Critical success factors for revegetation of heavily polluted sites.

A cost-benefit analysis tool.

Jan Japenga, Paul Römkens, Luc Bonten

Soil Science Centre
ALTERRA Green World Research, Wageningen University and Research
P.O. Box 47, 6700 AA Wageningen, The Netherlands
e-mail: jan.japenga@wur.nl

Rafal Kucharski, Alexandra Sas-Novosielska

Institute for Ecology of Industrial Areas (IETU), Katowice, Poland
e-mail: sas@ietu.katowice.pl

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Background

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

IS REVEGETAION A SOLUTION?

Background

REVEGETATION OF DERELICT SITES

- Soil additives to immobilize contaminants
- Agronomic rehabilitation
- Selection of vegetation
- Cost-benefit considerations
- Risk containment considerations

IS REVEGETAION A SOLUTION?

Objectives (I)

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

Objectives (II)

To develop a Decision Support System to quantify revegetation benefits in comparison with other soil remediation options

Presentation outline

I Critical success factors

economic benefits
reduced erosion
reduced leaching
crop quality
soil ecosystem functioning
revegetation sustainability

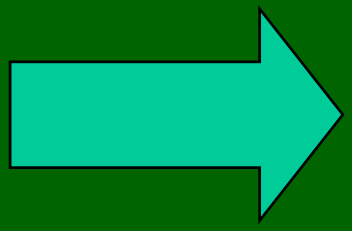
II The Decision Support System (DSS)

general structure
revegetation in the DSS
output

General conclusions

Presentation outline

I Critical success factors



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economic benefits

- ✓ **Decreased costs of risk containment at the site after revegetation.**
- ✓ **Direct market value of vegetation:**
  - ➢ energy crops (direct or vegetal oil)
  - ➢ non-food crops (flowers, fiber crops)

Cost categories:	**Initial costs**
	Recurrent costs
	Revenues

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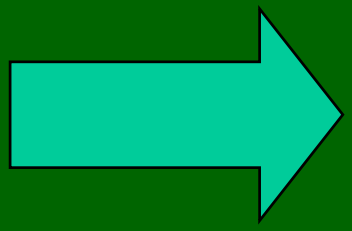

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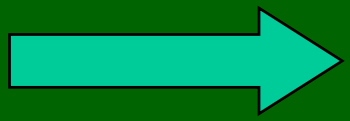


reduced erosion

Basic processes in the erosion model **LISEM**:

- ✓ rainfall
- ✓ interception
- ✓ surface storage in micro-depressions
- ✓ infiltration, vertical movement of water in the soil
- ✓ overland flow and channel flow (in man-made ditches)
- ✓ detachment by rainfall and throughfall
- ✓ transport capacity and detachment by overland flow.

Critical success factors

reduced erosion

Main input parameters in the erosion model **LISEM**:

- slope length
- slope gradient
- soil type
- rain event (type, intensity)

- **vegetation type (shrubs and grass)**
- **vegetation cover (0%, 5%, 10%, 20%, 50% and 80%)**

Critical success factors

reduced erosion

- vegetation type (shrubs and grass)
- vegetation cover (0%, 5%, 10%, 20%, 50% and 80%)

VEGETATION TYPE IS THE ESSENTIAL VARIABLE

Critical success factors

reduced erosion

Vegetation types:

GRASSES

+	perennial species
+	deep rooting
+	dense vegetation cover
+	suitable species available
+/-	sustainability ? (local species ?)

Critical success factors

reduced erosion

Vegetation types:

LOCAL NATURAL VEGETATION

+/-	perennial species ?
+/-	deep rooting ?
+/-	dense vegetation cover ?
+	suitable species available (even for extreme pollution levels)
+	sustainability (ecological restoration)

Critical success factors

reduced erosion

Vegetation types:

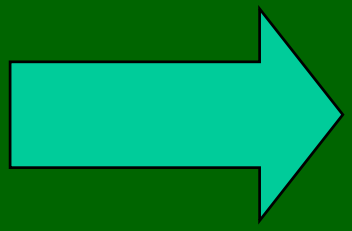
ENERGY CROPS AND OTHER NON-FOOD CROPS

+/-	perennial species ?
+/-	deep rooting ?
+	high percentage vegetation cover
+/-	suitable species available ?
+/-	sustainability ?

