ReSoil

Remediation case #1

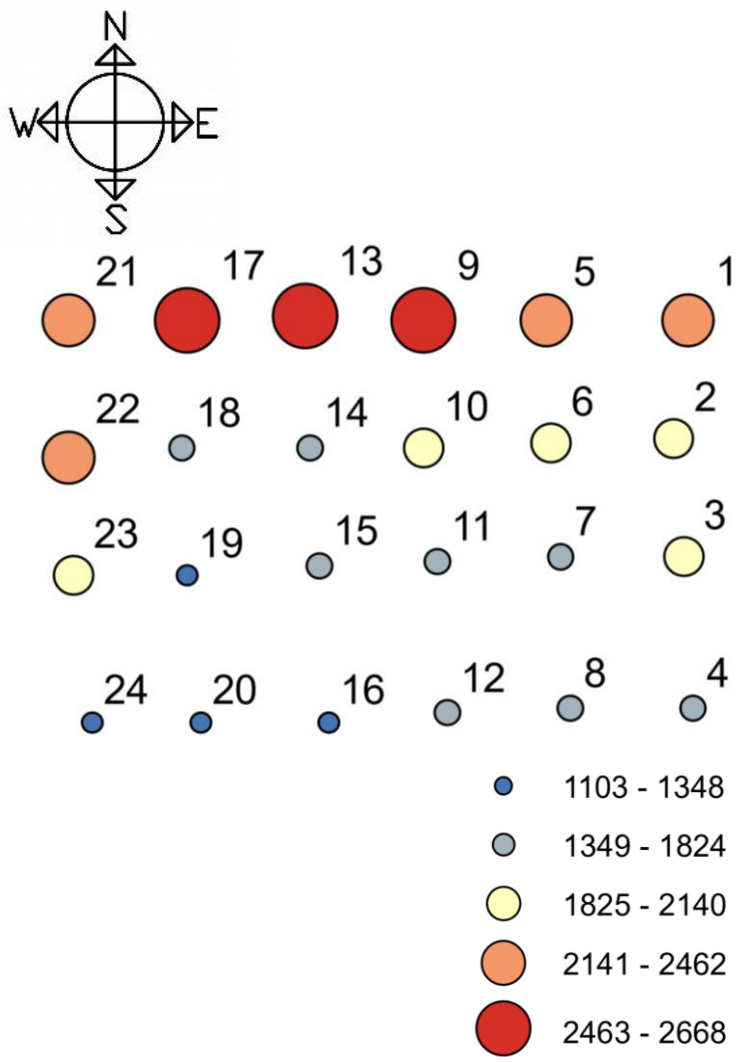
Construction of vegetable garden with raised beds with remediated soil in city of Prevalje, Meza Valley, Slovenia

November 2017 - September 2018

Contaminated site characterization

In order to estimate the apparent soil density, soil samples were taken with Kopecky cylinders with a volume of 100 cm^3.

Pasture soil from the upper 30 cm soil layer was taken in the area of abandoned Pb smelting industrial complexes in the Meza Valley, Slovenia (lat. 46,545791; long. 14,937384). Soil was calcareous, contaminated with Pb, Zn and Cd by floods of Meza River.



Soil Pb conc. (avg. 0-30 cm, mg kg^{-1})

Soil excavation…

… transportation and storage.

…homogenization,…

Approx. 70 m^3 of the upper 30 cm layer of contaminated soil above mineral bed was excavated.

