Revegetation as a tool for risk containment of heavy metal polluted sites

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Background

- All over the world extended sites exist with extremely high heavy metal contents in the soil
- Many of these sites are unable to sustain vegetation
- The sites may cause direct effects on human health and ecosystems, through leaching, erosion etc.
- Complete clean-up of the sites is generally no viable option

IS REVEGETAION A SOLUTION?

Objective

To assess the viability of revegetation of heavy metal polluted sites, focusing on verifiable "critical success factors":

- **Lysimeter and field experiments**
- **Decision Support System**

Presentation outline

1. Critical success factors
2. Lysimeter and field experiments

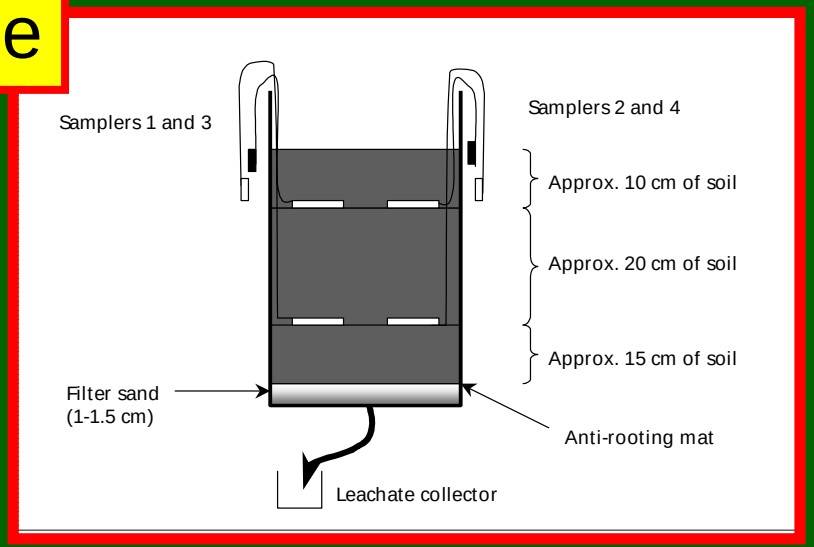
   Katowice, Poland
3. Short overview DSS
4. Application DSS
5. Conclusions

Critical succesfactors Phytostabilisation

- **No increase of *leaching* of heavy metals from soil**
- **Reduction of *wind and water erosion***
- **Acceptable *human risks***
- **Acceptable *ecological risks***

Katowice– mesocosm experiments

Mesocosm set-up at Katowice



Monitored heavy metals:

Zinc	1.3%
Cadmium	0.05%
Lead	0.9%
Arsenic	0.02%

Katowice – mesocosm experiments

Additives tested

- TSP 5%
- TSP 2.5% + lignite 10%

Plant species tested (focusing on **local wild species**)

- *Cardaminopsis arenosa* (marginally growing at the site)
- *Deschampsia cespitosa* (marginally growing at the site)
- Mixture of all three locally observed species in naturally found ratios (20% *Silene inflata*, 40% *Cardaminopsis arenosa*, 40% *Deschampsia cespitosa*).
- *Salix purpurea* (potential energy crop)

Katowice – field tests

Additives tested

- TSP 5% in upper 20 cm
- TSP 2.5% + lignite 10% in upper 20 cm

Plant species tested

- *Deschampsia cespitosa* (marginally growing at the site)
- *Salix purpurea* (potential energy crop)

Katowice – critical succes factors

- Effects on heavy metal leaching rates
- Effects on wind and water **erosion** rates; vegetation cover and root density
- Risks of food chain contamination and soil ecosystem risks