Miscanthus giganteus

Presentation outline

I Critical success factors



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reduced leaching

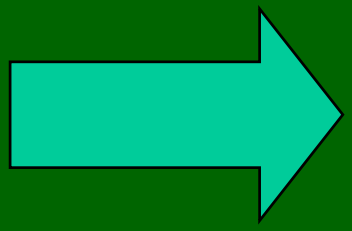
Reduced HM leaching is the result of:

+	phyoevaporation after revegetation
+	the effect of immobilizing agents
+/-	rhizosphere phenomena
+/-	soil structure changes

generally:
net reduced leaching

Presentation outline

I Critical success factors



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crop quality

Most important aspect of crop quality is HM content in (parts of) the shoots:

- food-chain contamination
- reduced price in the case of energy crops and non-food crops

Critical success factors

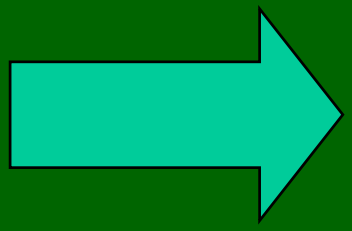
crop quality

Hyperacculumator
(non-perennial)

Non hyperaccumulating
grass (perennial)

Presentation outline

I Critical success factors



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soil ecosystem functioning

In general the soil ecosystem functioning will improve as a consequence of:

- better nutrient supply
  (agronomic measures)
- less bioavailable contaminants in the soil
  (immobilizing agents)
- positive effect of rhizosphere
  (soil life habitat and food supply)

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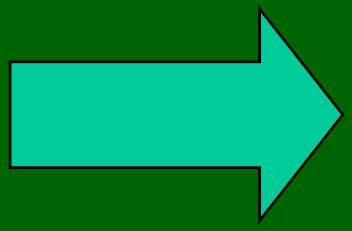

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Ecological restoration:

best chances for local wild species

Revegetation:

best chances for energy crops and non-food crops

Vegetation types

overview of vegetation types in relation to Critical Success Factors

	perennial grasses (local)		perennial grasses (non-local)		energy crops & non-food crops		local natural plant species	
	non-acc.	acc.	non-acc.	acc.	non-acc.	acc.	non-acc.	acc.
economic benefits	-	-	-	-	+	+	-	-
reduced erosion	+	+	+	+	-/+	-/+	-/+	-/+
reduced leaching	+	+	+	+	-/+	-/+	-/+	-/+
crop quality	+	-	+	-	+	-	+	-
soil ecosystem functioning	+	+	+	+	-/+	-/+	-/+	-/+
revegetation sustainability	-/+	-/+	-/+	-/+	-/+	-/+	+	+
ecological benefits	-/+	-/+	-	-	-	-	+	+

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Puławy, October 27, 2005

Vegetation types

non-accumulating local grasses + energy crops

	perennial grasses (local)		perennial grasses (non-local)		energy crops & non-food crops		local natural plant species	
	non-acc.	acc.	non-acc.	acc.	non-acc.	acc.	non-acc.	acc.
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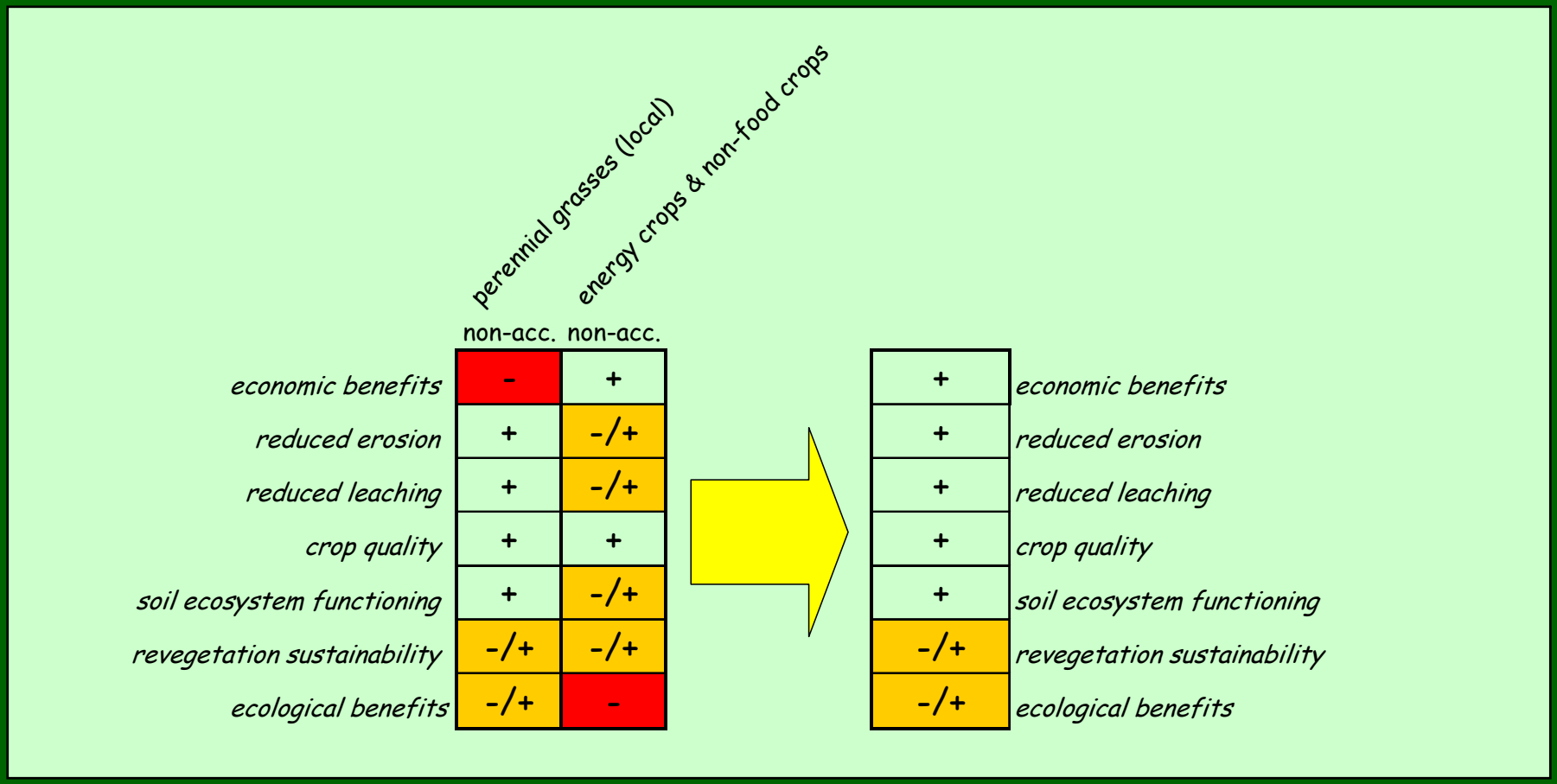
reduced erosion	+	+	+	+	-/+	-/+	-/+	-/+
reduced leaching	+	+	+	+	-/+	-/+	-/+	-/+
crop quality	+	-	+	-	+	-	+	-
soil ecosystem functioning	+	+	+	+	-/+	-/+	-/+	-/+
revegetation sustainability	-/+	-/+	-/+	-/+	-/+	-/+	+	+
ecological benefits	-/+	-/+	-	-	-	-	+	+