In the remediation plant

Soil washing

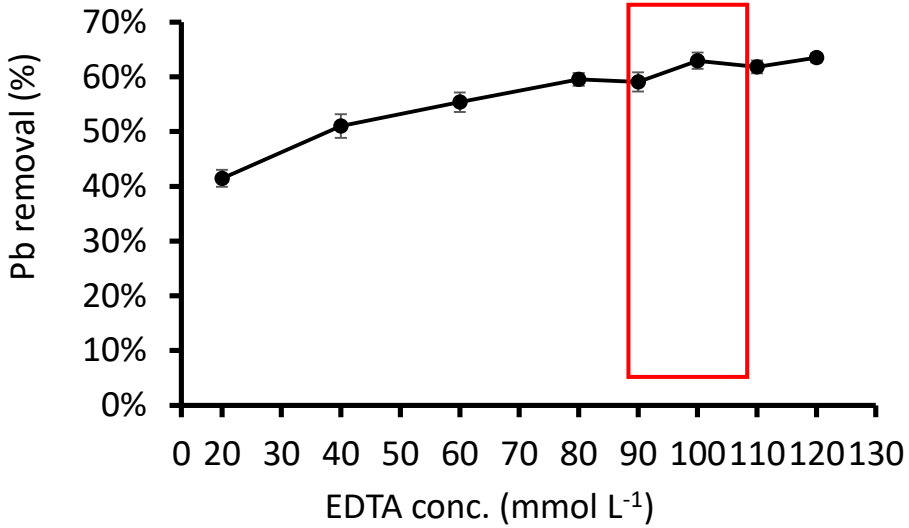
EDTA, water recycle …alkaline phase

Soil rinsing, separation

EDTA, water recycle …acidic phase

Remediation efficiency & Effect on soil properties

Calcareous soils are characterized by lower efficiency of toxic metal removal compared to acidic soils due to interference of soil Ca with toxic metal chelation. High EDTA dose of 100 ± 10 mmol EDTA ton^{-1} of soil was therefore used in remediation process.



Concertation of toxic metals in original and remediated soil and metal removal efficiency. 30 tons of soil were

	Original soil (mg kg^{-1})	Remediated soil (mg kg^{-1})	Removal (%)
Pb	1734±78	562±14	68
Zn	3313±178	2401±63	28
Cd	24±1	12±1	50

Soil properties were not significantly changed. Part of washed sand fraction was separated from remediated soil to improve soil gardening properties.

	Calcareous soil	
	Original	**Remediated**
pH ($CaCl_2$)	7.28	7.67
Org. matter (%)	5.3	5.6
C/N	10.7	11.9
P_2O_5 (mg 100 g^{-1})	7.5	11.1
K_2O (mg 100 g^{-1})	4.8	6.3
$CaCO_3$ (%)	21	19
Sand (%)	59.2	37.2
Silt (%)	32.3	51.9
Clay (%)	8.5	10.9
CEC($mmol_c$/100g)	18.48	18.23

Construction of raised beds with remediated soil

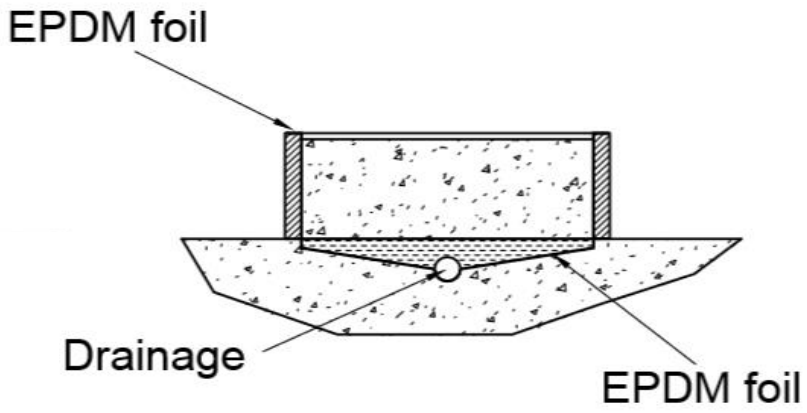
Sawing buckwheat (*F. esculentum*) as a green manure.

Leachate collection and secondary emissions

Vegetable beds were constructed as lysimeters to collect leachates and assess potential emissions of EDTA and toxic metals.

