

Soil Policy in the Netherlands

Recent Changes and potential for re-use of polluted soil

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Outline

- The Netherlands: a short overview.
- Soil policy: why? A short history of soil policy in the Netherlands.
- Current issues (EU/NL) and need for policy revision.
- Soil policy 2007 - 2015
- Practical implications: re-use of polluted land (including examples from NL/EU).

Soil (policy) in the Netherlands

- Densely populated (16 million/33.000 km²)
- Urban areas in the West, mixed rural and urban areas in the East
- (highly) Intensive agriculture (livestock)
- Trade (transport, both on land and water)
- Polluted hot-spots (old industry)
- Regional diffuse soil pollution (agriculture, industry)
- Strong interaction between soil, air and water

The Netherlands: from space (it's OK....)

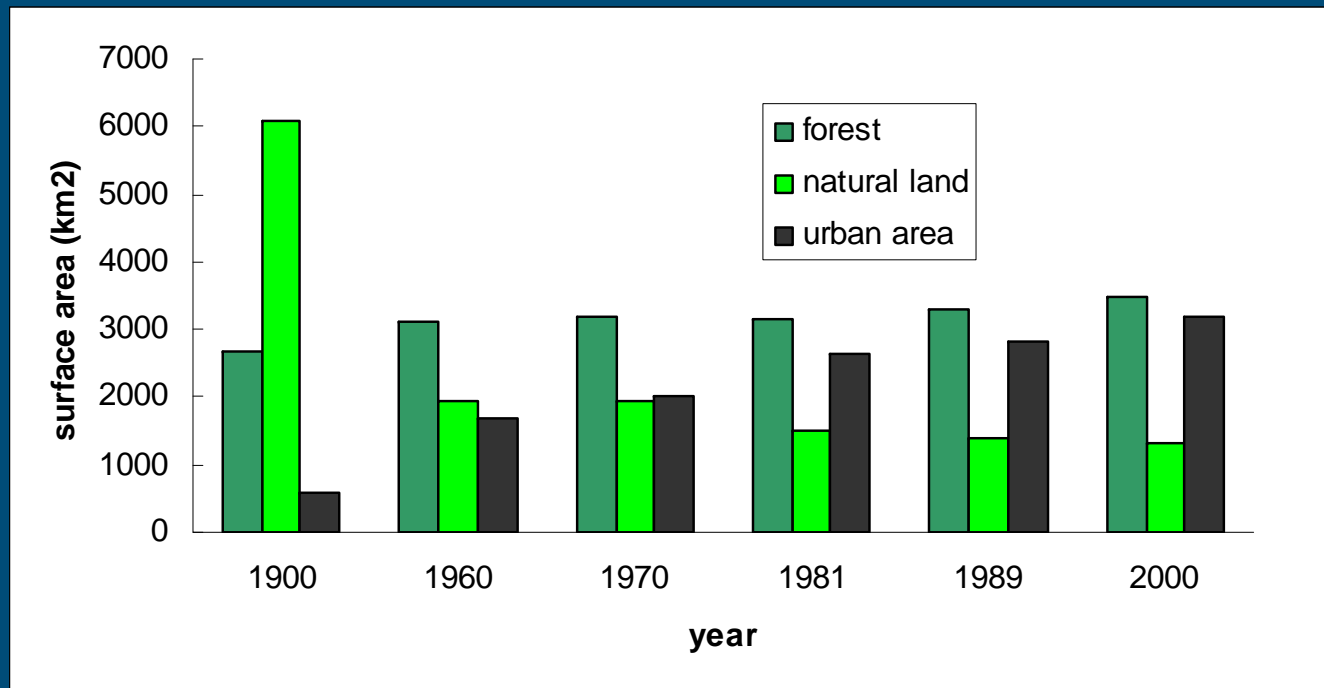


Wageningen

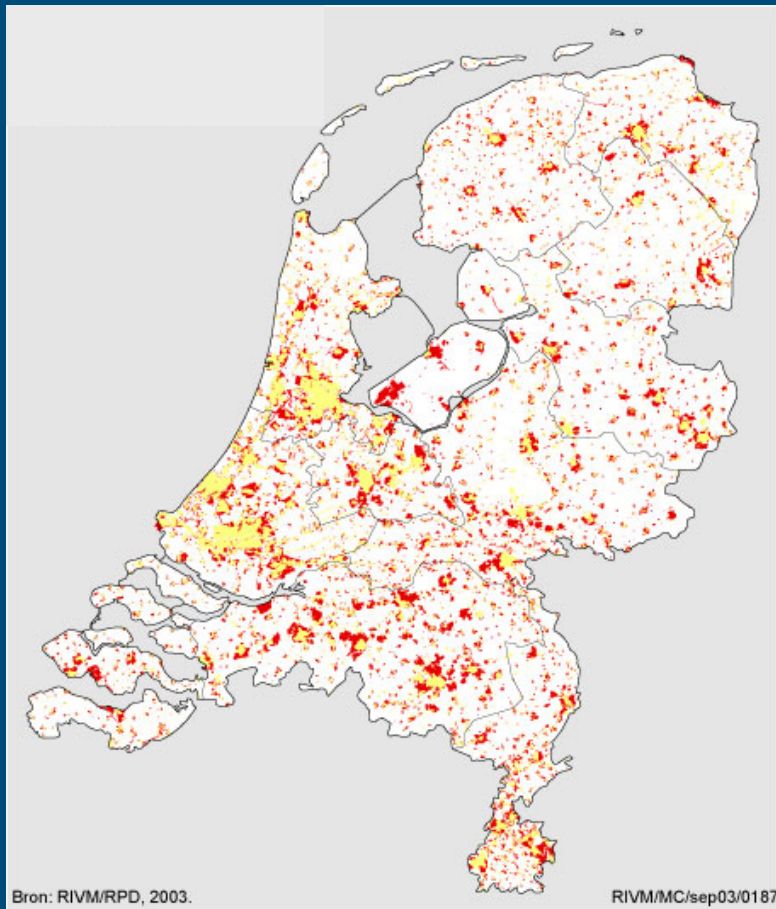


The Netherlands: urbanization and upscaling

Trends in the land use



Urbanization

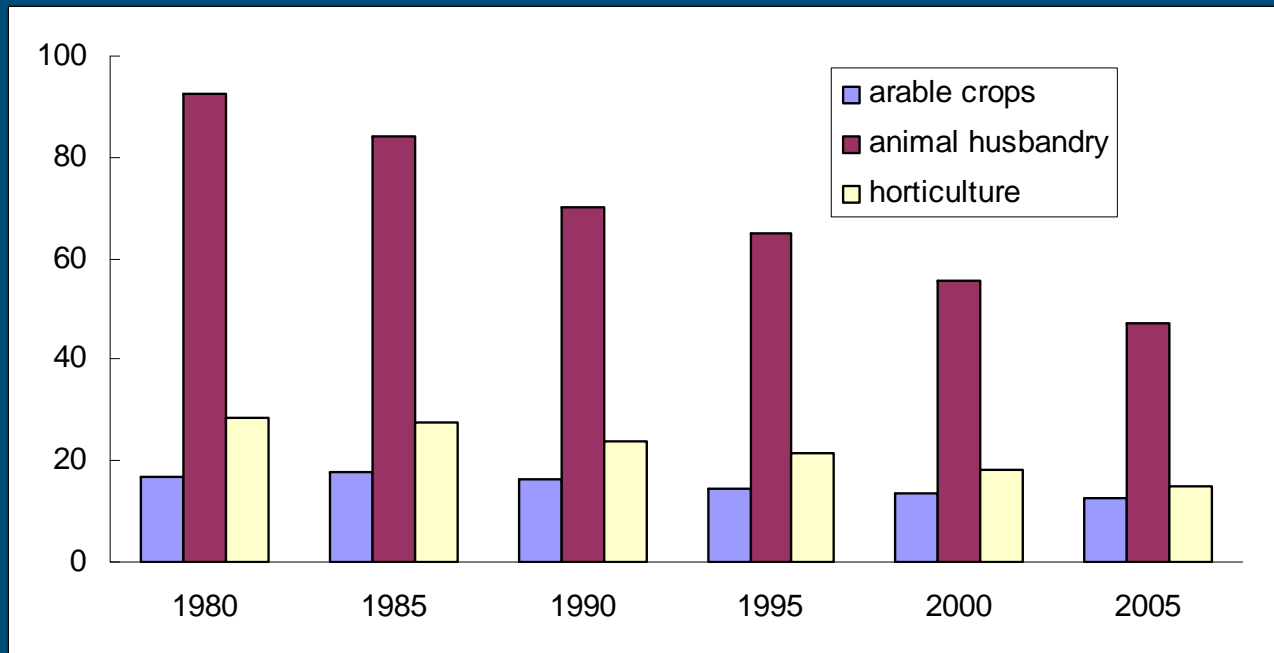


Yellow: urban area 1970 (8%)

Red: urban area 2000 (12%)

And upscaling

Decrease in # of farms from 140000 to 80000



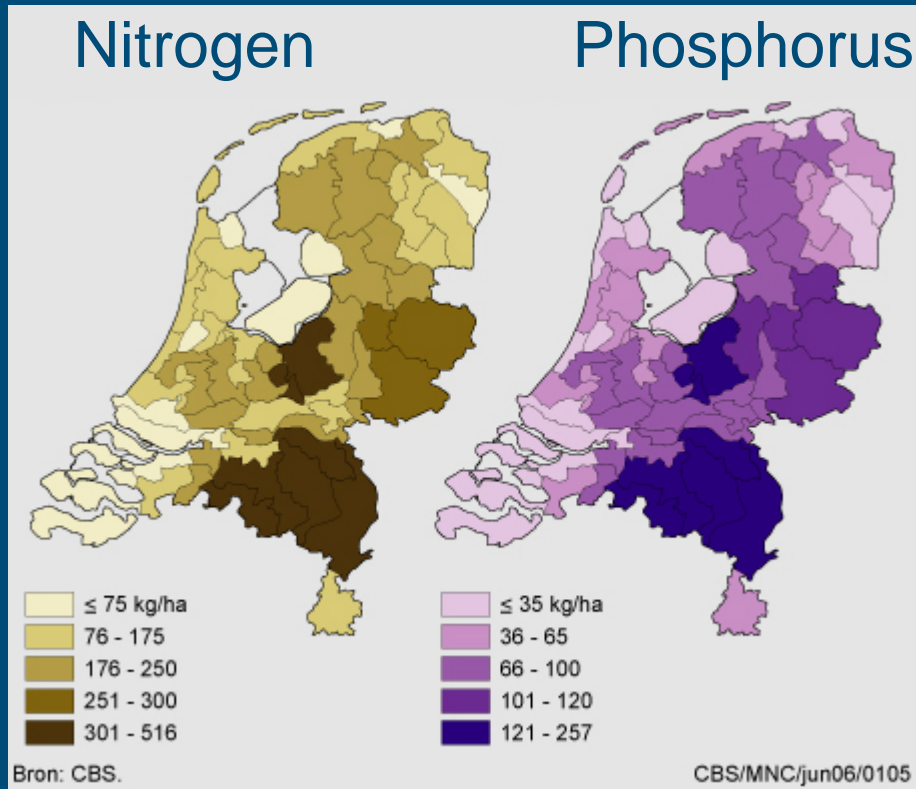
And upscaling

Big is beautiful....

| Number of farms relative to size | | | | | |
|-----------------------------------------|--------|---------|----------|-----------|----------|
| | 0-5 ha | 5-10 ha | 10-50 ha | 50-100 ha | > 100 ha |
| 1980 | 47 | 26 | 68 | 3 | 0 |
| 1985 | 44 | 23 | 64 | 4 | 0 |
| 1990 | 41 | 21 | 57 | 5 | 1 |
| 1995 | 38 | 18 | 50 | 6 | 1 |
| 2000 | 30 | 15 | 44 | 7 | 1 |
| 2005 | 24 | 12 | 36 | 9 | 2 |

