Sanfte Sanierung von schwermetall-kontaminierten Böden: Das GREENLAND-Projekt

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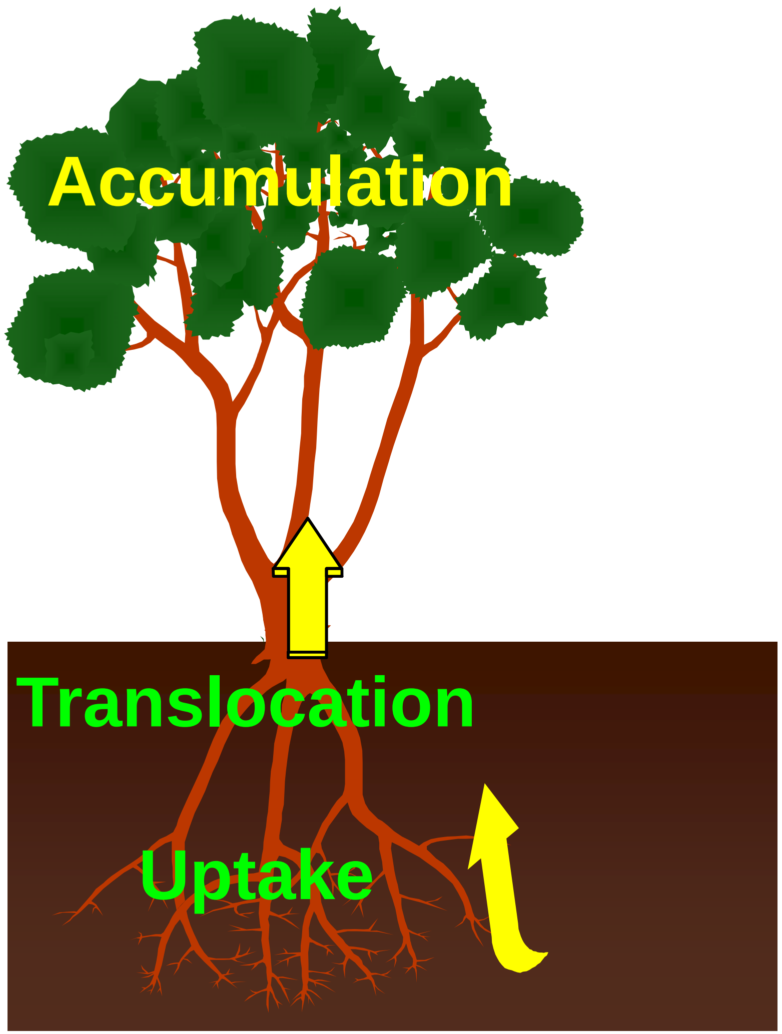
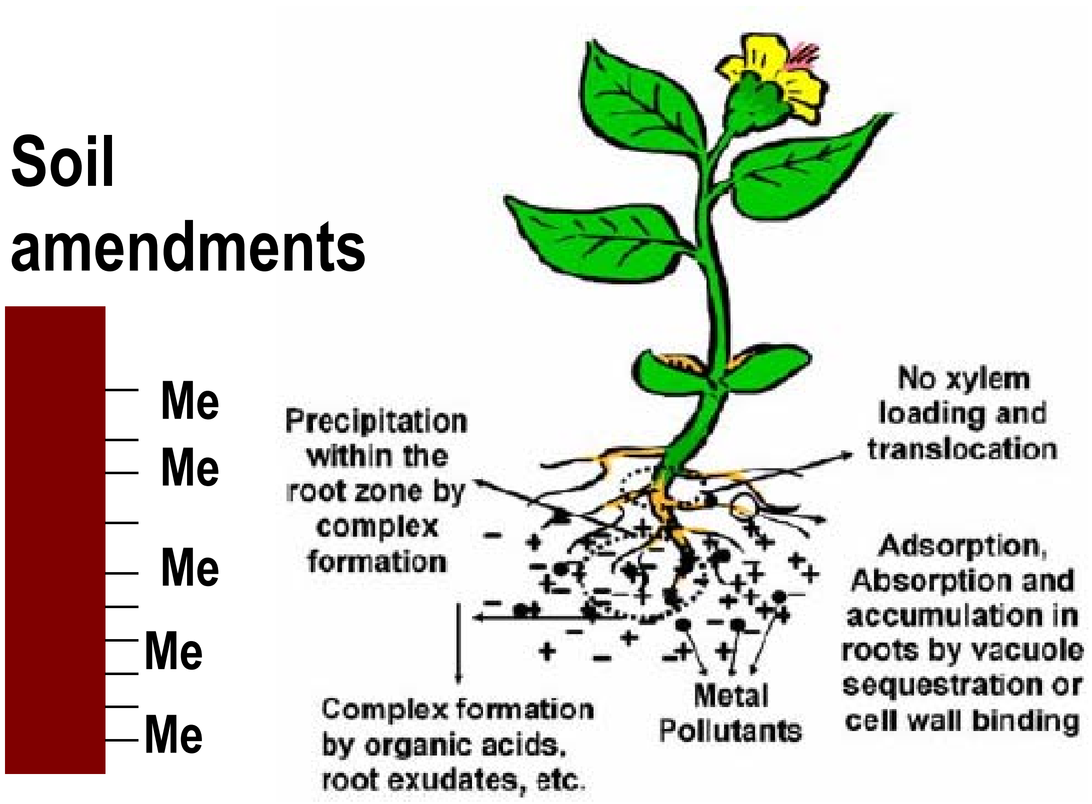
Gentle remediation options - GRO

Phytoextraction



In situ immobilisation
Aided phytostabilisation



Why are GRO not applied yet as practical site solution?