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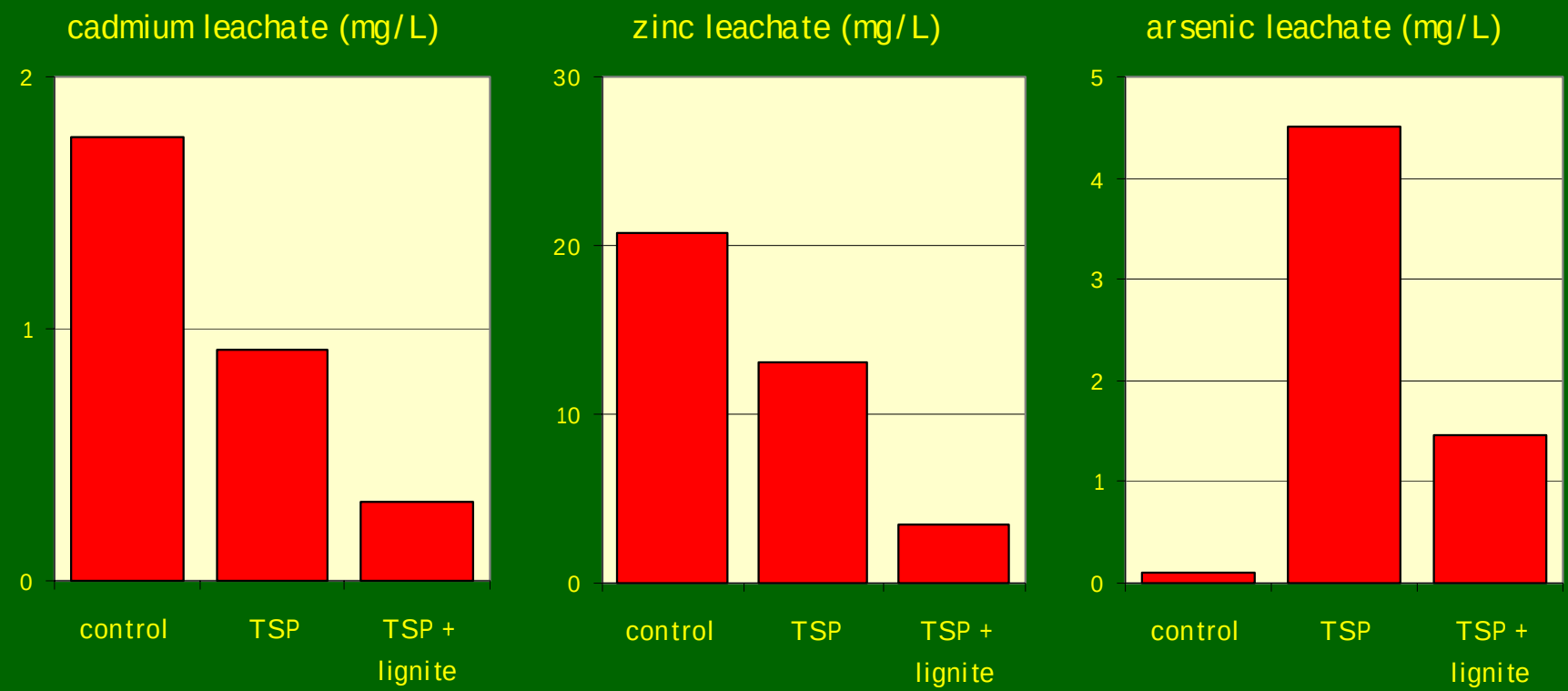
Katowice – mesocosm leaching



Additives reduce heavy metal concentrations in leachates for Cd and Zn, but not for As

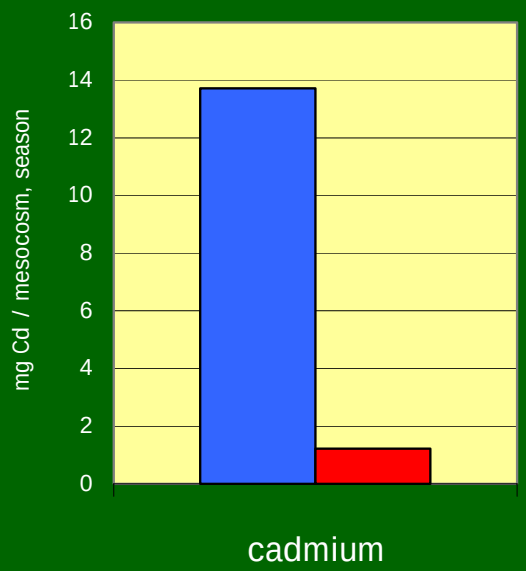
Average data May 2002-June 2003

Katowice – mesocosm leaching

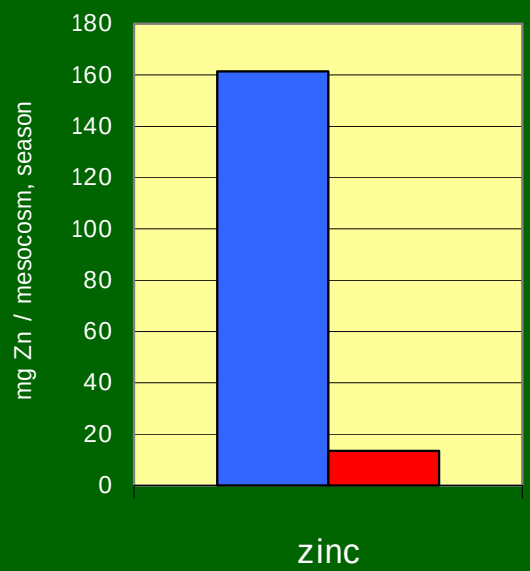
Influence of vegetation cover on leaching rates

Leachate volumes:

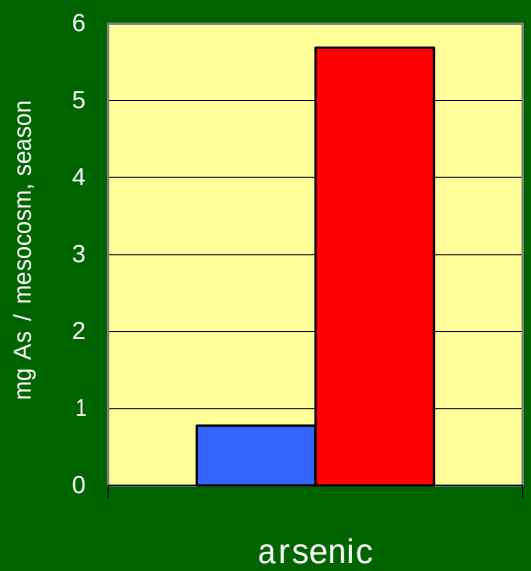
Bare soil:	7.8 L/season
Deschampsia cespitosa	3.9 L/season



cadmium



zinc



arsenic

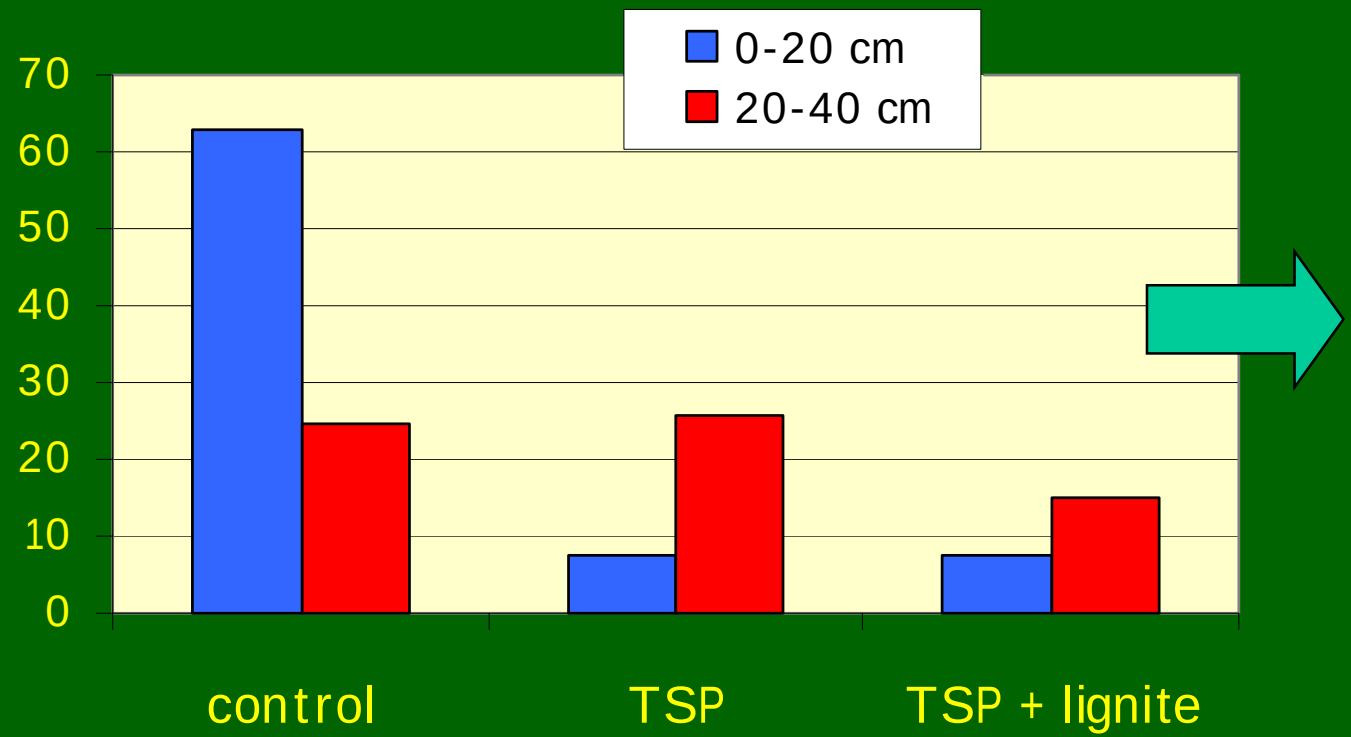
Deschampsia cespitosa / TSP+lignite

Bare soil without additives

Average data May 2002-June 2003

Katowice – field site leaching

Influence of vegetation cover on "available" cadmium concentration (0.01 M $CaCl_2$ extraction, mg/kg) at different depths



Leaching rates in the field higher than in the mesocosms

Data March 2004

Katowice – leaching conclusions

The combination of TSP (+ lignite) and vegetation reduces leaching rates for Cd, Zn & Pb by around 10.