Metal/soil	Bed No.	Gardening time (days)										
		41	49	56	78	257	303	319	363	397	418	488
Pb												
Orig	1	**78.8**	**31.0**	**29.3**	**80.3**	**25.5**	32.3	**19.4**	**43.0**	**25.3**	**27.1**	9.6
Orig	3	LOQ	4.7	10.2	16.3	4.1	**39.2**	LOQ	18.1	20.8	21.2	**9.9**
Rem	5	LOQ	LOQ	LOQ	LOQ	7.5	LOQ	7.3	LOQ	LOQ	LOQ	LOQ
Rem	6	LOQ	LOQ	LOQ	5.1	8.7	LOQ	LOQ			LOQ	9.5
Rem, Rem + V	2	LOQ	LOQ	LOQ	LOQ	4.4	5.2	4.6	LOQ	LOQ	LOQ	LOQ
Rem, Rem + V	4	LOQ	LOQ	LOQ	LOQ			LOQ			LOQ	9.5
Rem, Rem + V	9	LOQ	LOQ	LOQ	LOQ		LOQ	LOQ	LOQ		LOQ	LOQ
Zn												
Orig	1	234	454	304	189	74	85	104	84	90	**163**	73
Orig	3	84	116	203	121	41	82	72	49	115	191	82
Rem	5	2228	2209	2432	1528	**329**	307	349	**203**	**161**	162	96
Rem	6	2020	1454	1187	748	264	**582**	347			126	117
Rem, Rem + V	2	1649	2032	2097	1249	196	279	**534**	101	49	143	102
Rem, Rem + V	4	**2853**	**2664**	**2617**	**1538**			198			154	**162**
Rem, Rem + V	9	2735	2019	1637	577		186	152	81		144	114
Cd												
Orig	1	**4.0**	**7.5**	**4.4**	**4.7**	1.9	1.9	2.5	**2.8**	2.3	2.8	1.0
Orig	3	1.1	1.8	3.5	2.0	0.9	1.3	1.4	1.0	**2.4**	**3.1**	1.3
Rem	5	1.5	2.9	2.2	1.3	**6.7**	1.6	2.8	2.4	1.1	2.1	1.7
Rem	6	1.7	1.8	2.0	1.0	3.9	**8.4**	4.3			2.2	4.0
Rem, Rem + V	2	2.4	0.7	4.2	1.7	3.8	2.7	**10.3**	2.0	0.1	2.3	2.1
Rem, Rem + V	4	3.0	1.3	1.9	1.3			2.2			2.7	**5.6**
Rem, Rem + V	9	3.5	0.3	0.4	0.9		2.7	1.7	1.5		2.1	1.7

The limit of quantification (LOQ) for Pb detection was 4 µg L^{-1},



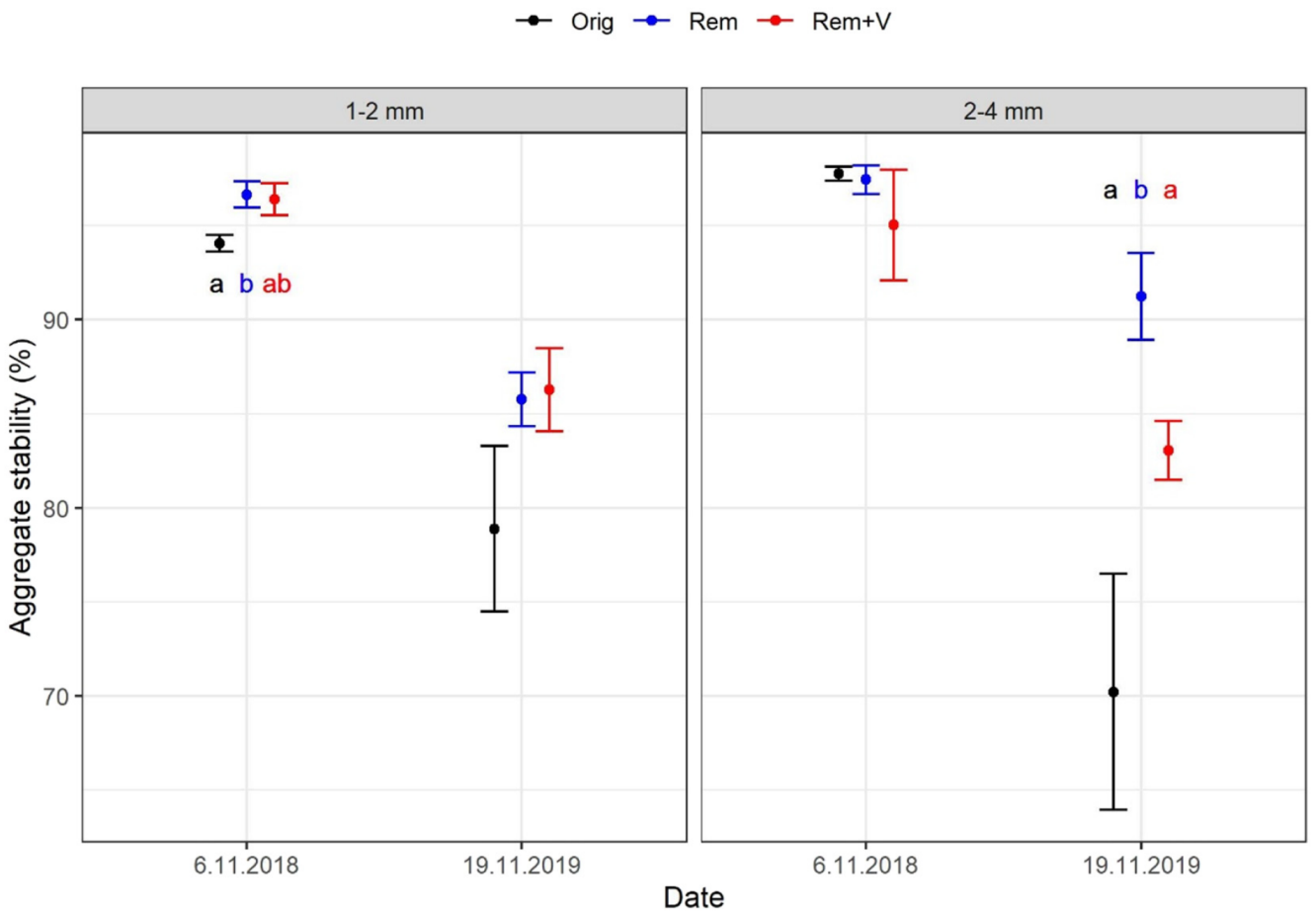
Emissions of EDTA from beds with remediated soil were below the limit of quantification. Pb and Cd leaching from remediated soils (Rem, Rem+V) was reduced. Emissions of Zn were initially higher from remediated soil, but decreased with time.

