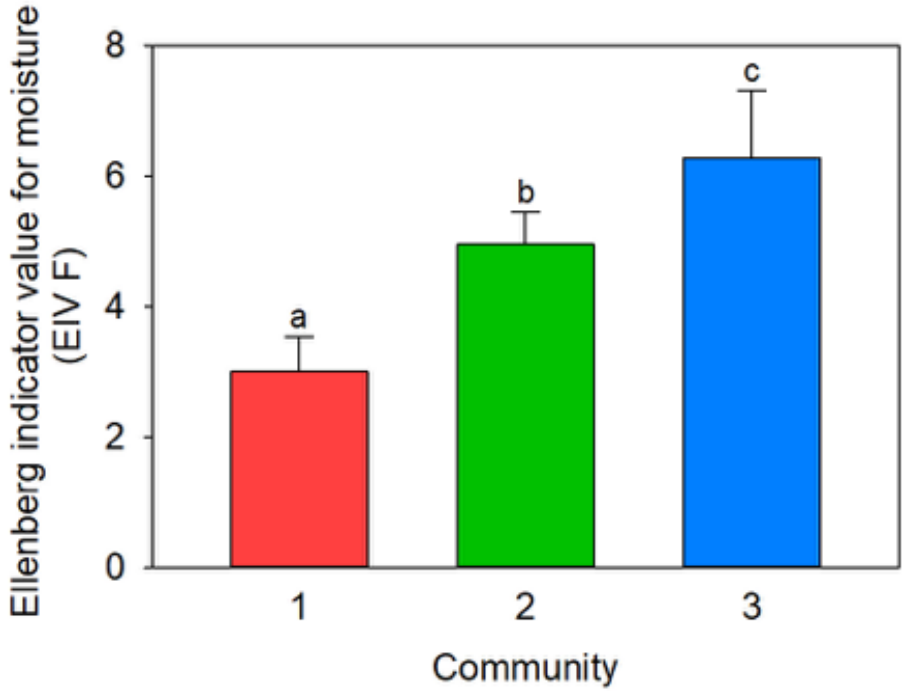
Non-serpentine grassland

Serpentine grassland

Parameter	Non-flooded	Flooded
Cr_{tot} (mg kg^{-1})	299 ± 68 a	355 ± 90 a
Ni_{tot} mg kg^{-1}	923 ± 160 a	905 ± 181 a
Ni_{DTPA} (mg kg^{-1})	70 ± 16 a	64 ± 17 a
Ca: Mg	0.5 ± 0 2 a	1.9 ± 0.3 b
pH	7.6 ± 0.2 b	6.9 ± 0.1 a
Biomass DW (g m^{-1})	**24 ± 2 a**	**121 ± 13 b**

Exclusion of soil drought abolishes the “serpentine syndrome”!





Three herbaceous communities on the serpentinite hillside along the the flooding gradient: 15 samples, 45 species

(M. Stanojevic PhD Thesis, 2022)