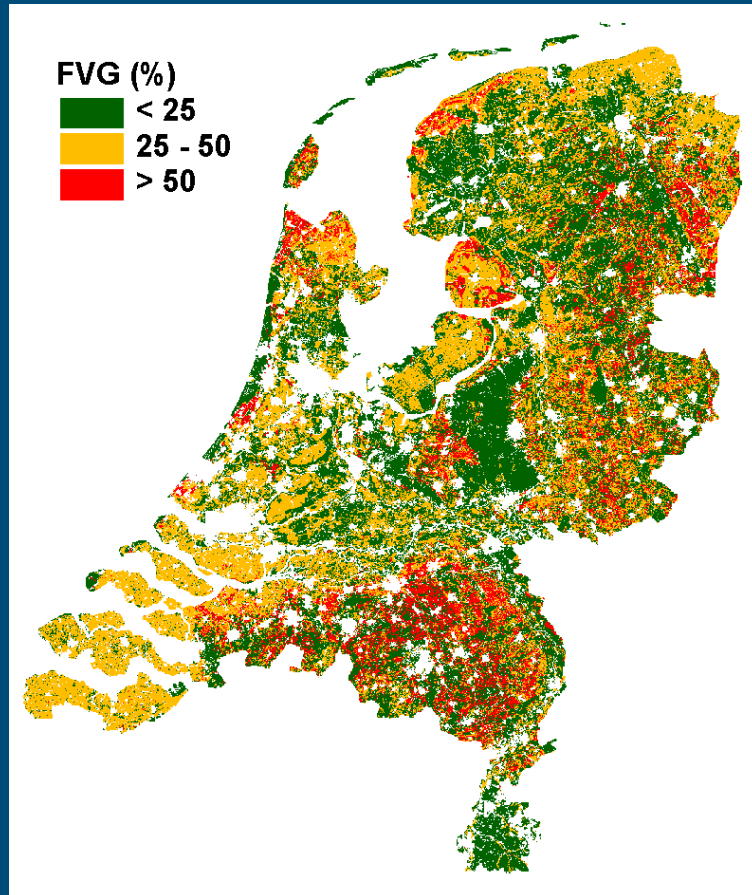
But has its consequences

The Netherlands: N & P production at a regional level



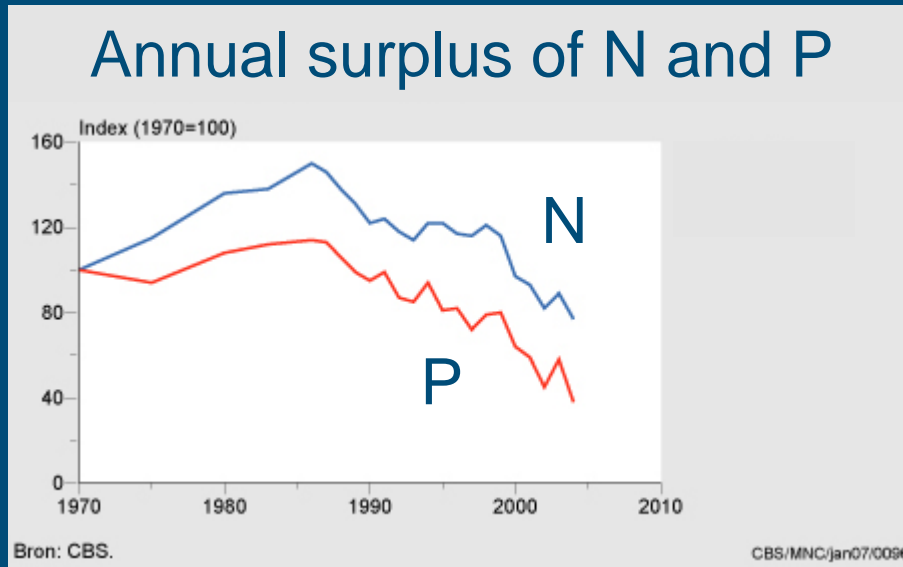
Linked to animal husbandry
(eastern sandy district)

The Netherlands: diffuse pollution - Phosphate



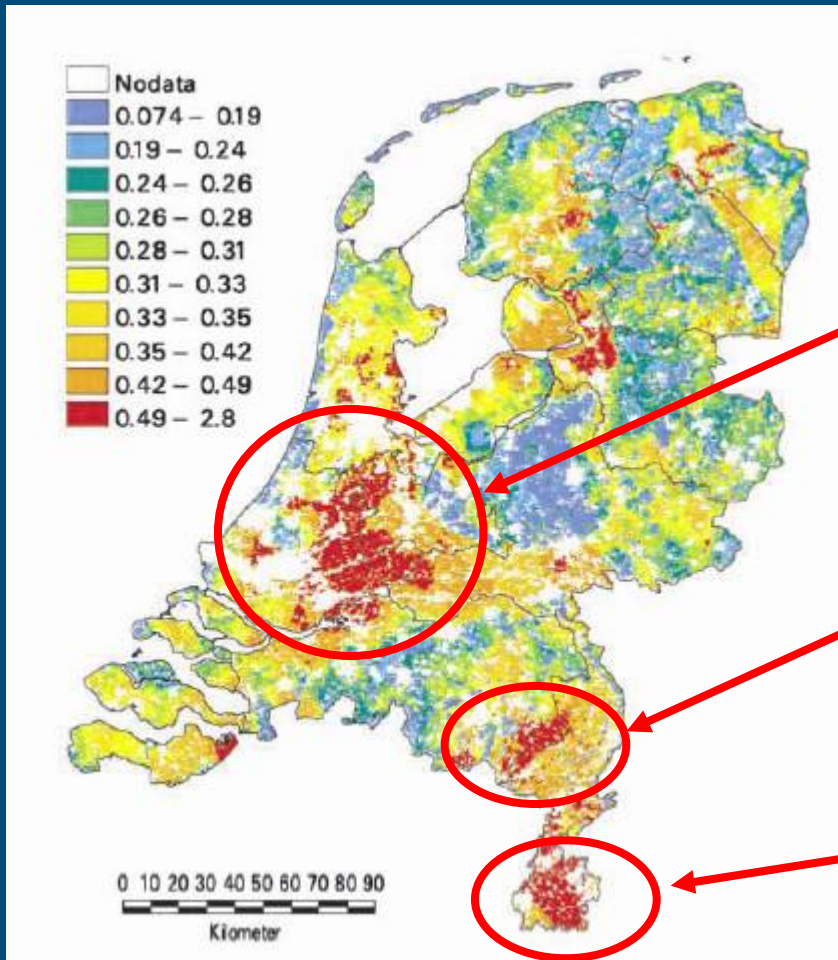
1. High degree of P-saturation in sandy soil
2. High leaching losses to ground- and surface waters

The Netherlands: trends



1. Decrease # of animals
2. Decrease allowed N and P loads to soil (EU)
3. Decrease allowed P-content in additives
4. MINAS (minerals accounting system)
5. Yearly fluctuation (high yields in 2004)

The Netherlands: diffuse pollution - Metals

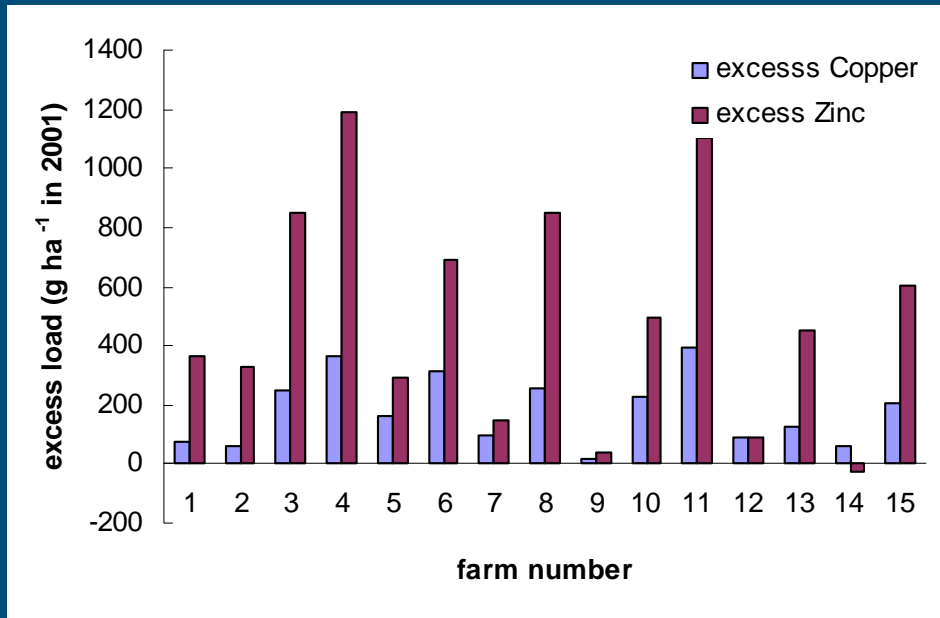


Peat areas (“Toemaak”)

Kempen (industrial)

Limburg (geogenous/industrial)

Diffuse pollution - Agriculture

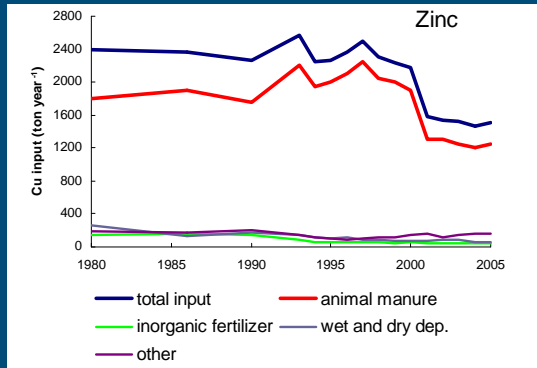
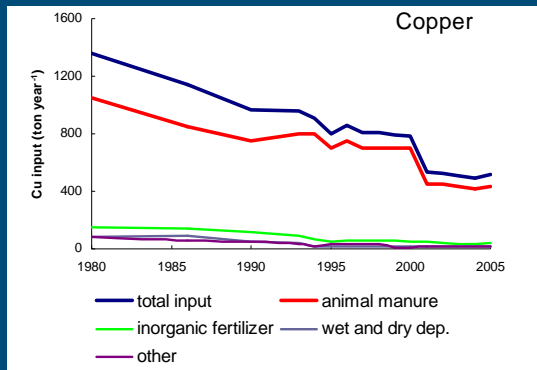