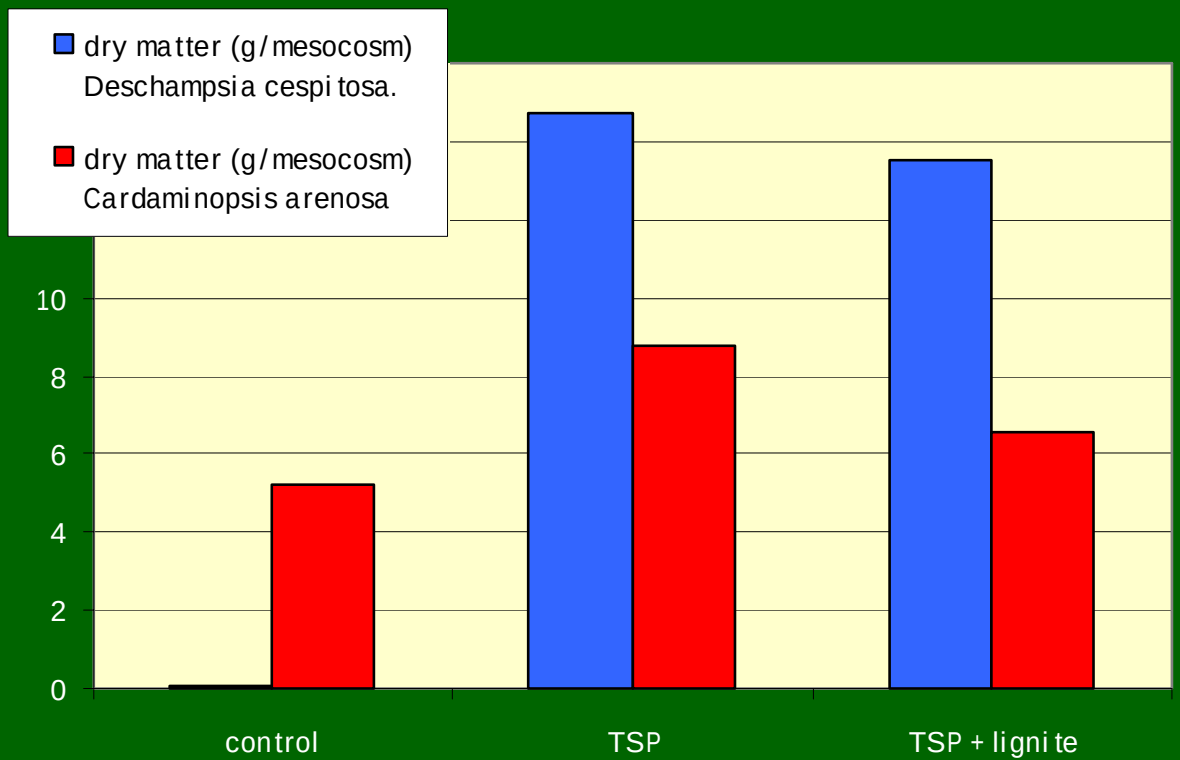
Leaching rates of As are increased 5-fold due to P-As competition

Katowice – critical succes factors

- Effects on heavy metal leaching rates
- Effects on wind and water erosion rates; vegetation cover and root density
- Risks of food chain contamination and soil ecosystem risks

Katowice – mesocosm vegetation

Dry matter production after stabilisation of the mesocosms



Deschampsia c. favored over *Cardaminopsis a.* in additive-amended mesocosms

Additives increase vegetation cover.

Data summer 2003

Katowice – field site vegetation

general
overview
summer 2003

Deschampsia grows well

Salix shows very marginal growth

Katowice – field site vegetation

Root density / distribution measurements

"Fakir bed" technique

healthy roots

deep rooting

Katowice –vegetation conclusion

Deschampsia cespitosa effectively revegetates the site, but only when immobilising agents are added.

Effects are proven sustainable for at least 2-3 years. Experiments continue.

Katowice – critical succes factors

- Effects on heavy metal leaching rates
- Effects on wind and water **erosion** rates; vegetation cover and root density
- Risks of food chain contamination and soil ecosystem risks