Vegetation types

non-accumulating local grasses + energy crops (optimized benefits if erosion is a problem)



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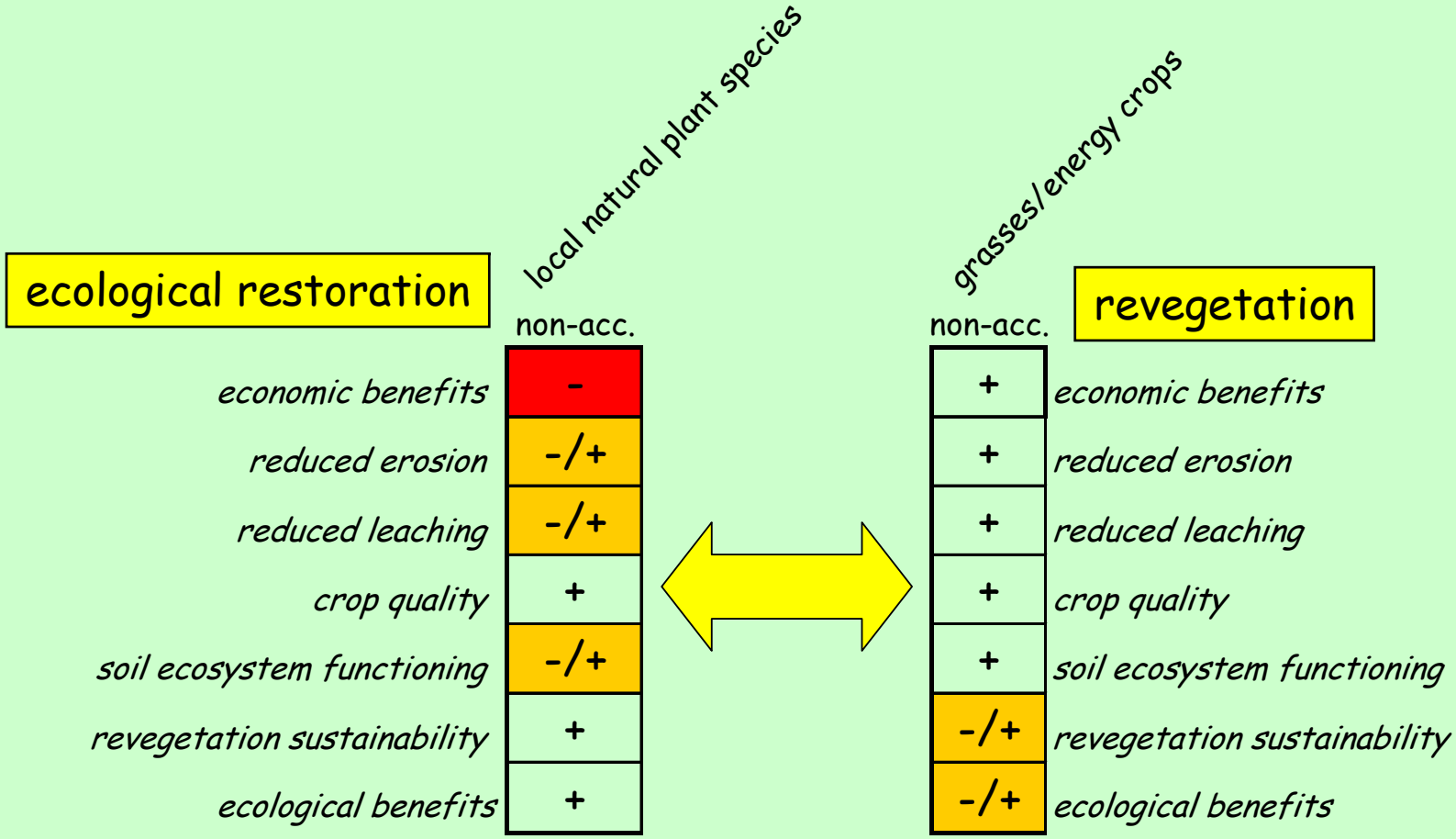