Excess load highly variable:

Cu [$17 \sim 574 \text{ g ha}^{-1}$]

Zn [$-29 \sim 1187 \text{ g ha}^{-1}$]

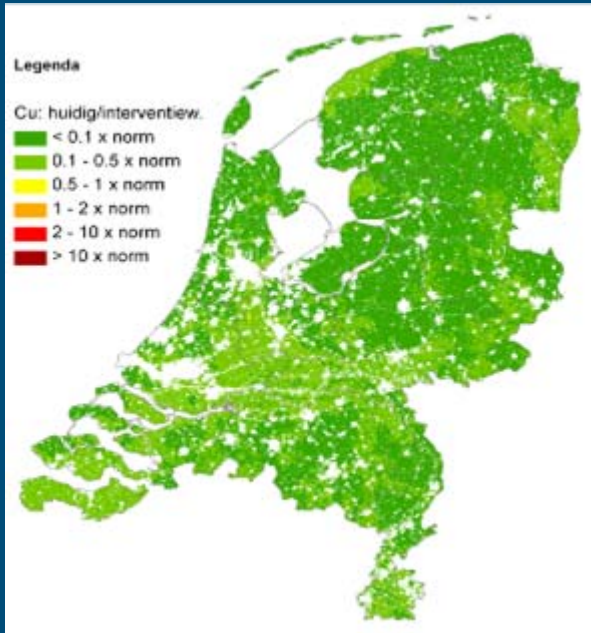
Diffuse pollution – Agriculture (trends)



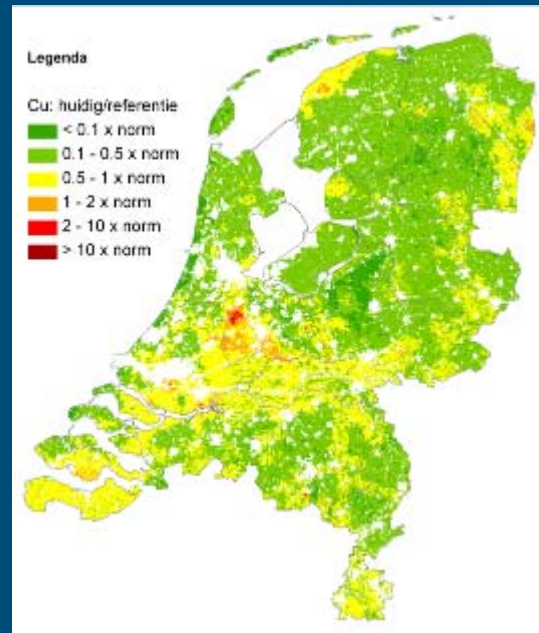
1. Reduction of # of animals (20%)
2. Reduction in allowed levels in feed
3. Stricter policy regarding manure application (N, P)