Soil physical properties

Soil physical properties varied during the time of gardening experiment, but differences between original and remediated soil generally remained within the same range.

List of pedological parameters and laboratory analyzes for original (Orig) and remediated soils (Rem, Rem+V).

Parameter	Standard	Orig soil	Rem soil	Rem + V
Sample preparation (drying, grinding, sieving)	ISO 11465:1993	X	X	X
Soil texture	ISO 11277:2009	X	X	X
Apparent specific gravity / Volume density	ISO 11465:1993	X	X	X

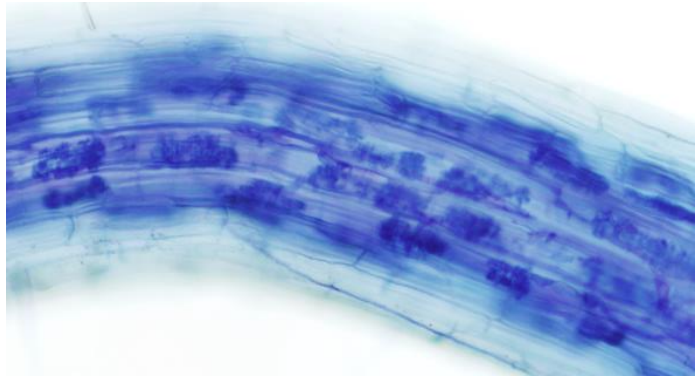


Agregate stability in original (Orig) and remediated soils (Rem, Rem+V).