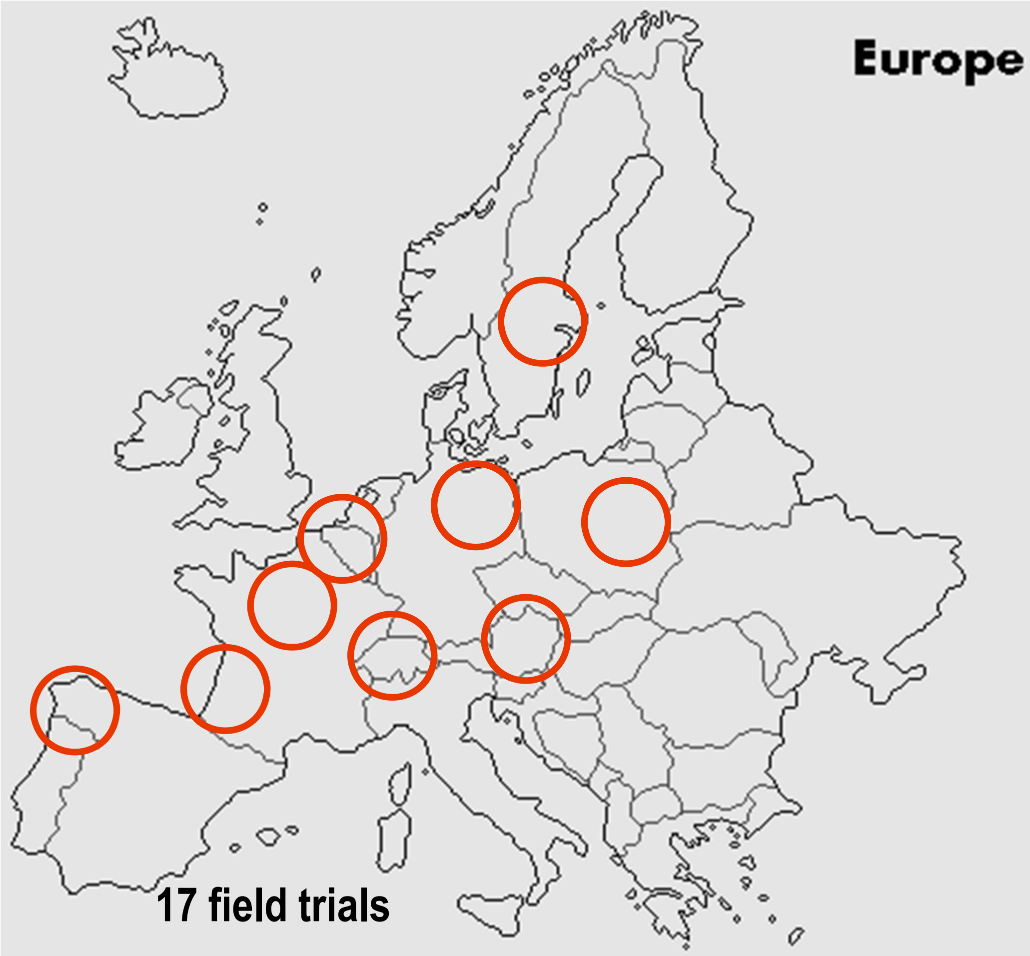
- Performance on **large field scale (up-scaling)** remains to be demonstrated
- **Treatment / Valorisation of TE-contaminated plant biomass** needs to be tested
- **Stakeholders and decision makers** are little informed about GRO
- **Decision support tools** do not sufficiently consider GRO (Onwubuya et al, 2009)
- The success of GRO is mostly reflected by **changes of TE bioavailability**, which is currently not sufficiently considered by legal frameworks; changes in other pollutant linkages should be also assessed.

GREENLAND – Gentle remediation of trace element contaminated land* project objectives

- **Assess the efficiency tested in long-term field trials**
- **Test the possibilities for biomass valorisation**
- **Evaluation of a set of soil tests to assess the pollution level, the progress and success of GRO and the monitoring of sustainability**
- **Enhance the efficiency of GRO (e.g. by selection of most effective plants, microbes, and soil amendments)**
- **Development of a decision support system and publication of a guide for practical application**

* FP7-KBBE-266124; 2011-2014

GREENLAND



European network of field experiments for:
- climatic conditions
- soil types
- contaminants
- re-use for non-food crops
- recycling of organic waste products

Main objectives

To obtain sustainable ecosystems, without or minimized pollutant linkages/risks, producing (non-food) crops for plant-based feedstock (local market), and promoting ecosystem services
(positive Life cycle analysis)

Main outcome

to promote Bio-Economy and gain environmental, health and societal benefits

Ecosystem services

Biomass production C sequestration minimal use or substitution of nonrenewable inputs
Avoid diversion of cropland
Soil biodiversity, promote animal communities, Habitat, connexion
Storing, filtering and transforming nutrients, substances and water

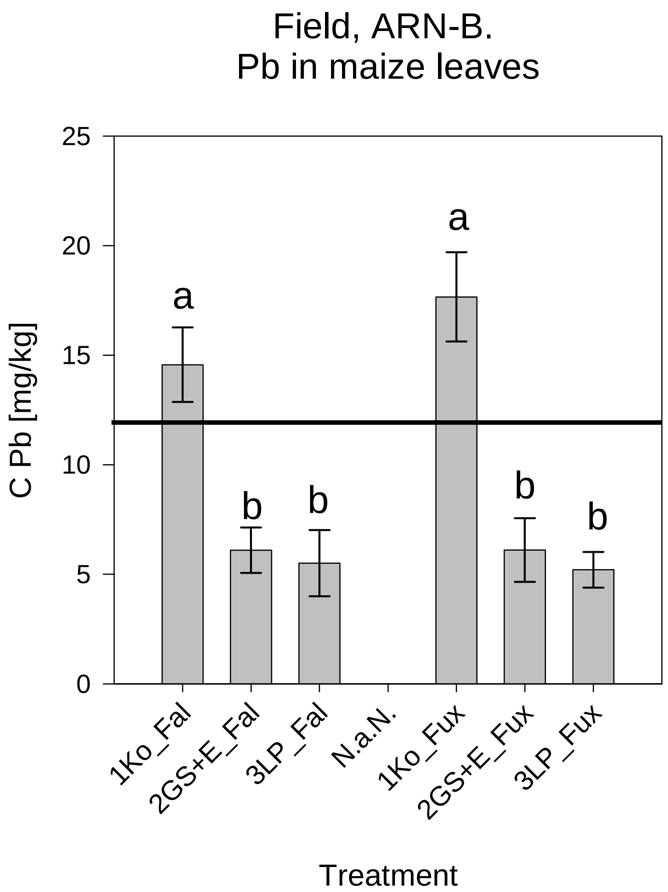
No.	Experimental coordinator	Strategy and gentle remediation technology	Plant species	Contaminants	Site type	Duration
1	UHASSELT	phytoextraction using SRC and crops	poplars, willows, maize, rapeseed	Cd, Zn	agricultural soils	7 yrs
2	SLU	phytoextraction using SRC	willows	Cd, Zn (Cu, Ni, Cr, Pb)	Commercial sludge-amended fields	18 yrs / 7 yrs
3	INERIS	phytoextraction using HA and high biomass crop	*Arabidopsis halleri* rapeseed	Cd, Zn, Pb	Marginal lands in surrounding industrial facility	5 yrs
4	CSIC	phytoextraction using HA and SRC	*Thlaspi caerulescens,* willows	Cd, Zn	tailings	2 yr
5	INRA	aided phytoextraction using high biomass crops from fast-track breeding	sunflower, tobacco sorghum	Cu and Cu/PAHs	industrial soils	5 yrs
6	LfULG	phytoextraction using SRC	poplars, willows	Cd, As, Pb	agricultural soils	7 yrs
7	PT-F	phytoextraction using high biomass crop from fast-track breeding	sunflower, tobacco	Cd, Zn (Cu, Ni, Cr, Pb)	sludged and agricultural soils on landfill	7 yrs
8	INRA	phytostabilisation and rhizodegradation (SRC and grassy cover)	Poplars, willows, grasses, vetiver	Cu and Cu/PAHs	industrial soils	7 yrs
9	CSIC	phytostabilisation	Tobacco, willows	Cu	tailings	2 yr
10	INERIS	aided phytostabilisation	Miscanthus, spontaneous grasses, shrubs, trees	Cd, Zn, Pb, As, Cu	dredged sediments	1 yr
11	AIT	in situ stabilization/phytoexclusion	barley, maize	Cd, Pb, Zn, (As, Cu)	agricultural soils	10 yrs
12	IUNG	in situ stabilization (lime, sludges)/phytoexclusion	grassland	Cd, Zn, Pb	Post-industrial soils	17 yrs
13	LfULG	in situ stabilization/phytoexclusion	crops, grassland	Cd, As, Pb	agricultural soils	7 yrs