Present quality of soil

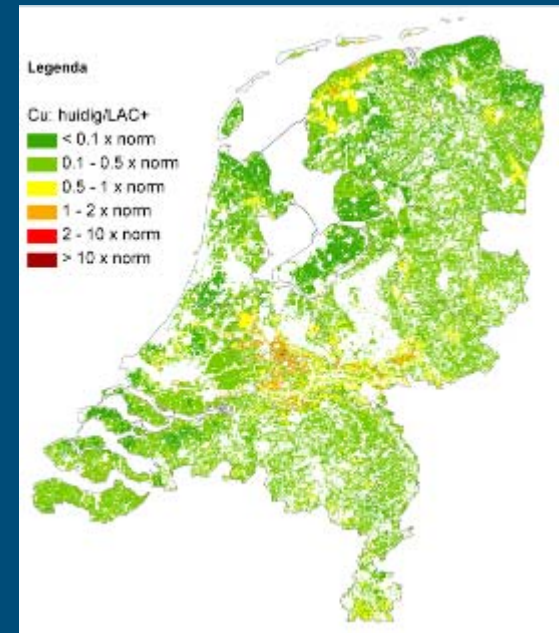
Intervention
value



Background
Value 2000

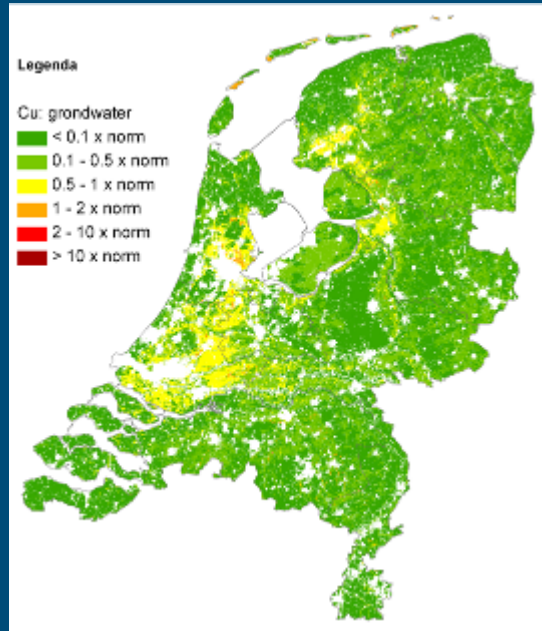


Agricultural
Advisory
Levels

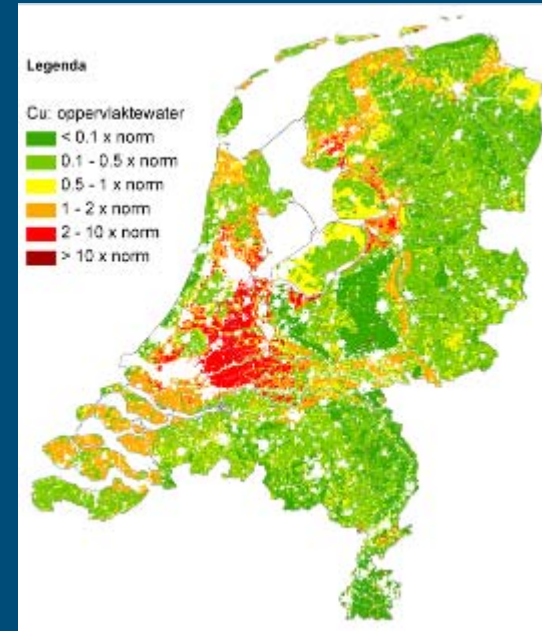


Present quality of ground- and surface waters

(shallow) groundwater