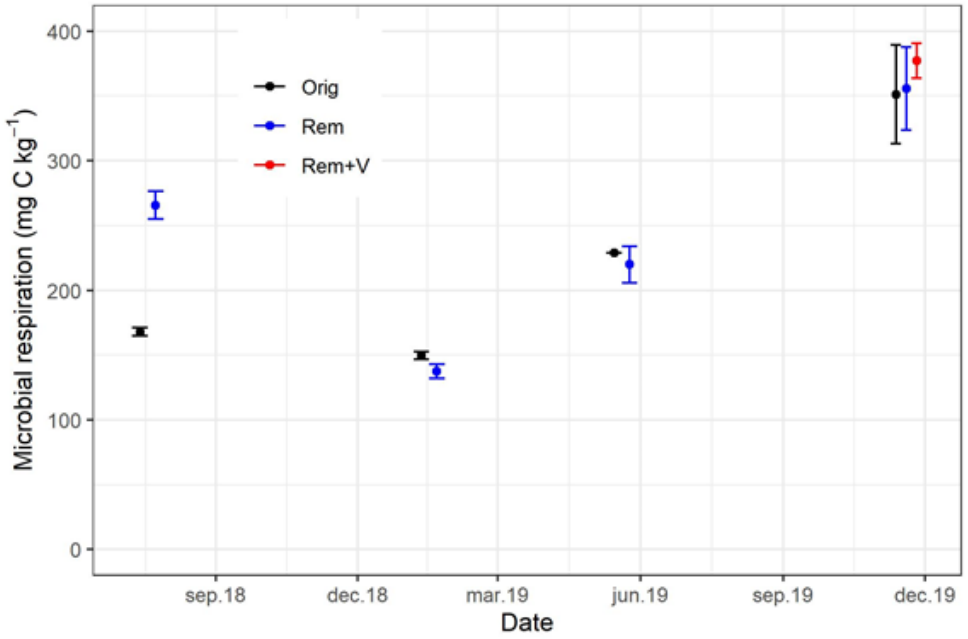
Soil biological properties

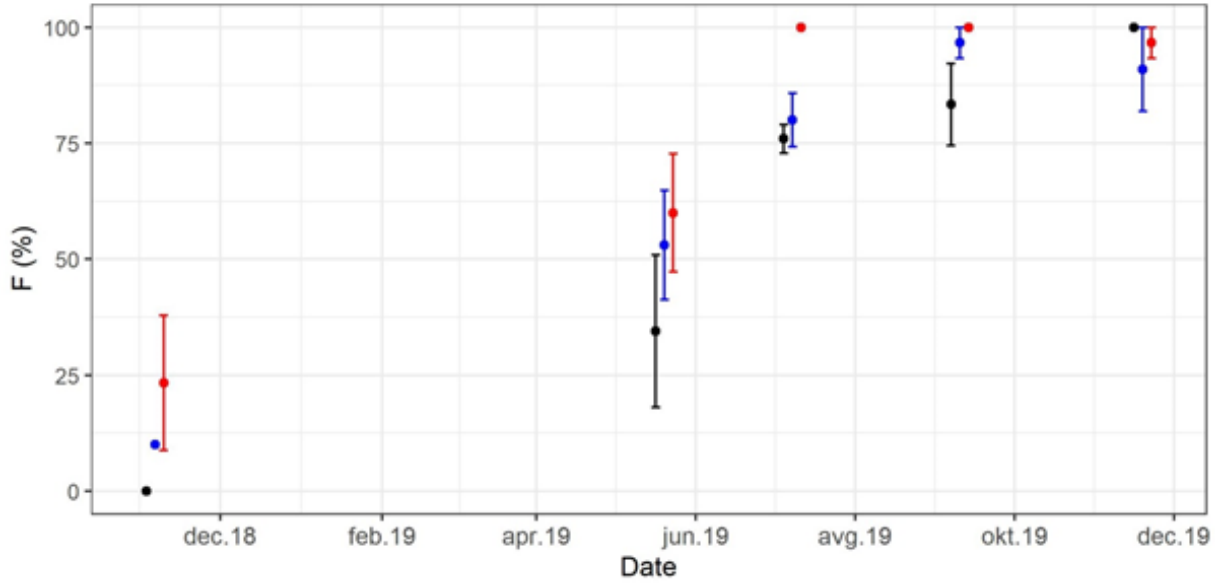
Common biological indicators of soil quality were used to assess soil functioning. Most of microbial activity in remediated soil was similar then in original or recovered by the end of gardening experiment.

Functional arbuscular mycorrhiza was established with or without inoculations (Rem+V) in remediated soils, under environmental conditions.