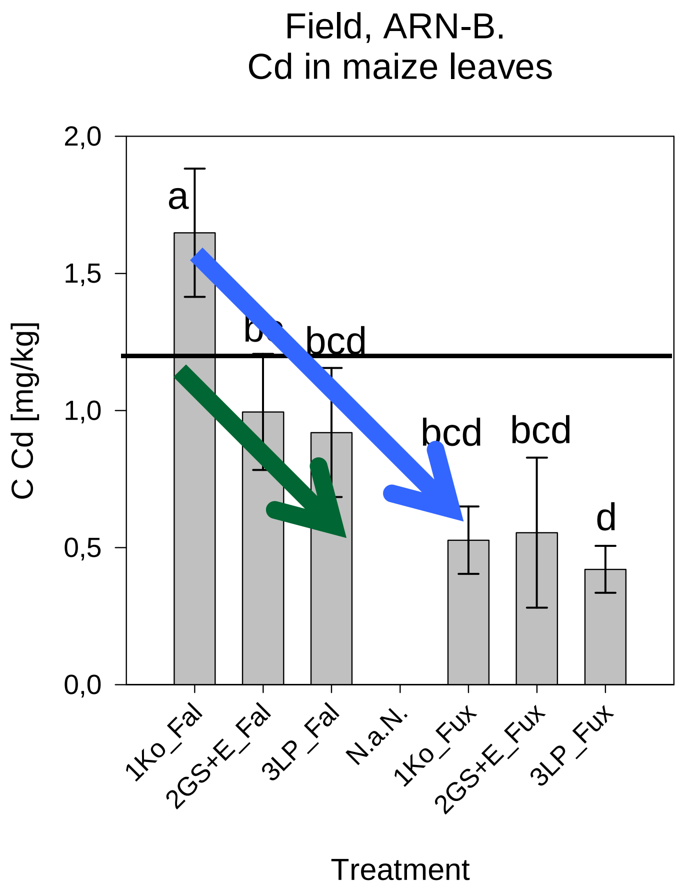
Field experiments – GRO efficiency: Arnoldstein, AT

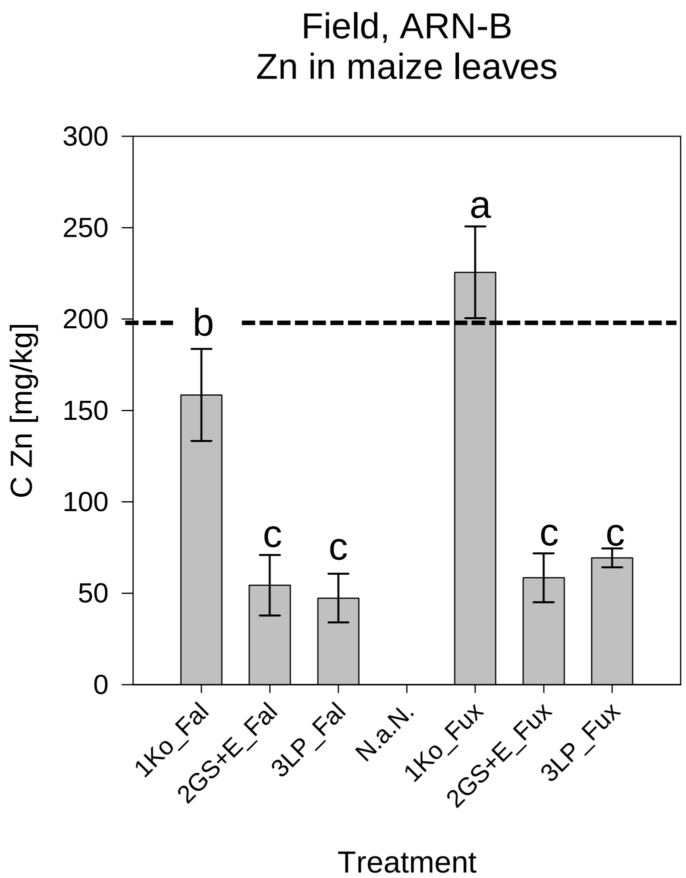
- ARN-B soil (moderate contamination)
- Cd (5), Pb (950), Zn (500), (As)

- ARN-D soil (high contamination)
  Cd (15), Pb (1600), Zn (1800), (As)

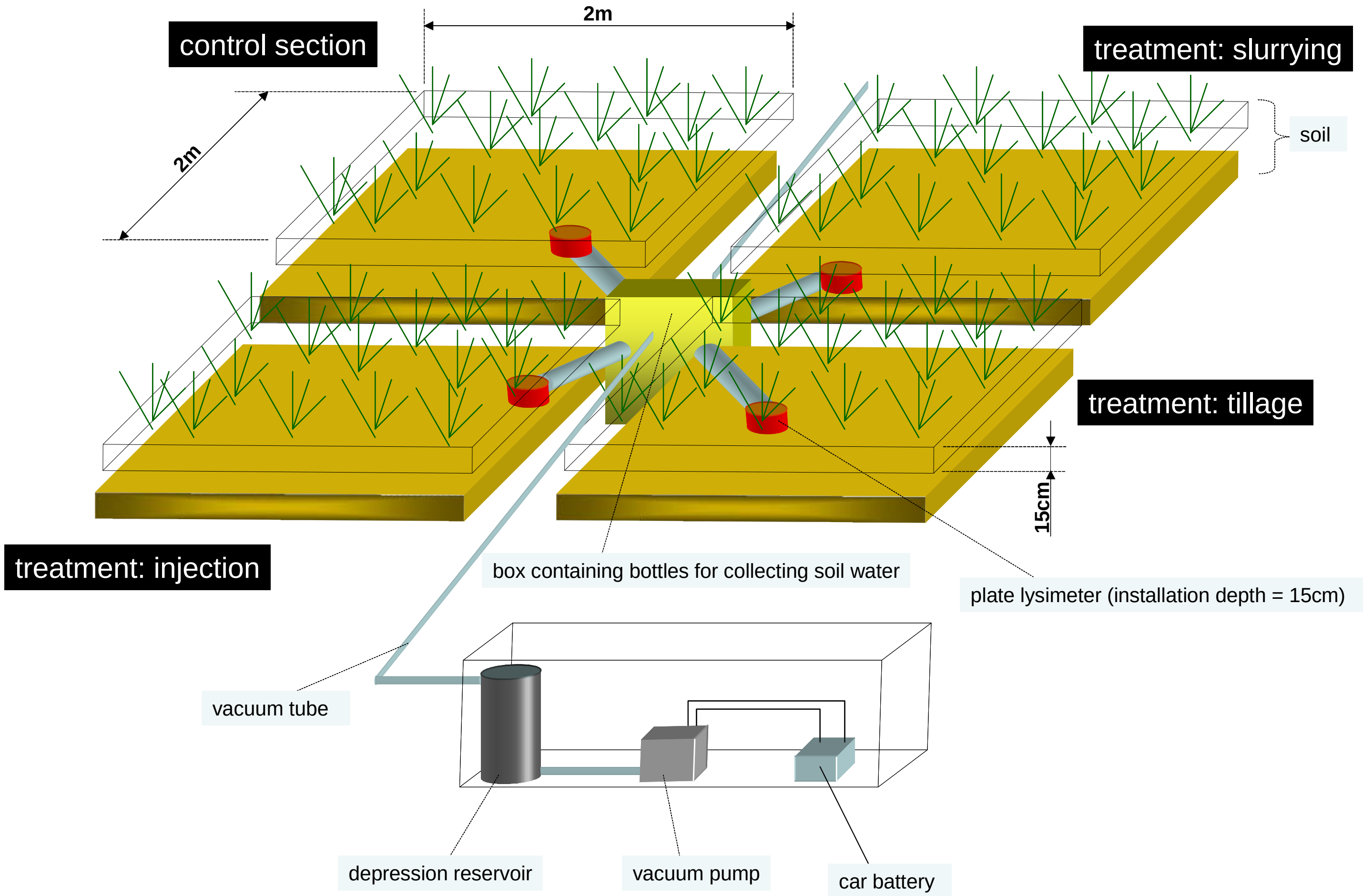
Results 2011: Soil ARN-B (moderately contaminated)