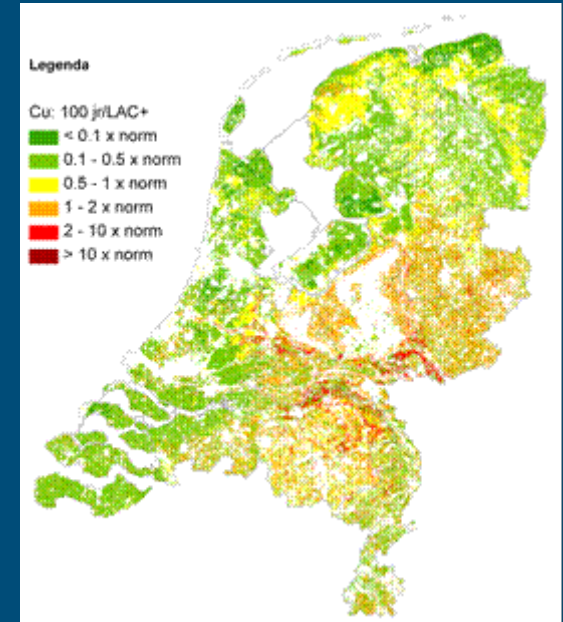
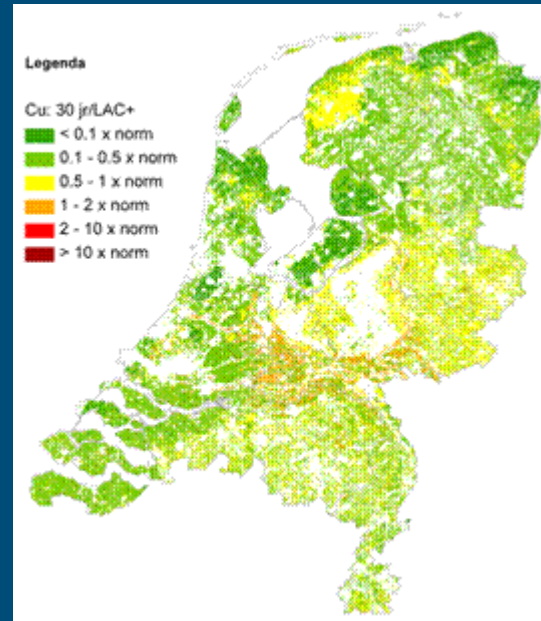
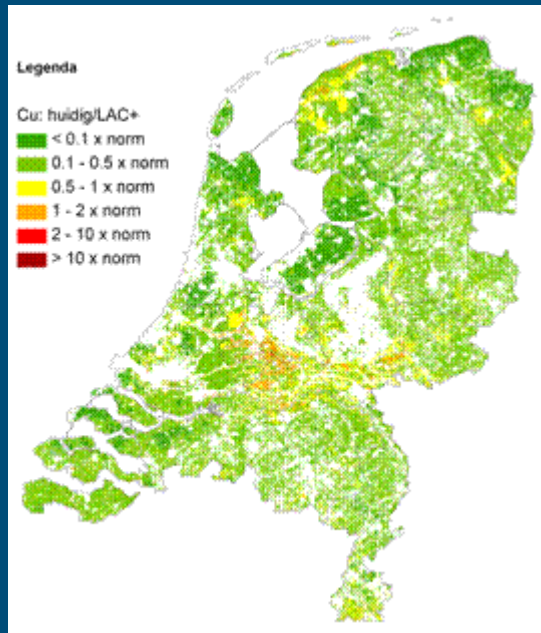


Surface water

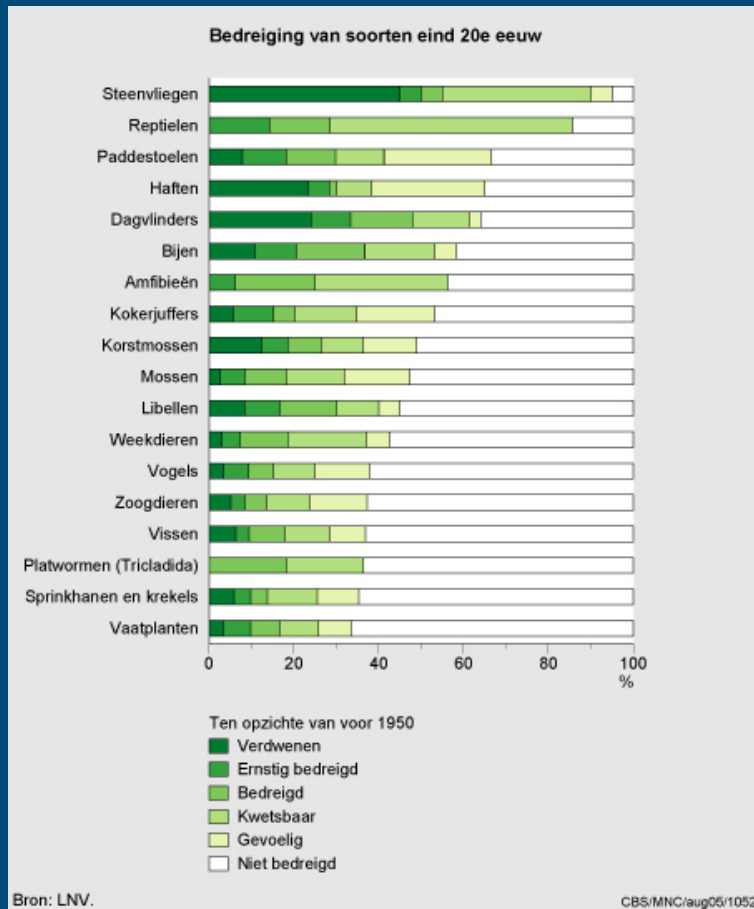


But what about the future?

2007 → 2037 → 2107



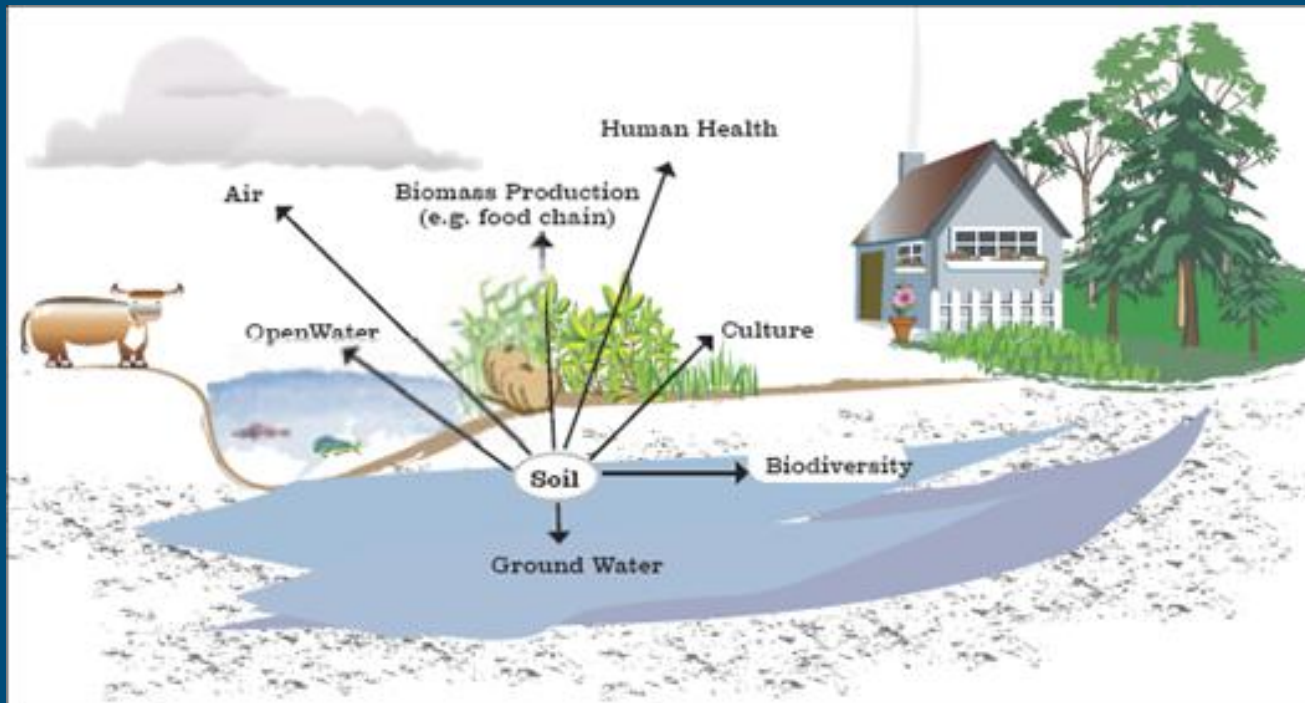
Diffuse pollution and land use: impact on ecosystem