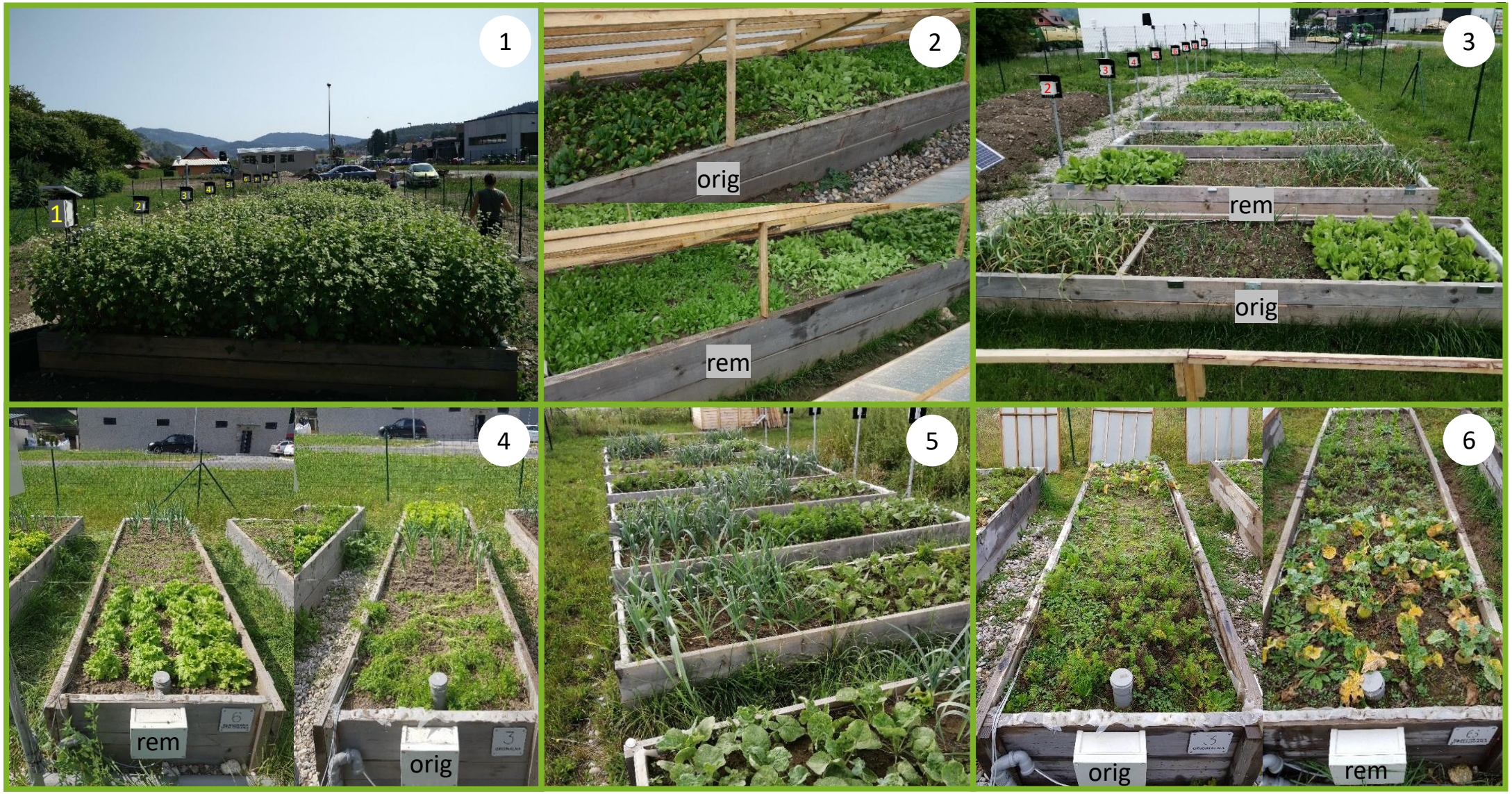


Microbial respiration and frequency of mycorrhiza in the root system (F) in original (Orig) and remediated soils (Rem, Rem+V).