Sulphidic Cu flotation waste deposited in a foodplain

Lower pollution

Restored to reference forests

Populus alba–Populus nigra

Highest pollution

Flooding

Betula pendula–Populus tremula

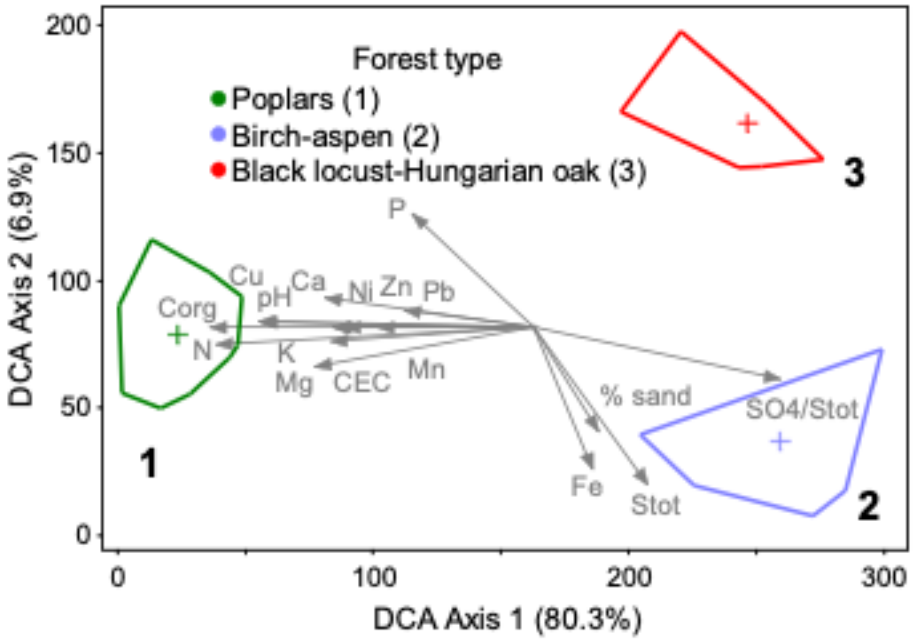
High pollution

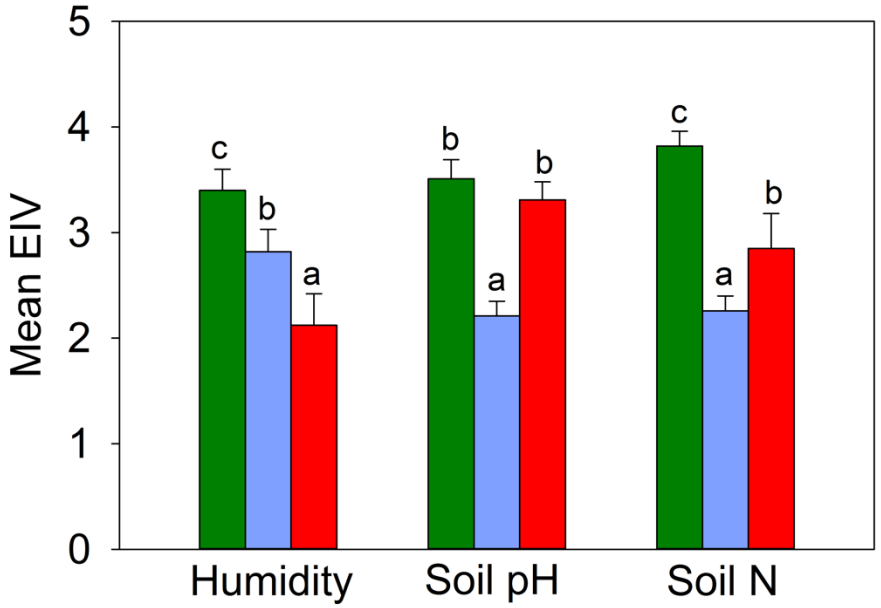
No flooding

Robinia pseudoacacia–Quercus frainetto

(Nikolic et al. Land Degrad Dev, 2018)

Flooding profoundly influences restoration time and outcome

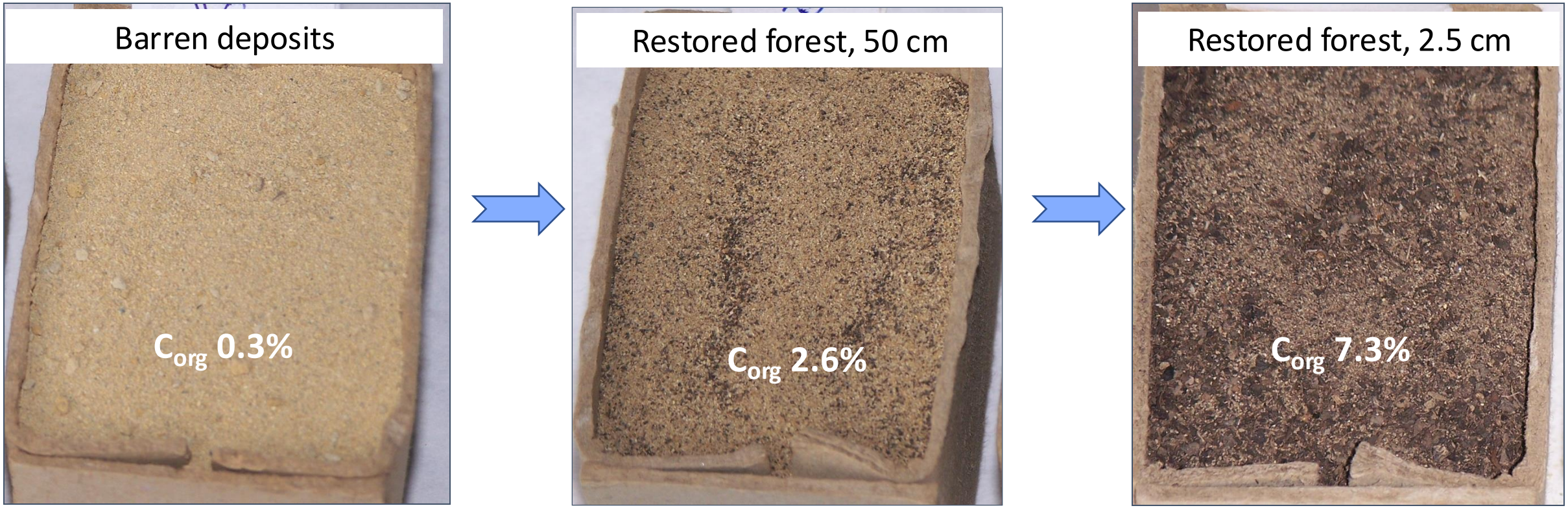




Restored forest	Start of development after mining	Estimated species richness	Tree density (m^2 trunks ha^{-1})	Soil C_{org} (t ha^{-1})
Reference	5 years	81	58 ± 8 c	162 ± 17 c
Flooded	10-15 years	62.3	21 ± 4 b	65 ± 12 b
Non-flooded	20-25 years	60.5	12 ± 3 a	35 ± 9a

Soil restoration still long ahead

- Particulate organic matter, no true organomineral complex
- SOM enables phytostabilization of metals and nutrient retention



Cu-polluted site, after 50 years of spontaneous restoration

Summary

If there is free flooding:

- FASTER establishment of vegetation: YES ✓
- Required level of intervention: LOW ✓
- Probability of metal translocation: LOW ✓
- Probability of invasive/alien species: LOW ✓
- Resemblance of the established vegetation to the pre-mining one: NO ✗
- Possibility of post-revegetation land use change: NO ✗

➢ **Include facilitation of free flooding in restoration guidelines!**

Thank you for your attention!

Acknowledgements

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