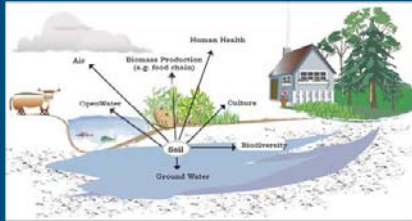
Soil and the Environment: time for action

- Increased pressure on land across EU/NL
- Soil as a sustainable resource
- Interaction between soil, ecosystem and water has become more evident
- Need to integrate soil, air and water policy

Soil and the Environment: the EU view



Soil Policy: key issues related to contaminants

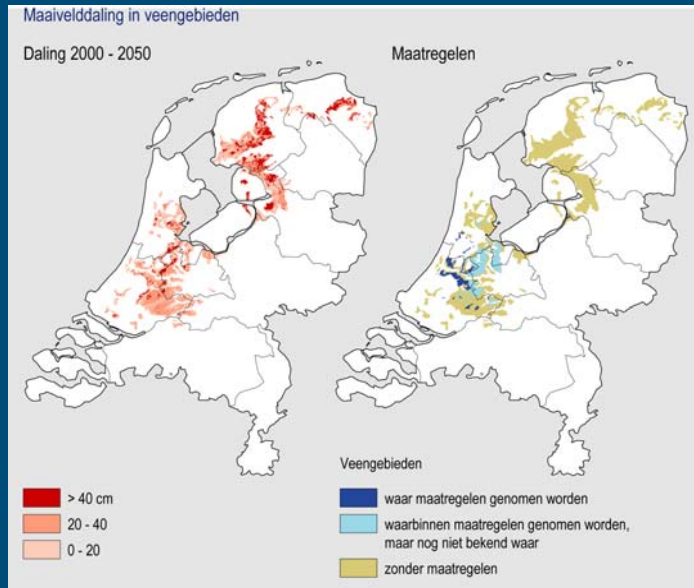


■ Key issues

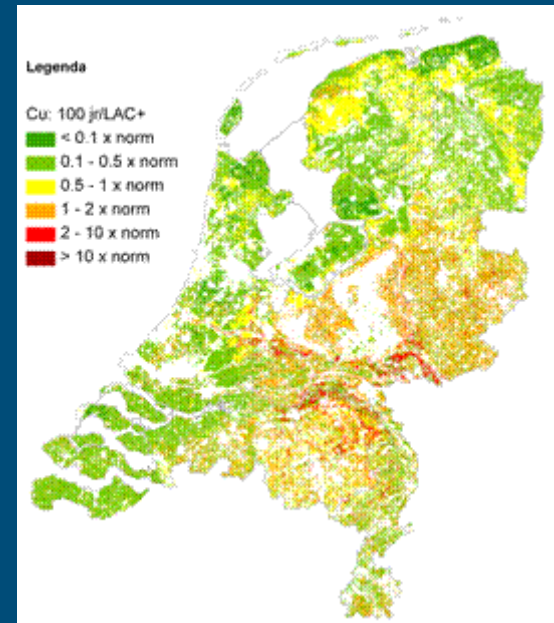
- Sustainable land use (aspect of time)
- Stand-still (no further accumulation) and reduced emission of “priority dangerous substances (oa Cd)”
- Important cross links with Water Framework Directive

The Netherlands: most important issues

Dynamics of organic matter in soils (peat areas)



Diffuse pollution



Dutch Soil Policy: the essentials

- Soil policy based on:
 - Protection of human health
 - Protection of ecosystem
 - Protection of agricultural production
- Directed towards cleanup operations and
- Soil management including application of dredgings and emission from constructions (Decree on Soil Quality)

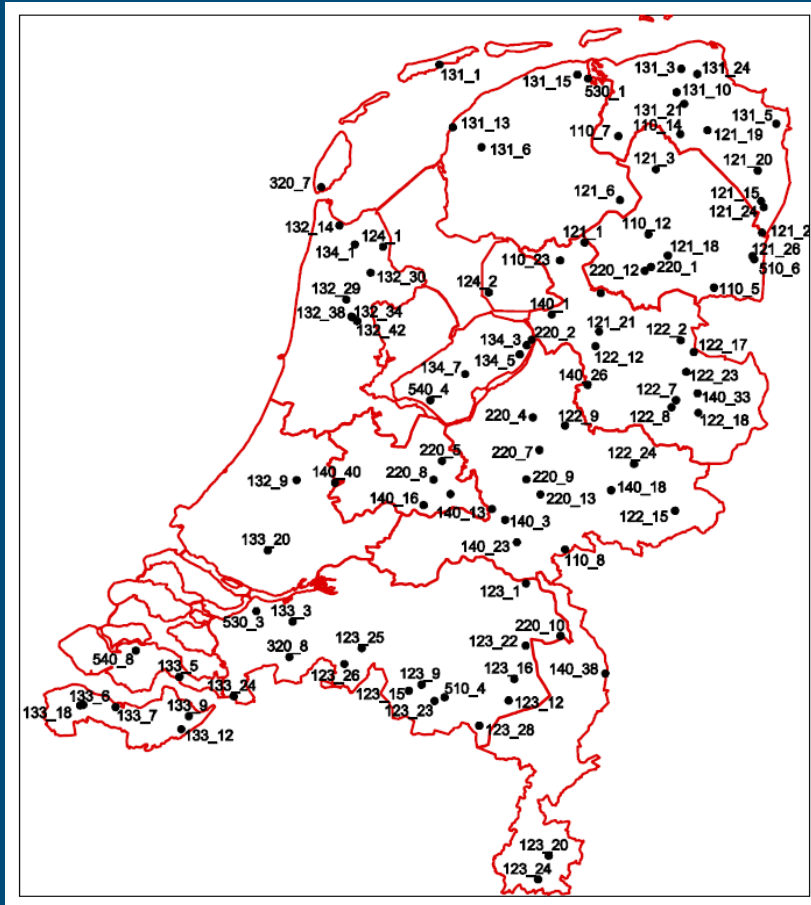
Dutch Soil Policy: the essentials

- Different (un)acceptable levels:
 - Background values in soil: current levels of contaminants in non-polluted soils
 - Reference values: acceptable levels depending on the use of the soil, 7 defined functions
 - Intervention values: action level above which further testing is required