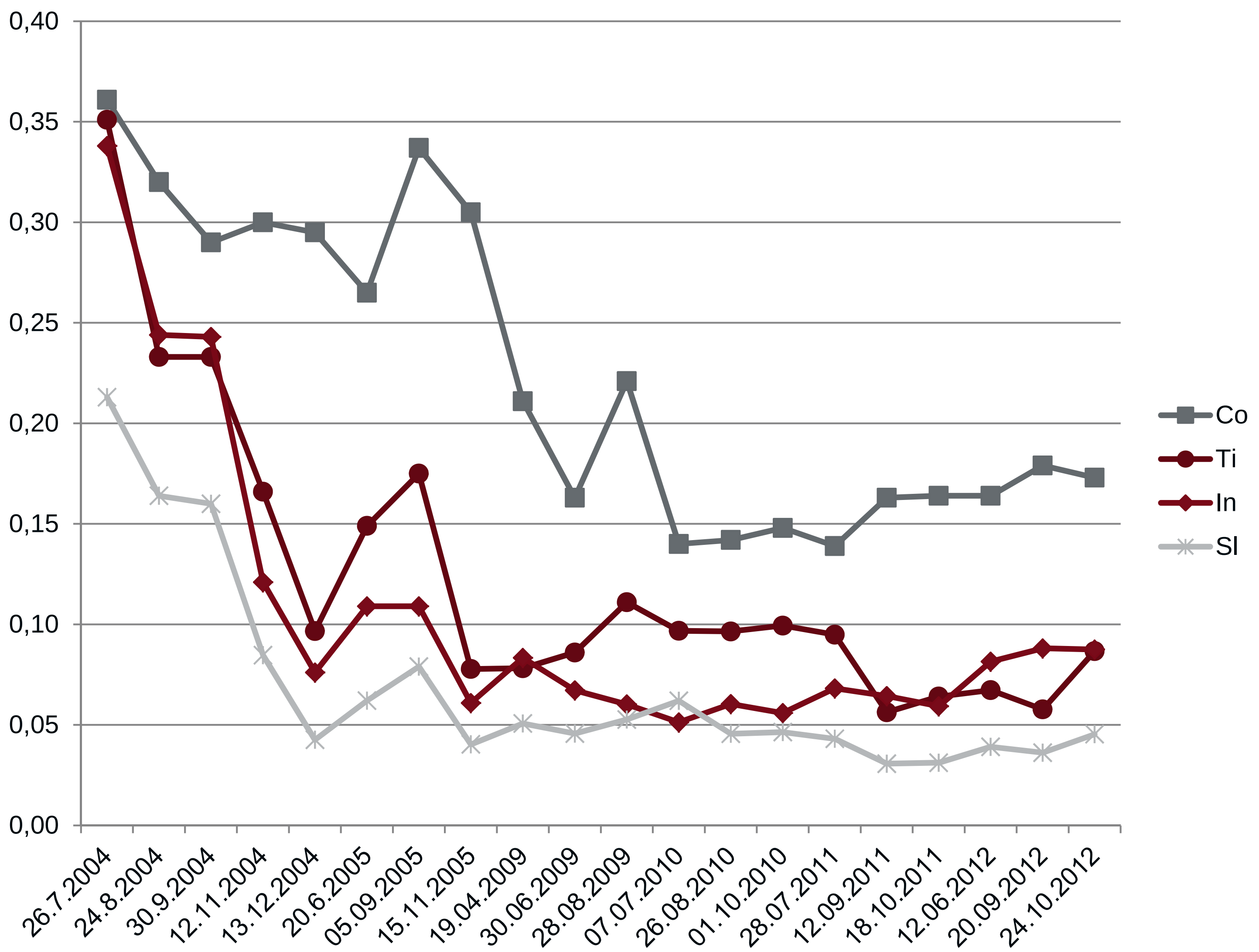




Metal immobilisation on grassland (ARN-D) Seepage water sampling system (plate lysimeters)