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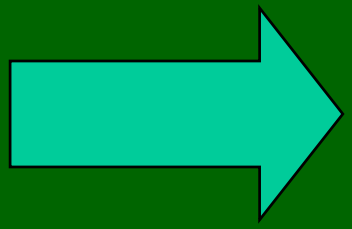

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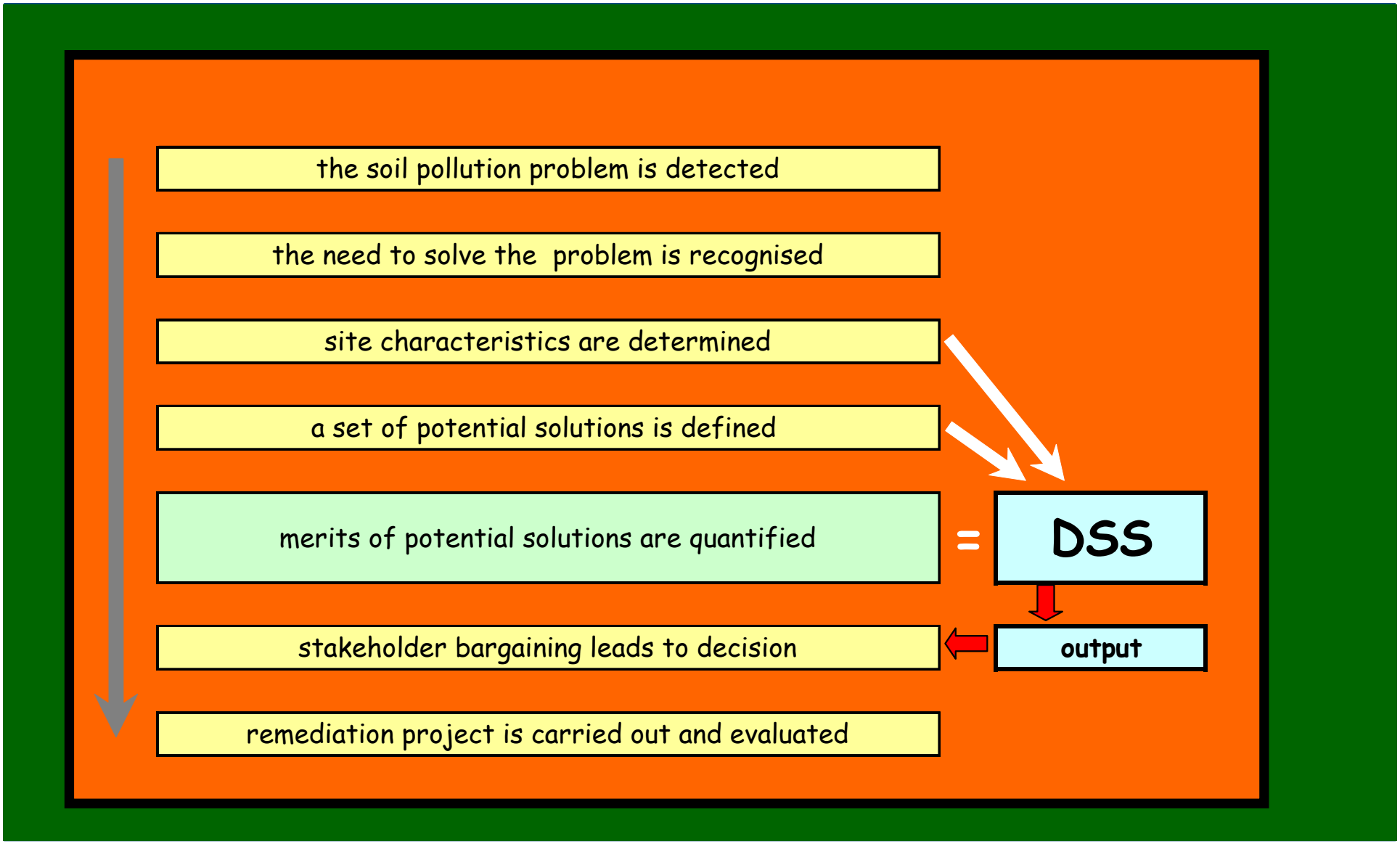
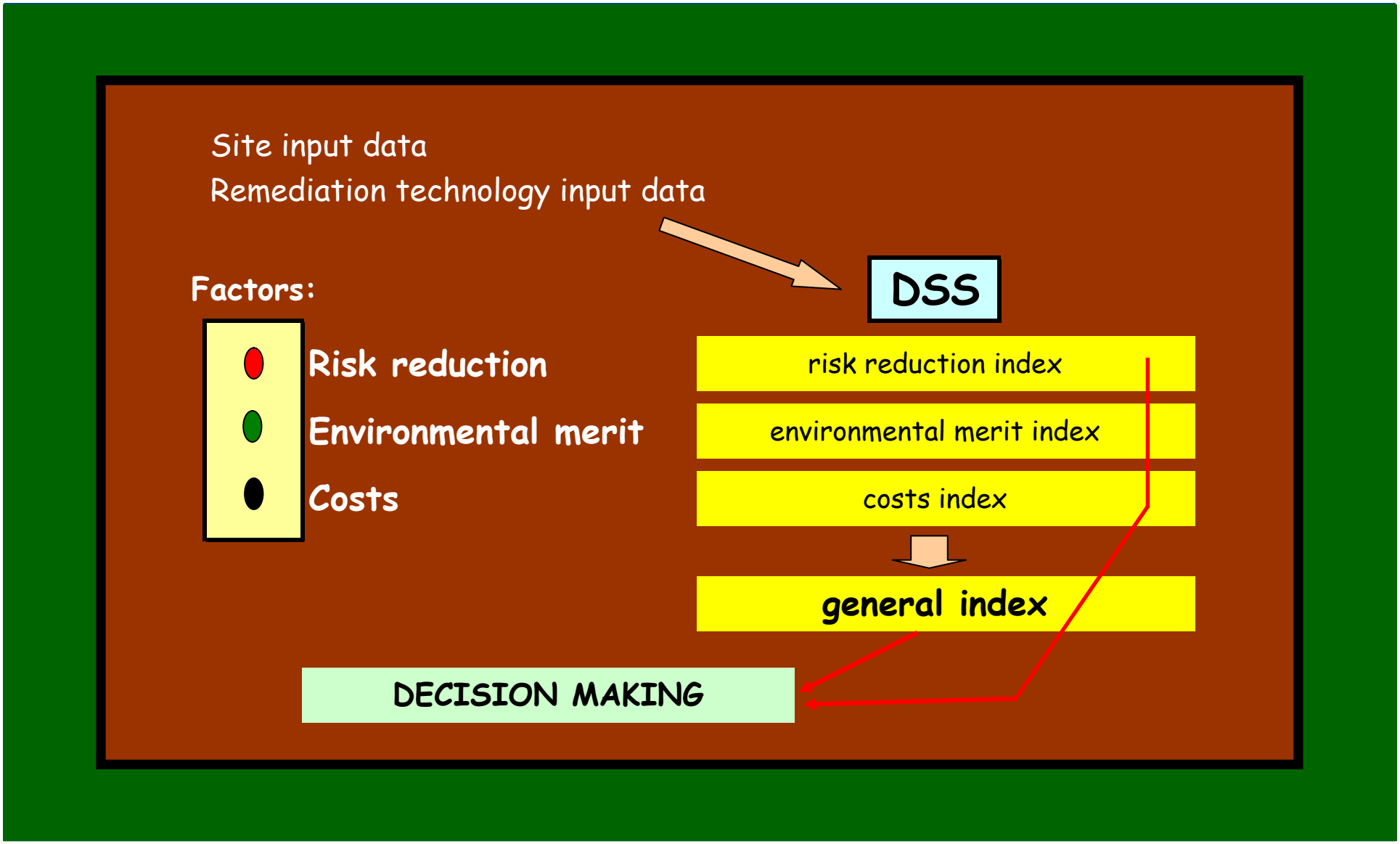
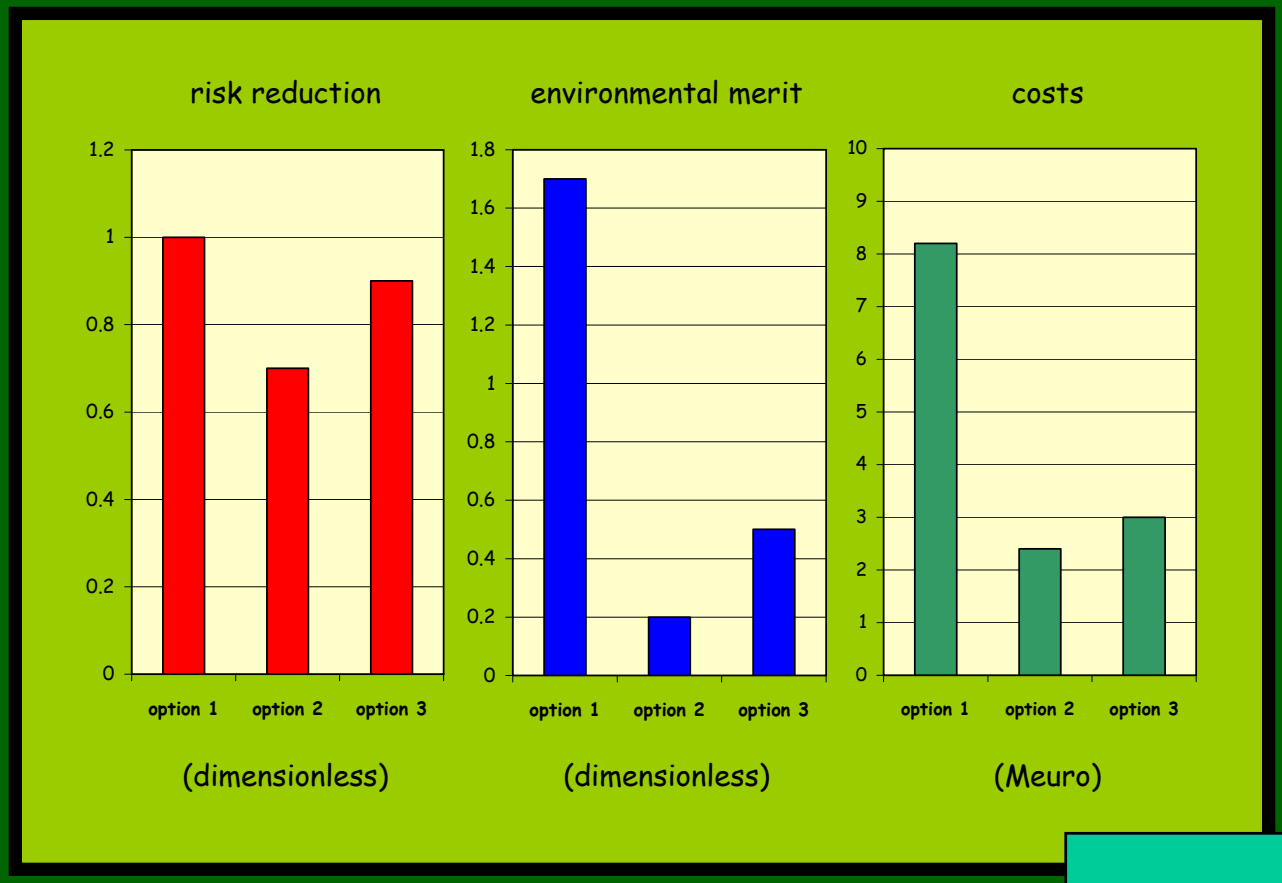
DSS – decision making process