Dutch Soil Policy: Background values

- Equal to average quality of soil in areas without obvious influence from industry
- Based on measurements in topsoil and subsoil at 100 statistically selected locations in the Netherlands (soil type/land use combinations)
- In total database for 252 difference substances
- 95 percentile of AW2000 level is equal to “no-risk” levels (practical definition)
- Correction for clay and organic matter

Dutch Soil Policy: Background values



| Stratum | Codering stratum | Oppervlakt (ha) | Aantal gelote locaties |
|-------------------------------------|------------------|-----------------|------------------------|
| Landbouw | | | |
| Veengronden | veen | 110 | 164.387 |
| Fries-Drents keileemplateau | zand | 121 | 331.823 |
| Oostelijk en Centraal dekzandgebied | zand | 122 | 288.404 |
| Zuidelijk dekzand en lossgebied | zand | 123 | 328.907 |
| Zandgronden kustgebied | zand | 124 | 48.780 |
| Noordelijke zeekleigebied | zeeklei | 131 | 261.049 |
| Hollands zeekleigebied | zeeklei | 132 | 184.595 |
| Zuid-Westelijk zeekleigebied | zeeklei | 133 | 239.946 |
| Zeeklei in IJsselmeerpolders | zeeklei | 134 | 102.119 |
| Rivierkleigronden | rivierklei | 140 | 265.108 |
| Bos en Natuur | | | |
| Bos op zandgronden | zand | 220 | 282.099 |
| Overige natuur op zandgronden | zand | 320 | 84.504 |
| Veengronden | veen | 510 | 36.048 |
| Zeekleigronden | zeeklei | 530 | 29.420 |
| Rivierkleigronden | rivierklei | 540 | 13.458 |

To 100 sampling sites

Dutch Soil Policy: Background values

| Contaminant | Level (mg kg ⁻¹) |
|-------------|---------------------------------|
| As | 20 |
| Cd | 0.6 |
| Cr | 55 |
| Cu | 40 |
| Hg | 0.15 |
| Pb | 50 |
| Ni | 30 |
| Zn | 140 |
| PAH (10) | 1 |
| DDT/DDE/DDD | 0.3 |
| Drins | 0.01 |

Note: these levels are valid for a soil containing 25% clay and 10% organic matter

Dutch Soil Policy: the essentials

- AW2000 serve as first testing level of soil quality:
 - If level in soil $<$ AW2000: free use and shipping of soil
 - If level in soil $>$ AW2000: restrictions in use
 - Further use of soil depends on function
 - But: no relation with risk of substance in soil!
(pragmatic approach)

Dutch Soil Policy: Reference Values

- Serve as basis for soil clean-up
- Function specific:
 - Living with gardens
 - Playground for children
 - Private gardens
 - Agriculture
 - Nature
 - “green” area with high contact level (sport)
 - Other including industry, building
- Levels are related to risk (calculations)

Dutch Soil Policy: Reference Values

- Human toxicological criteria (ingestion of soil, exposure to dust, inhalation, oral availability)

| substance | MTR µg/kg/d | background µg/kg/d | MTR-WAB µg/kg/d |
|-----------|----------------|-----------------------|--------------------|
| As | 1.0 | 0.3 | 0.7 |
| Ba | 20 | 9 | 11 |
| Cd | 0.50 | 0.22 | 0.28 |
| Cr | 5 | 1 | 4 |
| Co | 1.4 | 0.3 | 1.1 |
| Cu | 140 | 30 | 110 |
| Hg (met.) | 2.0 | 0.1 | 1.9 |

Dutch Soil Policy: Reference Values

- Human toxicological criteria (ingestion of soil, exposure to dust, inhalation, oral availability)
- Consumption of home grown vegetables (0 – 100% depending on use)
- Protection of agriculture (crop quality)
- Ecological criteria
- Quality of ground- and surface water (leaching)

Dutch Soil Policy: Reference Values

| | housing/ garden | playground children | private garden | agriculture | nature | parks | other |
|----|--------------------|------------------------|-------------------|-------------|--------|-------|-------|
| Sb | 15 | 22 | 4 | 4 | 4 | 22 | 22 |
| As | 27 | 27 | 27 | 20 | 20 | 27 | 76 |
| Ba | 550 | 550 | 550 | 190 | 190 | 550 | 920 |
| Be | 1.9 | 1.9 | 1.9 | 1.5 | 1.5 | 1.9 | 30 |
| Cd | 3.7 | 3.7 | 1.2 | 0.6 | 0.6 | 1.2 | 4.3 |
| Cr | 62 | 62 | 62 | 55 | 55 | 62 | 180 |
| Co | 35 | 35 | 35 | 15 | 15 | 35 | 190 |
| Cu | 54 | 54 | 54 | 40 | 40 | 54 | 190 |
| Hg | 8.4 | 8.4 | 8.4 | 0.15 | 0.15 | 0.83 | 4.8 |
| Pb | 210 | 210 | 70 | 50 | 50 | 210 | 530 |
| Mo | 88 | 88 | 54 | 1.5 | 1.5 | 88 | 190 |

Note: values for “standard soil” (10% org mat, 25% clay)

Dutch Soil Policy: Reference Values

- Boundary conditions:

Reference values cannot be lower than Background value

(Ref < 95% AW2000 data)

Reference values can not exceed Intervention values

Dutch Soil Policy: Intervention Values

- Action level: if soil metal content $>$ Intervention value, more testing is needed
- Same criteria as for Reference level but now related to serious effect
- Tierd approach: from generic assessment to location specific research if needed

Dutch Soil Policy: Intervention Values

| Contaminant | level (mg kg ⁻¹) |
|-------------|------------------------------|
| As | 55 |
| Cd | 12 |
| Cr | 380 |
| Cu | 190 |
| Hg | 10 |
| Pb | 530 |
| Ni | 210 |
| Zn | 720 |
| PAH (10) | 40 |
| DDT/DDE/DDD | 4 |
| Drins | 4 |

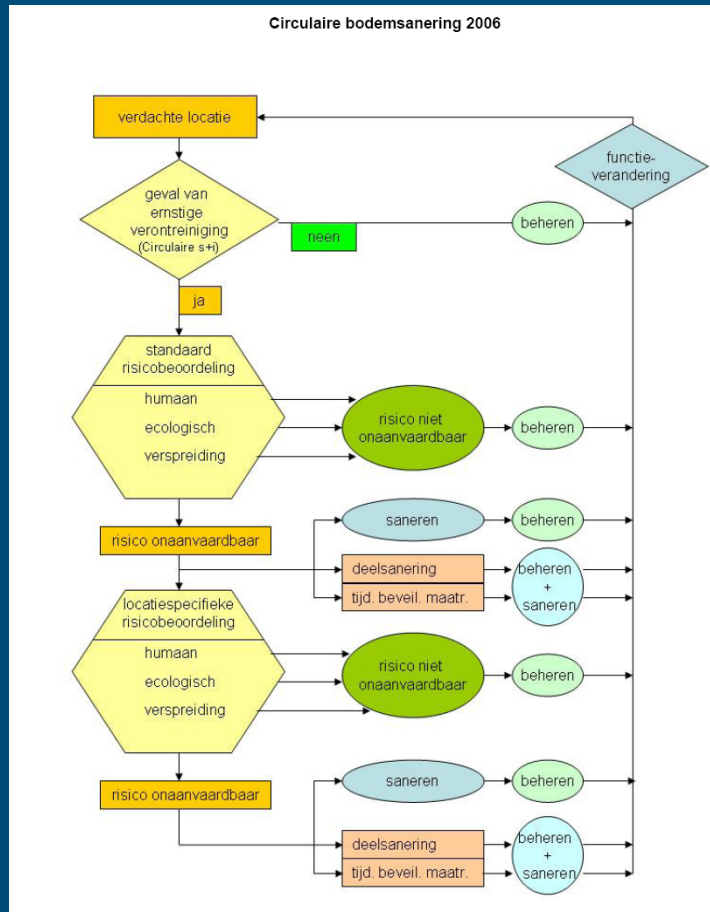
Dutch Soil Policy: correction for soil type