Katowice – food-chain contamination

Heavy metals in vegetation mg/kg dry matter

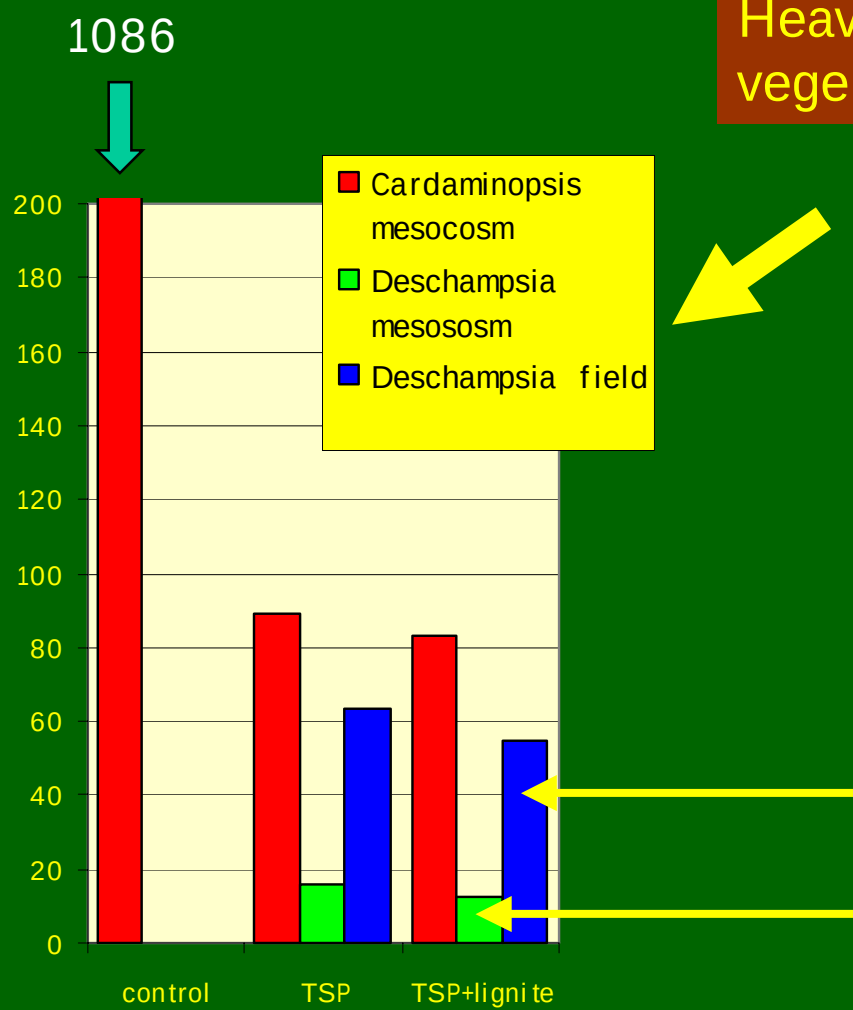
		As	Zn	Pb	Cd
Cardaminopsis mesocosm	control	5.1	10105	800	1086
	TSP	6.9	954	126	89
	TSP + lignite	11.5	1384	245	83
		As	**Zn**	**Pb**	**Cd**
Deschampsia mesocosm	control	n.d.	n.d.	n.d.	n.d.
	TSP	4.8	295	98	16.2
	TSP + lignite	3.8	418	92	12.6
		As	**Zn**	**Pb**	**Cd**
Deschampsia field	control	n.d.	n.d.	n.d.	n.d.
	TSP	n.d.	1108	648	64
	TSP + lignite	n.d.	1077	564	55

hyperaccumulator

Additive only in upper layer at field site

Data summer 2003

Katowice – food-chain contamination



Heavy metals in vegetation

Deschampsia:
Field site cadmium concentrations higher because roots penetrate unamended layers

field

mesocosm

Data summer 2003

Katowice – food-chain contamination - conclusions

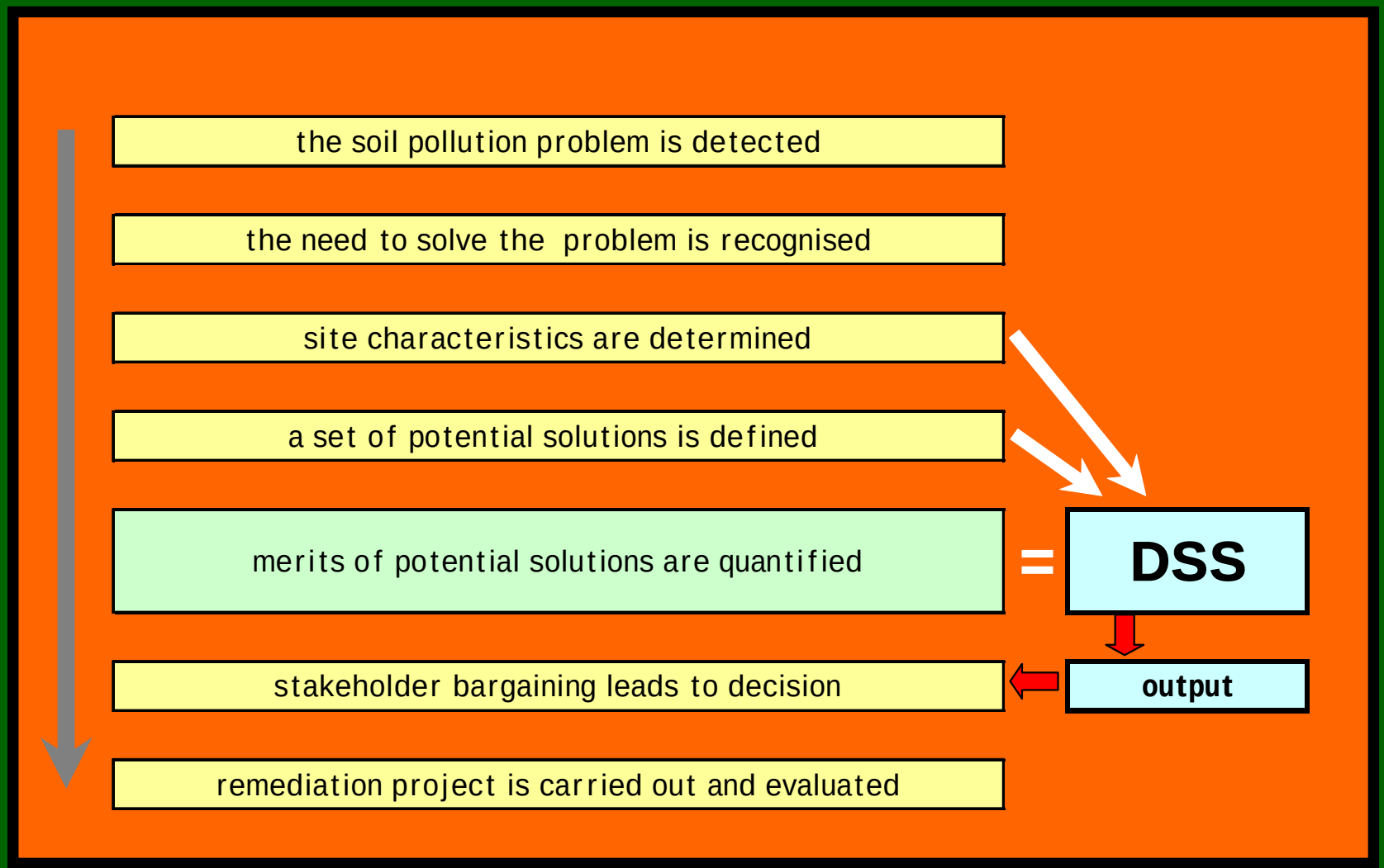
Deschampsia cespitosa in combination with soil additives gives good vegetation covers with low heavy metal contents in the plant shoot.