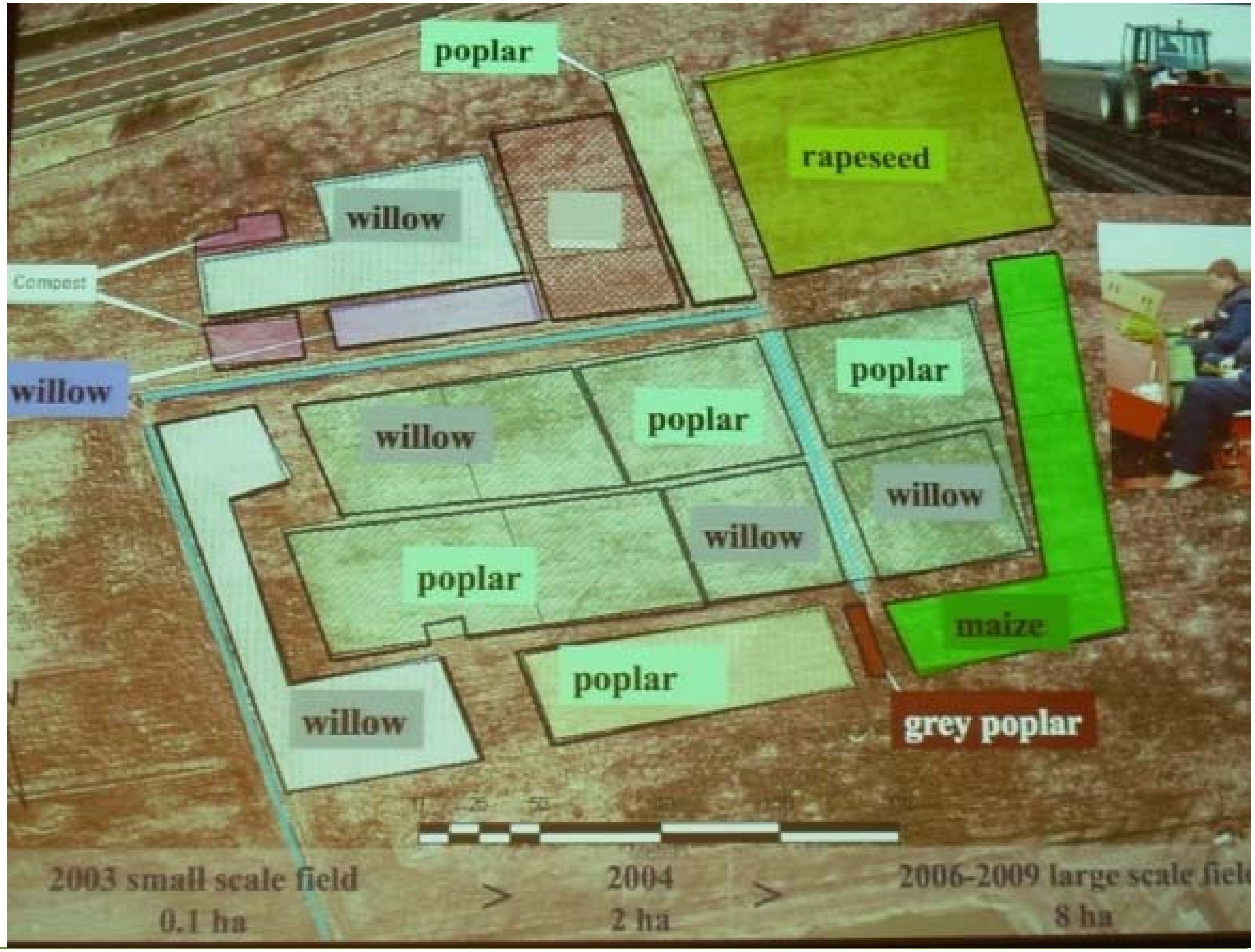


Zn (mg L^{-1}) in seepage water 2004-2012



field experiments – GRO efficiency: Hasselt/Belgium

Lommel 2006-2013

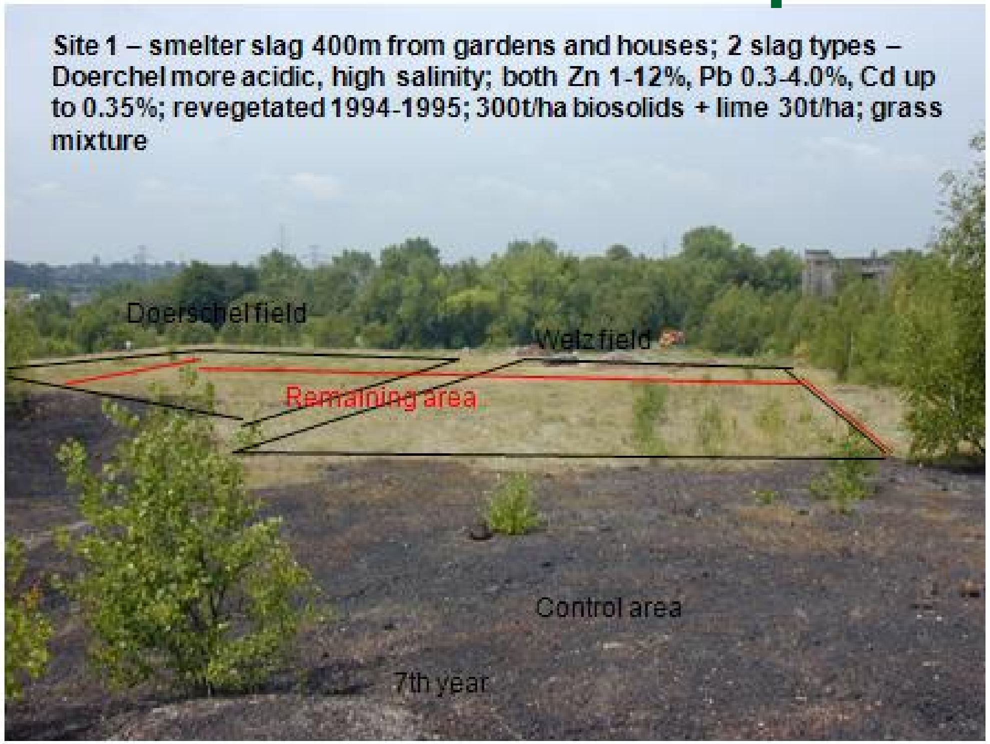


field experiments – GRO efficiency: Hasselt/Belgium

Phytoextraction potential of different species in a field experiment in Lommel

	Cd crop	Biomass	Cd removal	clean up time*
	mg/kg DW	ton/ha	kg/ha/y	5➔2 ppm Cd
Maize	3	20	0.06	188 years
Rapeseed	6	8	0.05	234
Sunflower	12	10	0.1	117
Tobacco	24	8	0.19	58
Poplar: twigs	11	8	0.09	255
Poplar: leaves	28	2.4	0.07	
Poplar: twigs+leaves			0.16	144
Willow: twigs	24	8	0.19	117
Willow: leaves	60	2.4	0.14	
Willow: twigs+leaves			0.34	67

field experiments: IUNG (Poland)



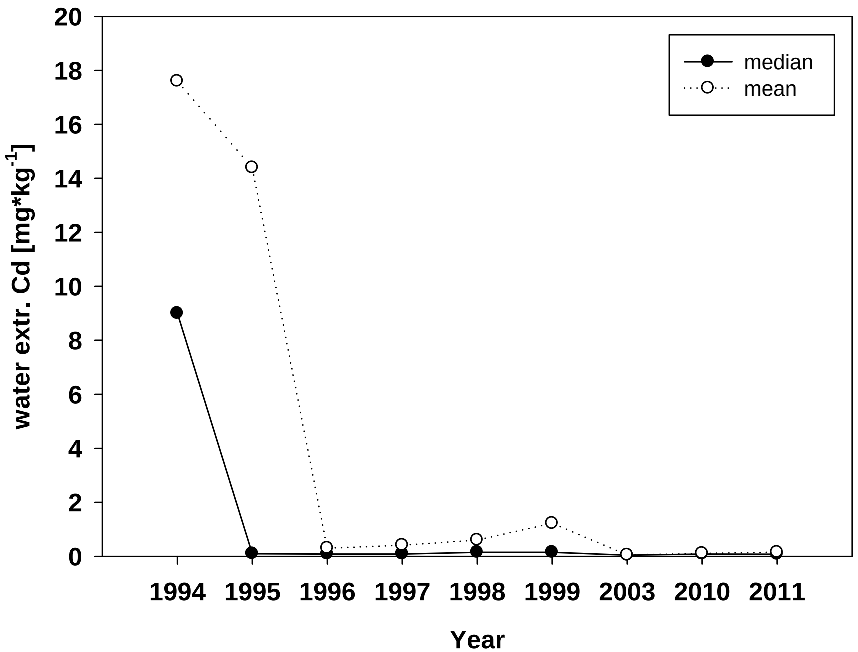


Table 3. Chemical properties of waste materials sampled before (1994) and after remediation amendment with biosolids and lime.