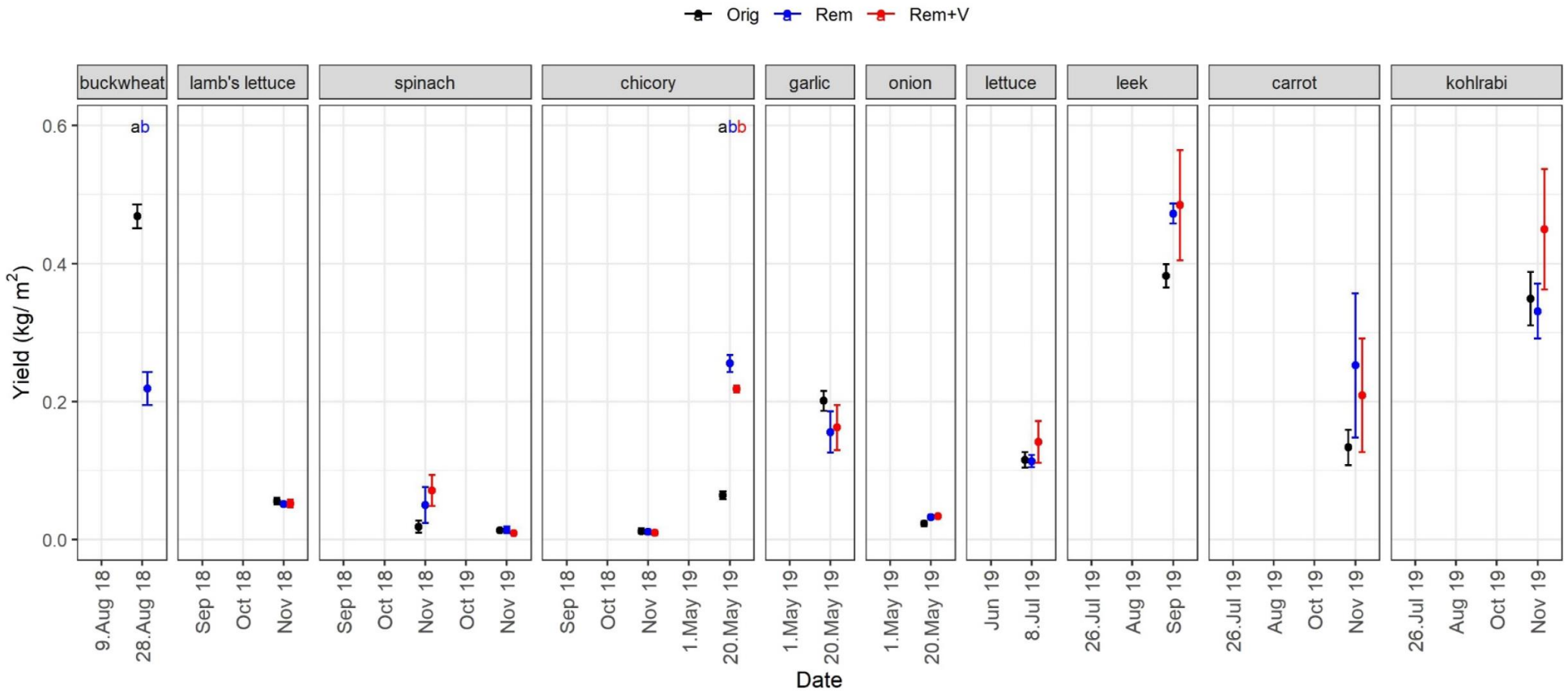
Crop rotations



1 - (1st fall rotation 2018) ***Buckwheat*** *(green manure)*
2 - (2nd fall rotation 2018) ***Spinach, Radicchio, Lamb's lettuce***
3 - (3rd fall rotation 2018) ***Radicchio, Garlic, Onion***
4 - (spring/summer rotation 2019) ***Lettuce, Leek, Carrot***
5 - (1st fall rotation 2019) ***Kholrabi, Leek, Carrot***
6 - (2nd fall rotation 2019) ***Kholrabi, Spinach, Carrot***

Plant growth and biomass yield

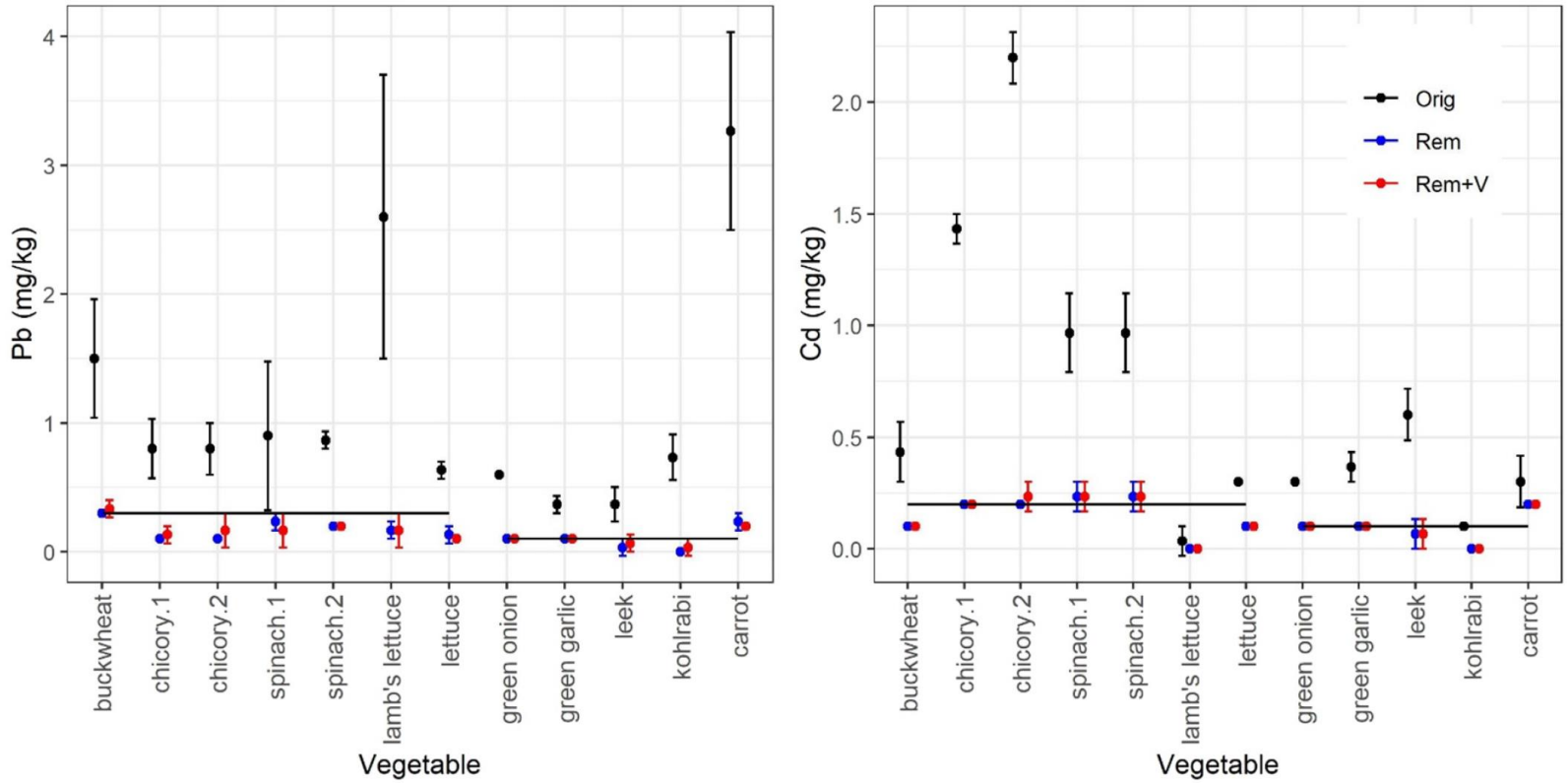
The growth of buckwheat sown as first crop was significantly suppressed in remediated soil. Mulching and green manuring with buckwheat biomass, and emergence of root system improved the remediated soil as a plant substrate: growth and performance of vegetables on the remediated soil were correspondingly robust thereafter.