Arsenic contents in the vegetation are quite low.

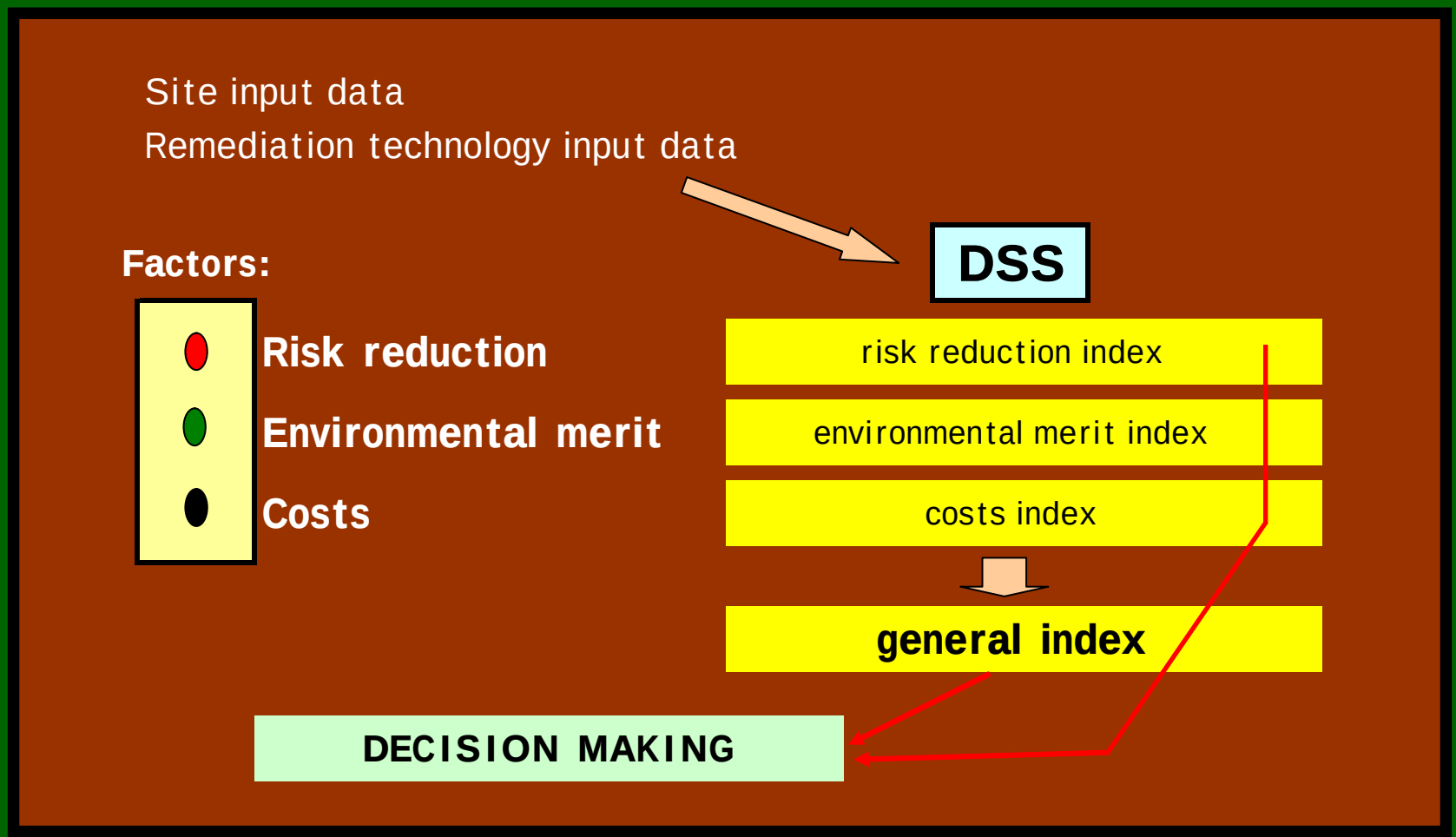
Deschampsia cespitosa wins the competition with *Cardaminopsis arenosa*, which reduces the food-chain contamination.