Waste material	Sampling time	Soluble Zn	Soluble Cd	Soluble Pb	pH	EC
		mg kg^{-1}				dS m^{-1}
Welz	Before	343	17.6	1.80	7.00	7.30
	1995	279	17.7	1.10	7.20	3.50
	1996	10.4	0.41	0.34	7.47	1.63
	1997	11.4	0.55	0.41	7.70	1.28
	1998	33.3	0.62	0.02	7.22	0.99
	1999	31.7	1.22	0.03	7.39	1.15
Doerschel	Before	1670	108	5.40	5.80	16.0
	1995†	983	57.4	2.90	6.00	9.00
	1996	12.4	0.66	0.42	7.44	2.98
	1997	17.9	0.80	0.40	7.74	2.06
	1998	24.1	0.48	0.01	7.28	1.53
	1999	104	0.99	0.02	7.36	2.08

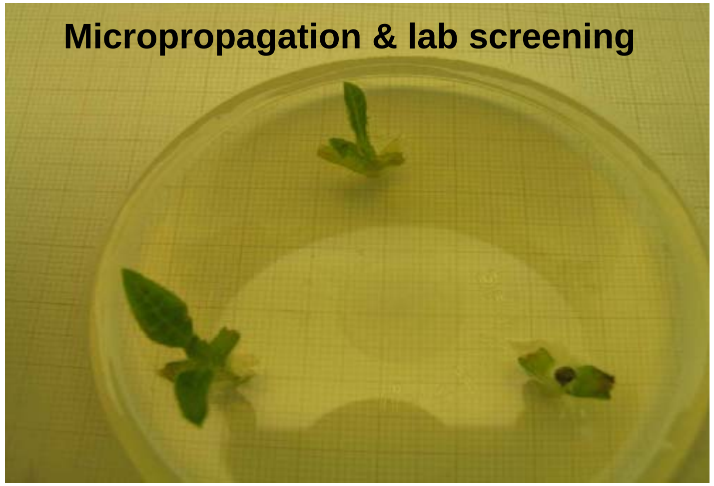
† Sampled before retreatment of Doerschel waste.

Struczynski et al. 2007

field experiments: Phytotech Foundation (CH): Improved metal phytoextraction of tobacco by *in vitro* breeding

1. Tobacco clones with improved metal uptake were obtained from *in vitro* breeding (non-GMOs)


Callus breeding and indirect shoot regeneration (somaclonal variation)


Micropropagation & lab screening

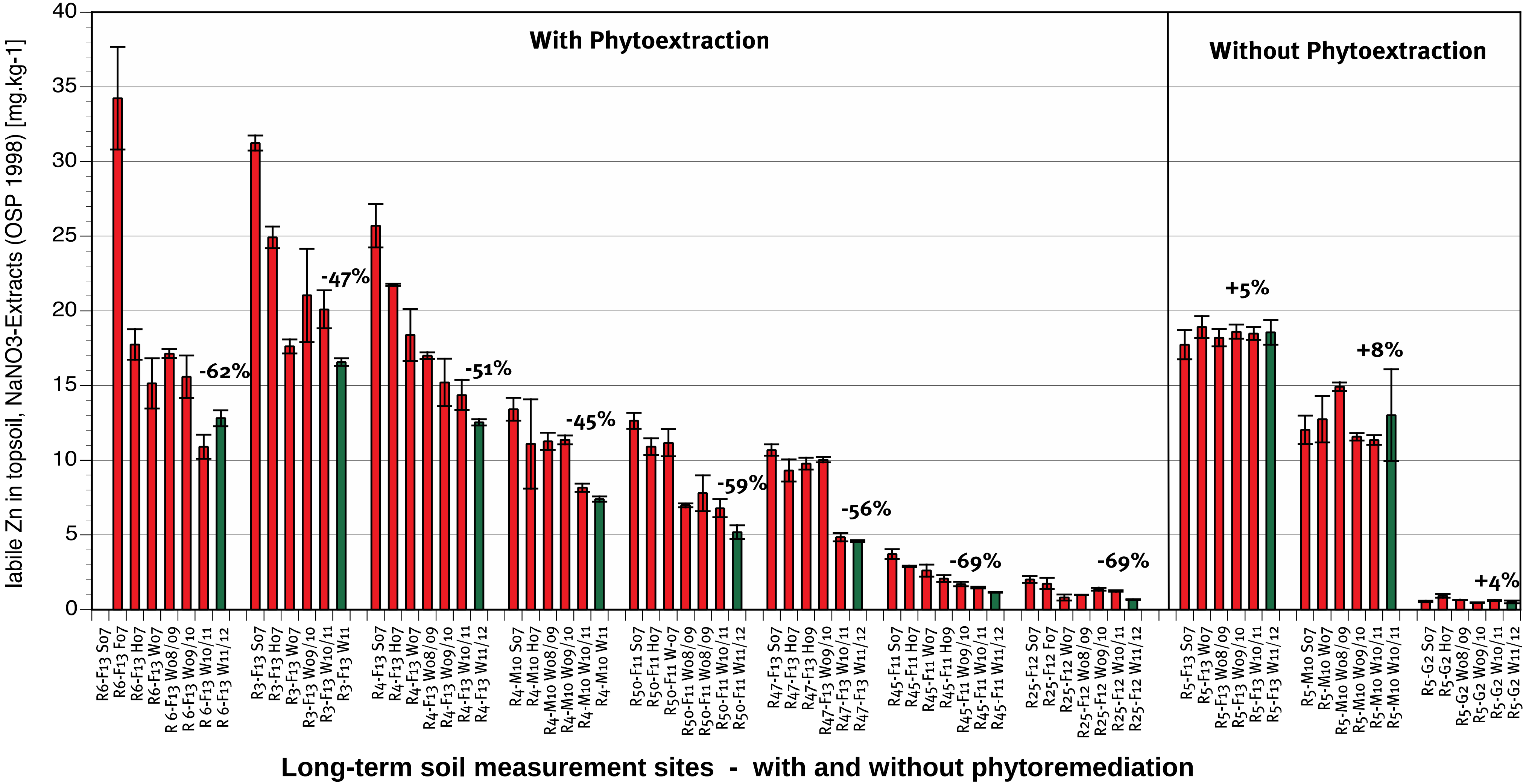
2. *In vitro* bred tobacco were tested since years under real field conditions (PHYTAC, COST 837, 859, GREENLAND...)