DSS – general aspects of the REC-approach



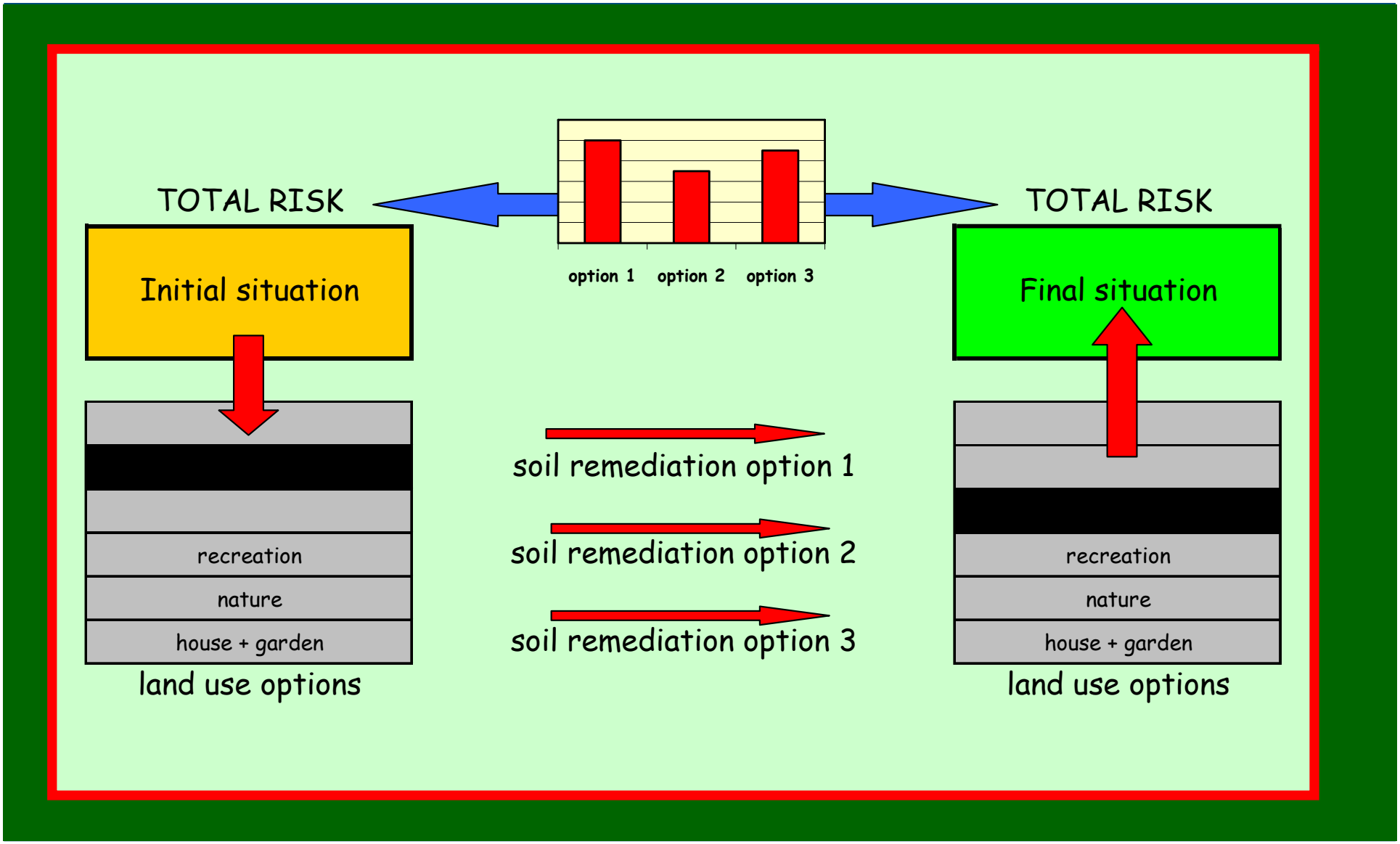
DSS – comparison between scenarios



DECISION

Option 1: rich man's choice
Option 3: poor man's choice

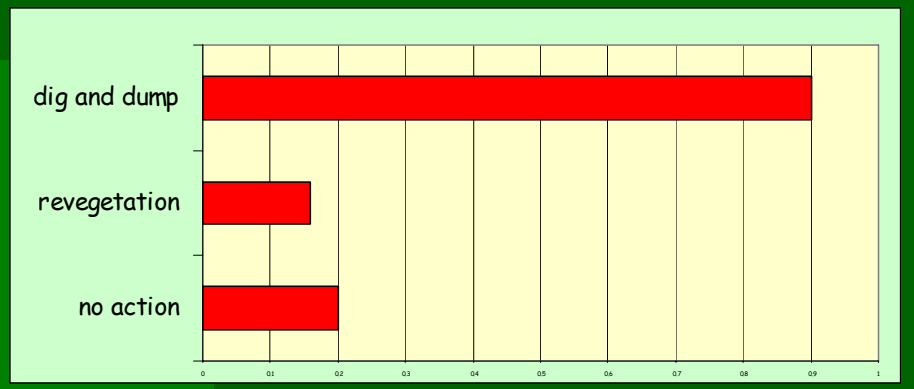
DSS – risk reduction



DSS – risk reduction

Comparison of remediation options:

1. dig and dump
2. no action
3. revegetation



- Leaching –
  lower leaching rates after revegetation
- Direct human uptake of polluted soil –
  decreased after revegetation
- Risks of "food-chain contamination"
  – increased (?) after revegetation

Land use important for risk estimation !

DSS – environmental merits

Environmental merits (negative or positive) include:

- production of clean soil/water
- production of polluted soil/water
- energy use
- use of water

DSS – environmental merits

Comparison of remediation options:

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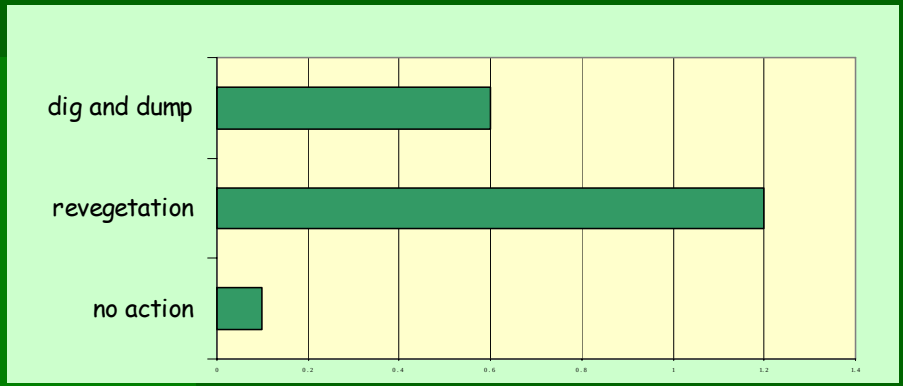

- Leaching/erosion – produced polluted soil and water reduced after revegetation

Leaching and erosion (wind/water) calculated by a simple erosion model

DSS – costs

Comparison of remediation options:

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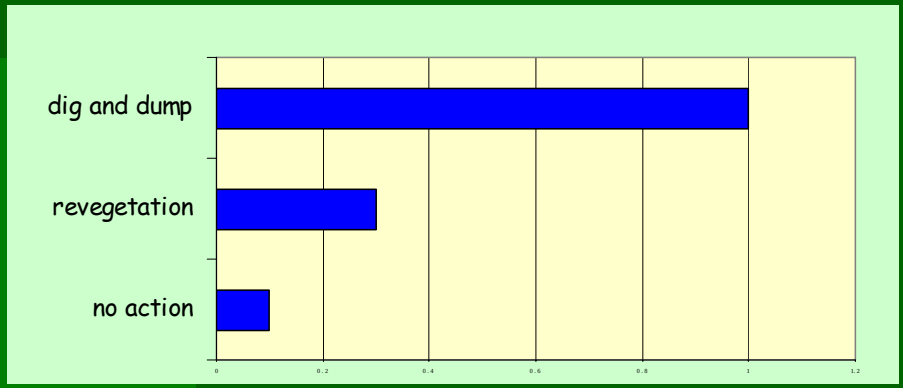
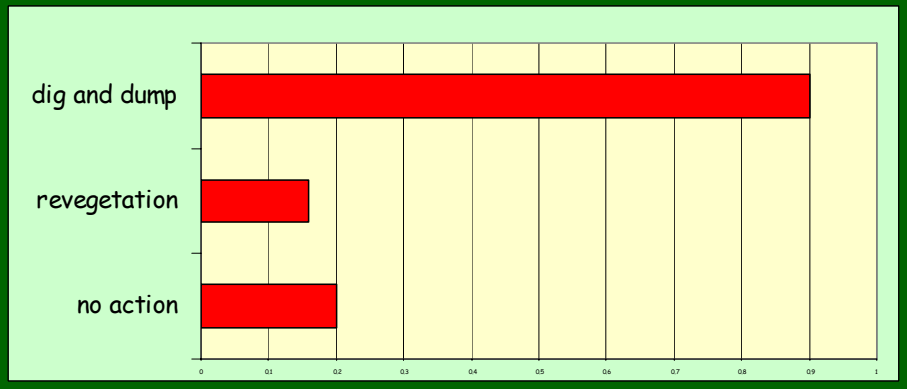
2. no action
3. revegetation

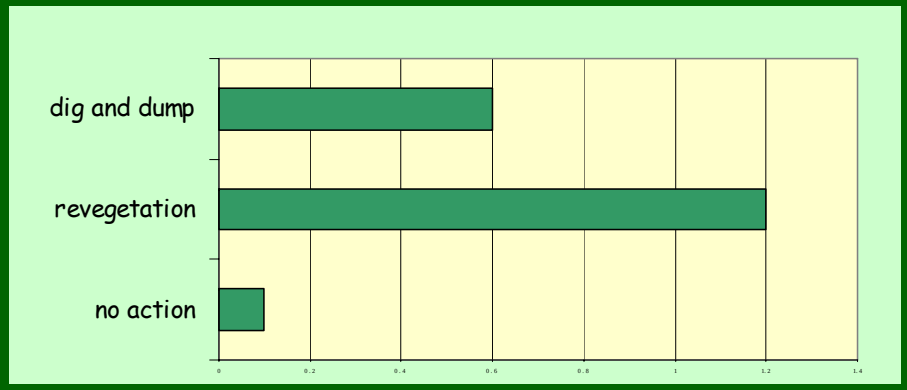


➢ Dig and dump by far the most expensive

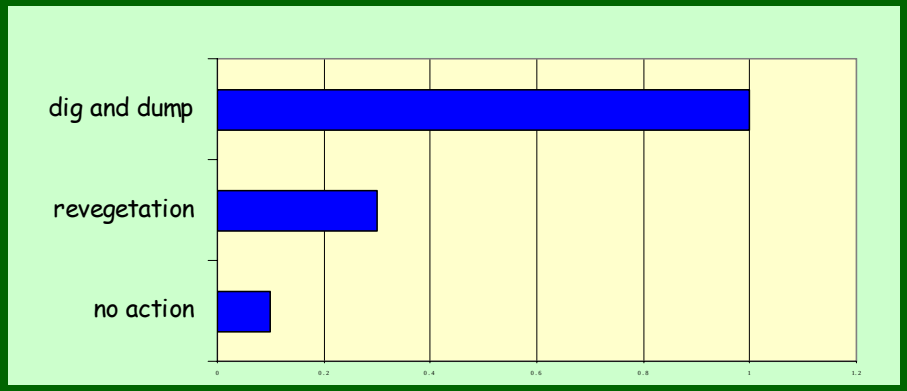
DSS - REC



Risk reduction



Environmental merits



Costs

Decision making depends on:

- Local exposure rates (land use)
- Vulnerability of adjacent areas
- Capital disponibility
- Soil economical value

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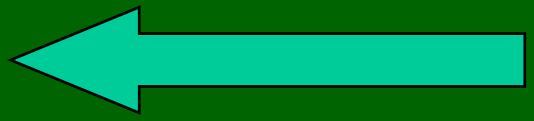

General conclusions

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

Revegetation does not reduce the risks at the sites, but only at adjacent sites and adjacent environmental compartments

Revegetation is a cost-effective option, whenever sustainability is assured and energy crops / non-food crops are used

General conclusions

Revegetation using a mixture of non-hyperaccumulating perennial species and energy crops can prove to give the right balance between erosion control and financial benefits at erosion-sensitive sites

Revegetation can be most sustainable if local species are used, which can be a good approach when ecological restoration ids the objective

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