Heavy metal uptake under field conditions is higher than in mesocosms (only upper soil layer treated with additives).

DSS – decision making process



DSS – general aspects of the REC-approach



DSS

- **R**isk reduction
  - risk for human health, agriculture and ecosystems
- **E**nvironmental merits
  - quality of soil and groundwater
  - side-effects of contamination/remediation
    - »energy use
    - »waste production
    - »air pollution
  - contains Phyto-DSS(!)
- **C**osts

DSS Risk reduction: human risks

Human risks:

Total Daily Uptake

- Soil ingestion
- Dermal uptake
- Crop consumption

DSS risk reduction: agricultural and ecological risks

scenario	nature	pasture	root crops	leaf crops	non-food crops	waste land
food safety	-	✓	✓	✓	-	-
animal health	✓	✓	-	-	-	-
food chain contamination	✓	✓	✓	✓	✓	-
ecosystem processes	✓	✓	✓	✓	✓	✓

DSS risk reduction: other risks

Other objects e.g.

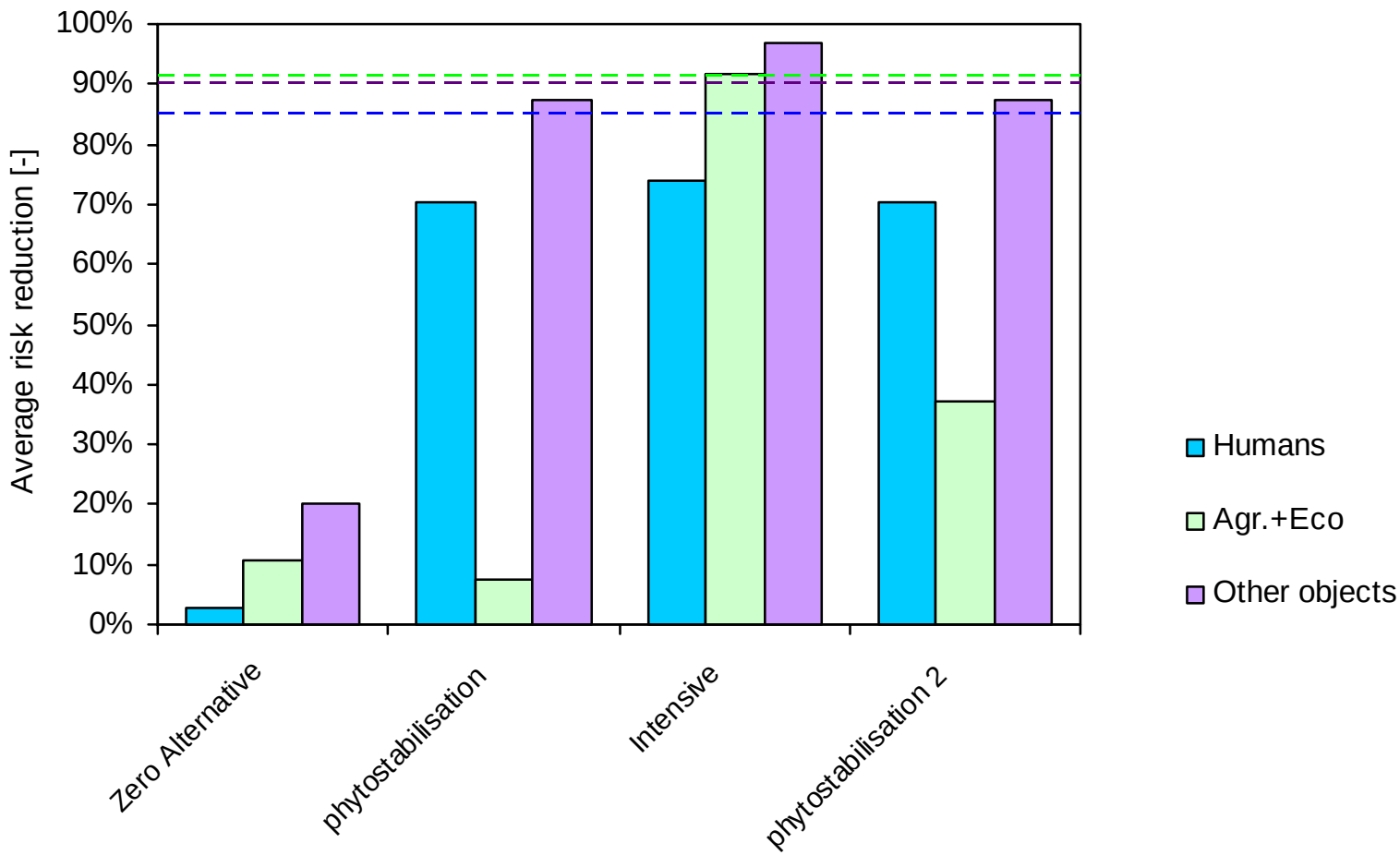
- Groundwater contamination
- Contamination surrounding area by wind erosion