Rafz (CH) 23.10.2003


Balen (B) 20.8.2003

- **<u>A freeland assessment</u> of 4th FWP PHYTAC on the <u>acid sandy soil of Balen</u> (zinc smelter) in Belgium showed a promising <u>enhanced metal extraction up to a factor of 12-15 for Cd, Zn, and Pb</u>.**

Field experiments: Phytotech Foundation (CH): Treatment effect over 5 Years - Reduction of labile Zinc in topsoil, site Bettwiesen on landfill Grüenau-Buech-Alpenblick 2007 – 2011/12

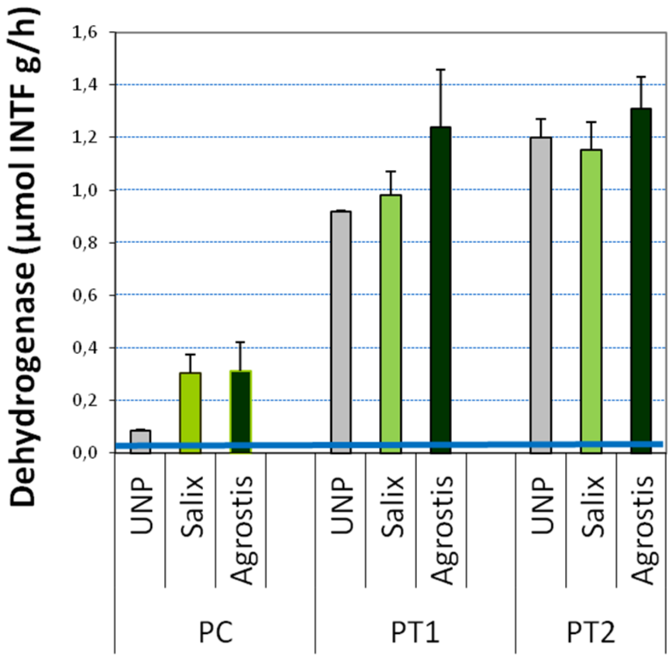


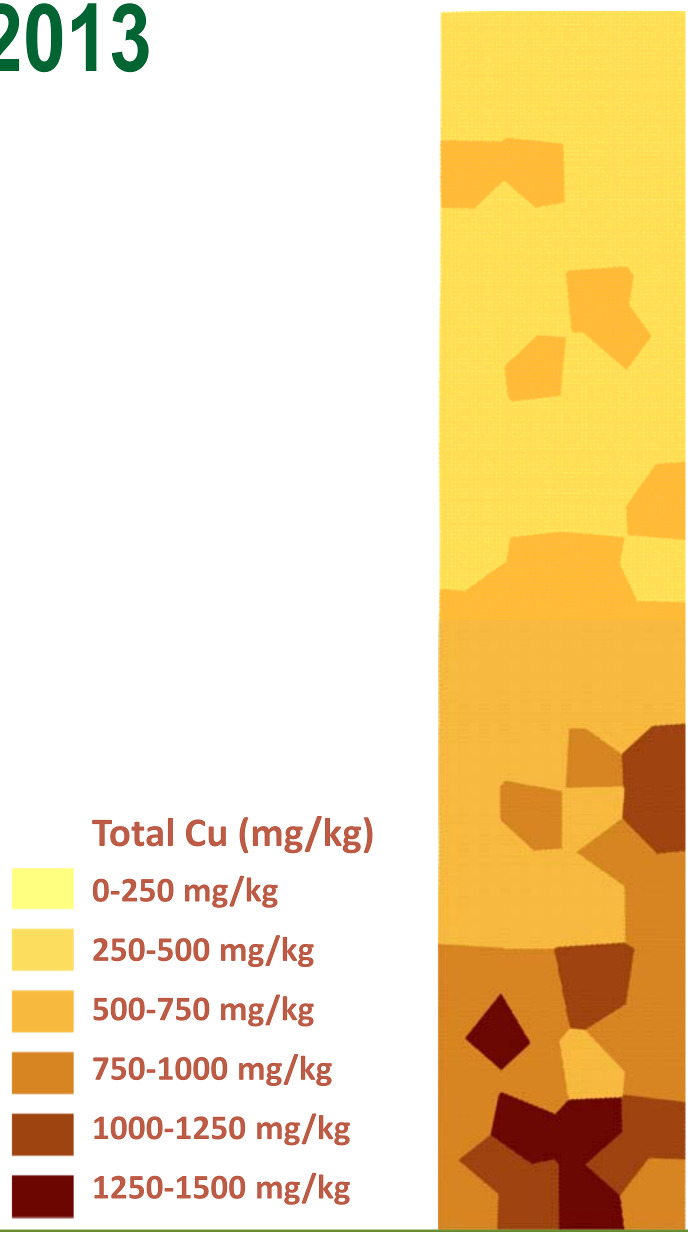
Site Bettwiesen on Landfill Grüenau-Buech-Alpenblick after 248 Weeks of Phytoextraction with improved sunflower and tobacco in crop rotation scheme - Soil Series June 2007 – Winter 2011/12 (A07-W11/12)

Phytotech Foundation PT-F & AGB
CH-3013 Berne / Switzerland

field experiments – GRO efficiency:

Touro, Spain; 2011-2013





CSIC

Harmonisation of methods to assess the bioavailability of TE and development of tool set to monitor the sustainability of GRO

- To achieve a convincing argument towards the decision makers, we need a harmonisation of methods to assess the initial and residual risks and the success of GRO on a comparable (and pan-European) basis.

- To select/harmonise methods describing the bioavailable/bioaccessible TE fractions among European case studies

- To select methods which can be used as indicators for GRO success and as sustainability monitoring tools.

Standard risk assessment and long term monitoring

Time (4 years)
(bi)annual (bio)monitoring

Plant-microbial-soil system

Characterisation of soils

- **General physicochemical properties**: pH, CEC, C, N, available P (olsens), total [metal], etc.
- **Intensity of contaminant exposures**: H_2O-, $NaNO_3$-, NH_4NO_3-, EDTA-extractable [metal], soil pore water, DGT
  Ecotoxicity tests: plants, bioaccessibility (DIN 19738), earthworms, nematodes, etc.
- **Biochemical properties**: Oxidoreductase & hydrolase (C, N, P, S cycles) enzyme activities

Plant growth and establishment

- Survival, growth & coverage
- Plant ionome; contaminant accumulation

Bacterial community structure

Ecosystem services:
water filtration, C sequestration, biodiversity, etc.

Case site	AIT Arnoldstein	IUNG Piekary		INRA Biogeco		HAU Lommel	PT-F Bettwiesen	LfULG Freiberg-Halsbrucke	SLU Högbytorp
Contamination level**	**H**	**VH**		**VH**		**H**	**VH**	**H**	**L**
Treatment	**Aided phytostabilisation**					**Phytoextraction**			
		Tr 1*	Tr 2*	Tr 1*	Tr 2*				
Extractions									
AqReg			Cd, Pb						
EDTA	Cd, Zn	Zn	Cd	Cu		Cd, Zn, Pb	Cd, Pb		
NH_4NO_3	Cd, Pb, Zn		Pb	Cu	Cu		Zn, Pb		Cd
$NaNO_3$	Cd, Pb, Zn		Zn, Cd				Zn, Cd, Pb		
H_2O	Cd, Zn	Pb	Pb	Cu			Zn, Cd		
C_{DGT}	-		-						-
C_{sln}	-		-		Cu				-
R_{DGT}	-		-	Cu		Zn			-
Plantox									
Lettuce									
shoot mass DW			X				-		
shoot mass FW			X	X	X		-		
Turnip									
seed germination			-	X	-		-		
shoot mass DW	X		-	X	-		-		X
Dwarf beans									
shoot mass DW	X		X				X		
primary leave mass	X			X	X		X		
root mass	X		X	X			X		
shoot length	X	X					X		
Soil Ecotoxicity									
Number of worms			-		-		-		
Nematode growth			-		-		-		X
Nematode reproduction			-		-		-		X
Plant Enzymes									
Leaves									
ME	X						X	X	X
ICDH	X		X				X		
GPOD	X						X		X
Roots									
ME			X						
GIDH	X			X					
GPOD	X								