Vegetable biomass in original (Orig) and remediated soils (Rem, Rem+V).

Production of safe vegetables

Remediation significantly reduced the plant uptake of toxic metals in all parts of plants. Pb levels in edible plant parts were largely acceptable, while Cd levels in some vegetables, particularly in spinach and carrot, exceeded those required by EU legislation (black line). Vegetable type is a strong determinant of metal concentrations in edible plants. Therefore, the choice of excluder rather than accumulator is critical for the production of safe food on soils remediated with ReSoil®.

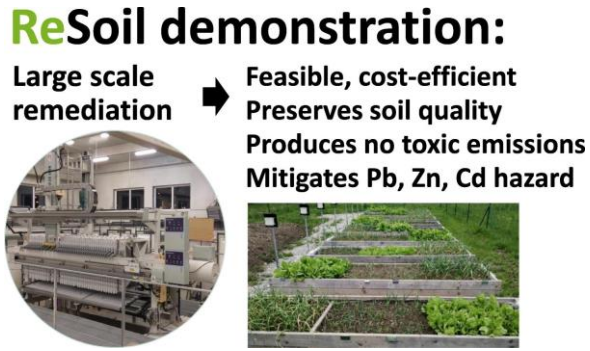


Toxic metal concentration in edible parts of plants grown on original (Orig) and remediated (Rem, Rem+V) soil.

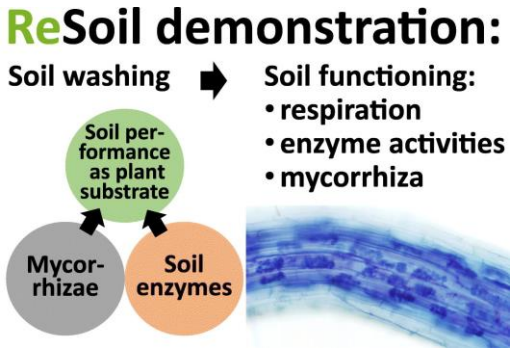
Published papers on this study case

(Open access)

Gluhar, S., Kaurin, A., Finžgar, N., Gerl, M., Lestan, D., 2021. Demonstrational gardens with EDTA-washed soil. Part I: Remediation efficiency, effect on soil properties and toxicity hazards. Sci. Total Environ., 792, p.149060. https://doi.org/10.1016/j.scitotenv.2021.149060



Kaurin, A., Gluhar, S., Maček, I., Kastelec, D., Lestan, D., 2021. Demonstrational gardens with EDTA-washed soil. Part II: Soil quality assessment using biological indicators. Sci. Total Environ., 792, p.148522. https://doi.org/10.1016/j.scitotenv.2021.148522



Gluhar, S., Kaurin, A., Vodnik, D., Kastelec, D., Zupanc, V., Lestan, D., 2021. Demonstration gardens with EDTA-washed soil. Part III: Plant growth, soil physical properties and production of safe vegetables. Sci. Total Environ., p.148521. https://doi.org/10.1016/j.scitotenv.2021.148521