DSS Environmental merits

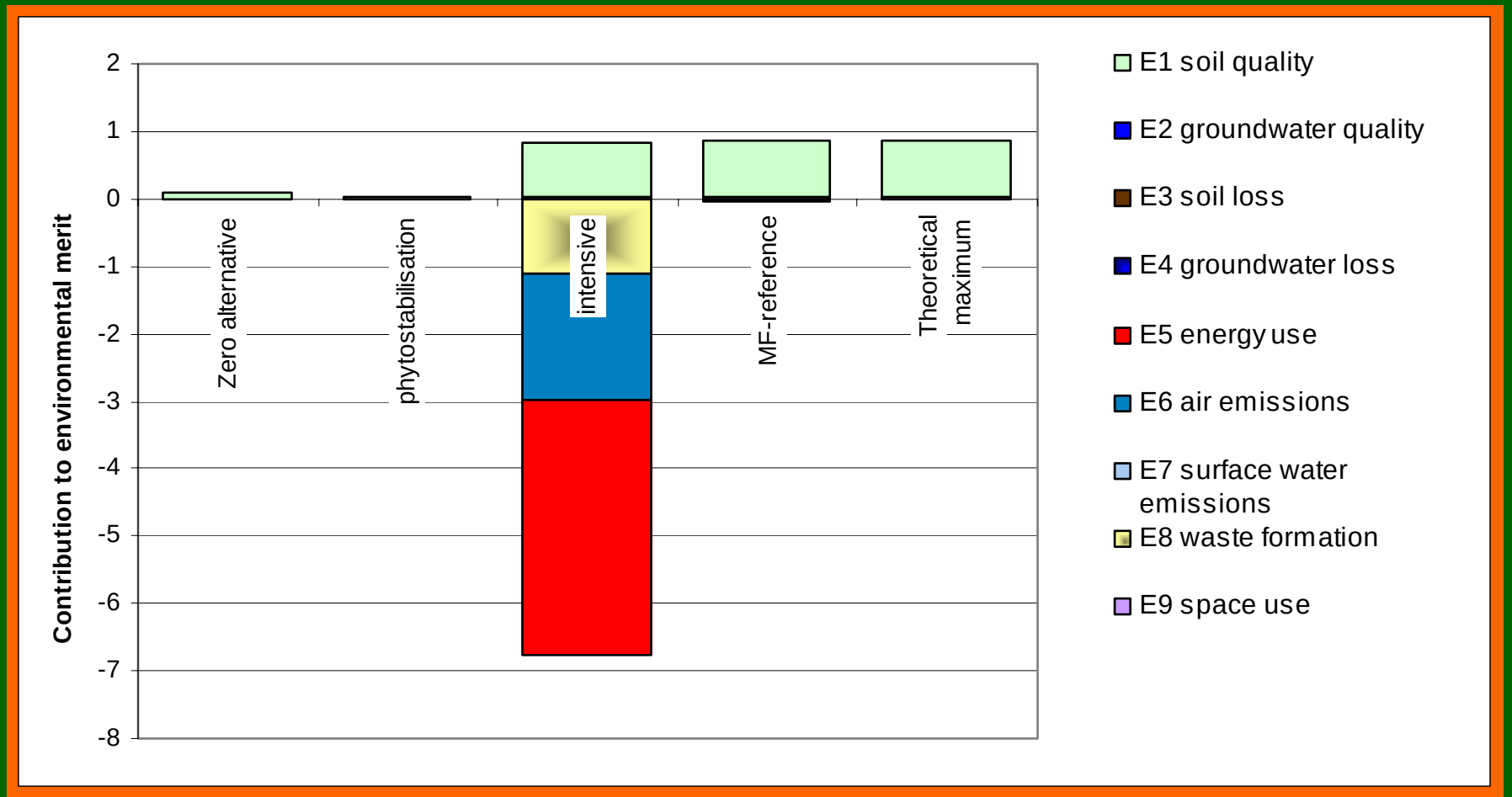
- plant uptake models (Risk and Environmental merit section)
- leaching calculations

- erosion calculation

DSS – results risk reduction



DSS – results environmental merits



Leaching

Revegetation in combination with soil additives reduces leaching from the contaminated soil layer (experiments and DSS). Because the groundwater table is deep no positive effects to groundwater contamination were calculated (DSS)

Erosion

Revegetation increases the vegetation cover (experiments). This results in a substantial decrease of wind erosion (DSS)

Human risks

Human riks are decreased substantial according to the DSS due to a decrease in soil ingestion. Remaining risks are comparable to those after intensive remediation

Ecological risks

The risk reduction by phytostabilisation is too small to exclude animal health effects

DSS

The DSS should be improved by including the bio-availability concept

General conclusion

Revegetation is a viable option to decrease transport of heavy metals through erosion and leaching

Revegetation is a viable option to decrease human riks

Revegetation is not able to exlude ecological risks at the site with respect to animal health

Revegetation is a cost-effective option, whenever sustainability is assured

THANK YOU FOR YOUR ATTENTION