Assessment of biomass valorisation options

- to review existing processes and types of biomass; to compile information on current and under development processes
- to test various types of plant biomass collected on case study sites (WP1)
- to assess advantages and limitations regarding technical aspects, regulations, acceptance and costs
- Treatment options:
  - Incineration
  - Gasification
  - Anaerobic digestion
  - Solvolysis
  - Microwave thermal treatment
  - Oil production

Improvement of GRO efficiency

- Selection and testing of more efficient plant species, varieties, clones
- Selection and testing of more efficient microbial strains (rhizobacteria, endophytes)
- Application of agronomic practices for improving GRO efficiency

Development of a decision support tool and a best-practice guidance document

- → best-practice guidance document for the application of GRO at field-scale
- → Guidelines for stakeholder participation, engagement and empowerment when implementing GRO
- → To develop a decision support tool, focused on GRO, which can be integrated into existing, well-established and utilised (national) DSTs / decision-frameworks.

Journal of Environmental Management 129 (2013) 283–291

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: The European context

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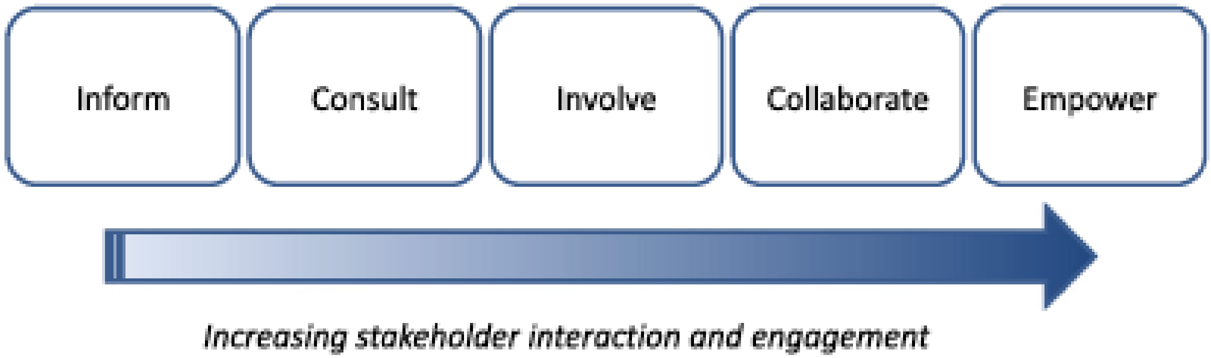
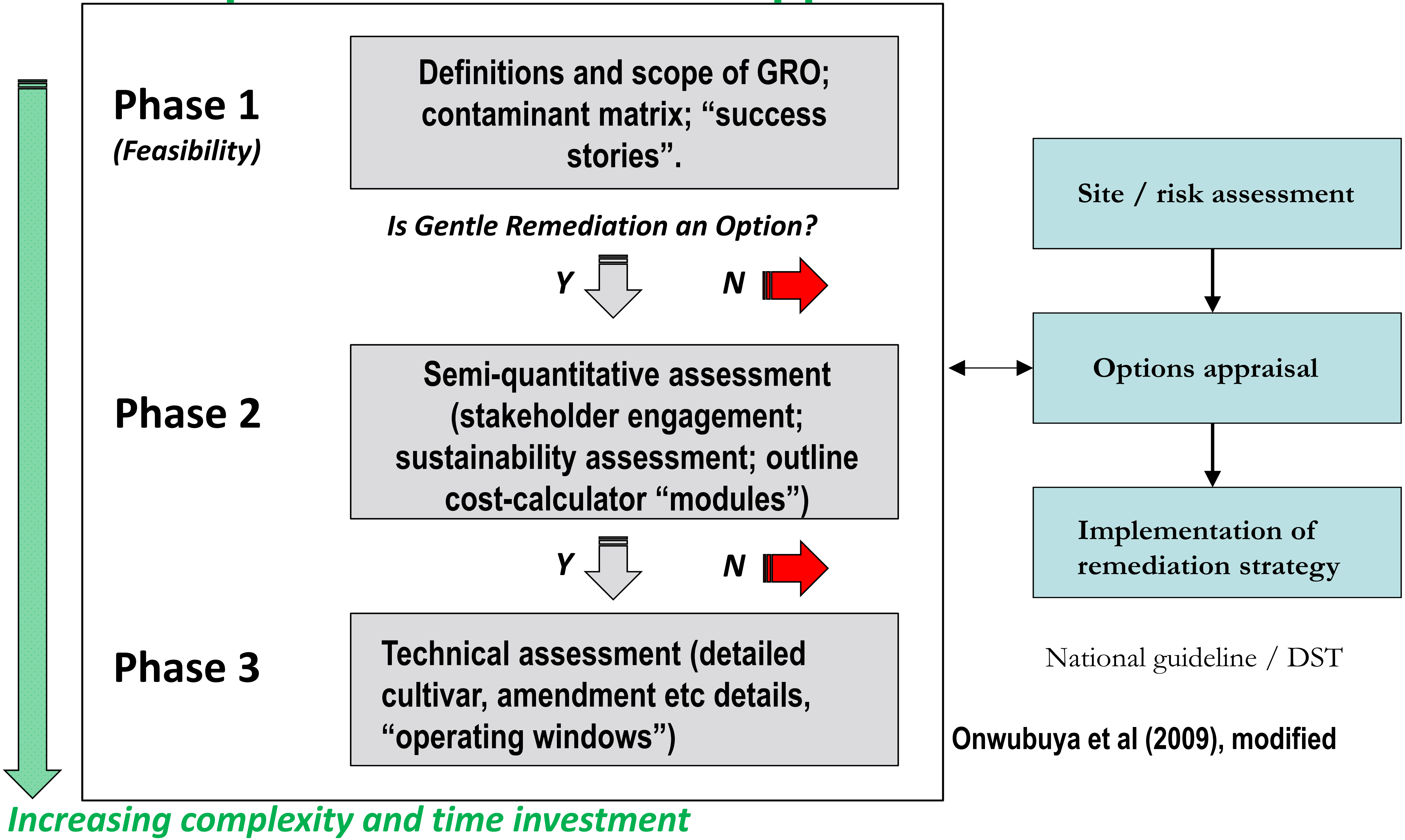


Fig. 3. Spectrum of stakeholder engagement and empowerment activities (after REVIT Project, 2007). Note that the lower arrow shows direction of increasing depth of stakeholder interaction and engagement and is not intended to show a "flow" of activities, as stakeholder engagement activities are frequently iterative and non-linear in nature and may involve the full range of these involvement measures (see text for discussion).

Development of a decision support tool



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