Soil type correction:

$$\text{Me-soil} = A + B \cdot \text{clay} + C \cdot \text{Organic matter}$$

| | | | As | Ba | Cd | Co | Cr | Cu |
|----------|----|------|-----------|-----------|-----------|-----------|-----------|-----------|
| | | A | 15 | 30 | 0.4 | 2 | 50 | 15 |
| | | B | 0.4 | 5 | 0.007 | 0.28 | 2 | 0.6 |
| | | C | 0.4 | 0 | 0.021 | 0 | 0 | 0.6 |
| | OM | clay | | | | | | |
| standard | 10 | 25 | 55 | 625 | 12 | 240 | 380 | 190 |
| sand | 3 | 3 | 33 | 181 | 7 | 76 | 213 | 98 |
| clay | 5 | 25 | 51 | 625 | 10 | 240 | 380 | 174 |
| peat | 30 | 15 | 63 | 423 | 17 | 165 | 304 | 222 |
| loess | 3 | 10 | 38 | 323 | 8 | 128 | 266 | 120 |

Dutch Soil Policy: tiered approach



From generic level
(Intervention value)

To risk assessment
(SUS: model
calculation of risk)

To location specific
tests
(field/laboratory)

Dutch Soil policy: tools and harmonization

- Tools for calculation of risk levels:

[“Risk Assessment Toolbox”](http://www.risicotoolboxbodem.nl)
www.risicotoolboxbodem.nl

- European activities on harmonization of risk assessment methods:

HERACLES

HUMAN AND ECOLOGICAL RISK ASSESSMENT
FOR CONTAMINATED LAND IN EUROPEAN MEMBER
STATES: Towards the development of common references

HERACLES

- Development of conceptual framework:
 - Negligible risk level – background level
 - Intermediate risk level – further testing
 - unacceptable risk level – intervention level
- Screening versus site-specific testing

HERACLES: still some way to go

Table 4.6. Screening values for potentially unacceptable risk (residential soil-use) for metals and metalloids (mg/kg d.w.).

Legend: Austria (AUT); Belgium Flanders (BE(F)); Belgium Bruxelles (BE(B)), Belgium Walloon (BE(W)); Czech Republic (CZE); Finland (FIN); Italy (ITA); Lithuania (LTU); Netherlands (NLD); Poland (POL); Slovakia (SVK); United Kingdom (UK); Denmark (DNK)

| | AUT | BE(F)* | BE(B) | BE(W) | CZE | FIN | ITA | LTU | NLD | POL | SVK | UK | DNK |
|-----------|-----------|----------|----------|-----------|-----------|-----------|----------|----------|-----------|------------|-----------|----------|----------|
| As | 50 | 110 | 110 | 300 | 70 | 50 | 20 | 10 | 55 | 22.5 | 50 | 20 | 20 |
| Ba | | | | | 1000 | | | 600 | 625 | 285 | 2000 | | |
| Bi | | | | | 30 | | 3 | 10 | 30 | | 30 | | |
| Cd | 10 | 6 | 6 | 30 | 20 | 10 | 2 | 3 | 12 | 5.5 | 20 | 2 | 5 |
| Co | | | | | 300 | 100 | 20 | 30 | 240 | 45 | 300 | | |
| Cr | 250 | | 300 | 520 | 500 | 200 | 150 | 100 | 380 | 170 | 800 | 130 | 1000 |
| Cu | 600 | 400 | 400 | 290 | 600 | 150 | 120 | 100 | 190 | 100 | 500 | | 1000 |
| Hg | 10 | 15 | 15 | 56 | 10 | 2 | 1 | 1.5 | 10 | 4 | 10 | 8 | 3 |
| Pb | 500 | 700 | 700 | 700 | 300 | 200 | 100 | 100 | 530 | 150 | 600 | 450 | 400 |
| Mo | | | | | 100 | | | 5 | 200 | 25 | 200 | | |
| Ni | 140 | 470 | 470 | 300 | 250 | 100 | 120 | 75 | 210 | 75 | 500 | | 30 |
| Sb | 5 | | | | 40 | 10 | 10 | 10 | 15 | | | | |
| Se | | | | | | | 3 | 5 | 100 | | 20 | 35 | |
| Sn | | | | | 300 | | 1 | 10 | 900 | 40 | 300 | | |
| Te | | | | | | | | | 600 | | | | |
| Tl | 10 | | | | | | 1 | | 15 | | | | |
| V | | | | | 450 | 150 | 90 | 150 | 250 | | 500 | | |
| Zn | | 1000 | 1000 | 710 | 2500 | 250 | 150 | 300 | 720 | 325 | 3000 | | 1000 |

*For new contaminants only

Dutch soil policy on soil protection: 1980



Discovery of polluted material
(toluene/xylene)
underneath houses in
Lekkerkerk

(thanks to a broken
water pipe!)

...but there were little or no risks for public health

Soil Pollution and Spatial Planning

- Some examples on the re-use of (formerly) polluted or treated soil/areas
- Source: ministry of VROM (Housing, Spatial Planning and the Environment)

Krimpenervaard



Problem:

presence of ditches filled with all kinds of waste

Effect:

risks for cattle and ecosystem

Treatment:

1. Mapping of worst sites;
2. Covering with clean soil
3. Monitoring of soil/ecosystem

Recreational area on waste dump



Problem:

presence of waste dump

Effect:

smell, not attractive

Treatment:

1. Landscaping
2. Covering with clean soil
3. Monitoring of drainage water

In situ clean-up of existing housing area



Problem:

presence of chlorinated solvents (10 ha)

Effect:

dangerous, potential large impact on housing if classically treated (decrease groundwater)

Treatment:

1. biological in situ remediation
2. Monitoring of groundwater quality

Remediation of former power plant/waste incinerator



Problem:

presence of industry near residential area

Effect:

human health effects (air quality, soil pollution)

Treatment:

1. Excavation of soil, replacing by clean soil
2. Install playgrounds/sporting fields

Transformation of Gasworks to urban park



Problem:

presence of gasworks
(Utrecht)

Effect:

brown field within city limits,
polluted soil

Treatment:

1. Excavation of soil, replacing by clean soil, isolation of polluted soil (reactive barriers)
2. Creation of ponds and green

From polluted harbor area to yachting club



Problem:

presence of deserted and polluted harbor area (Middelburg)

Effect:

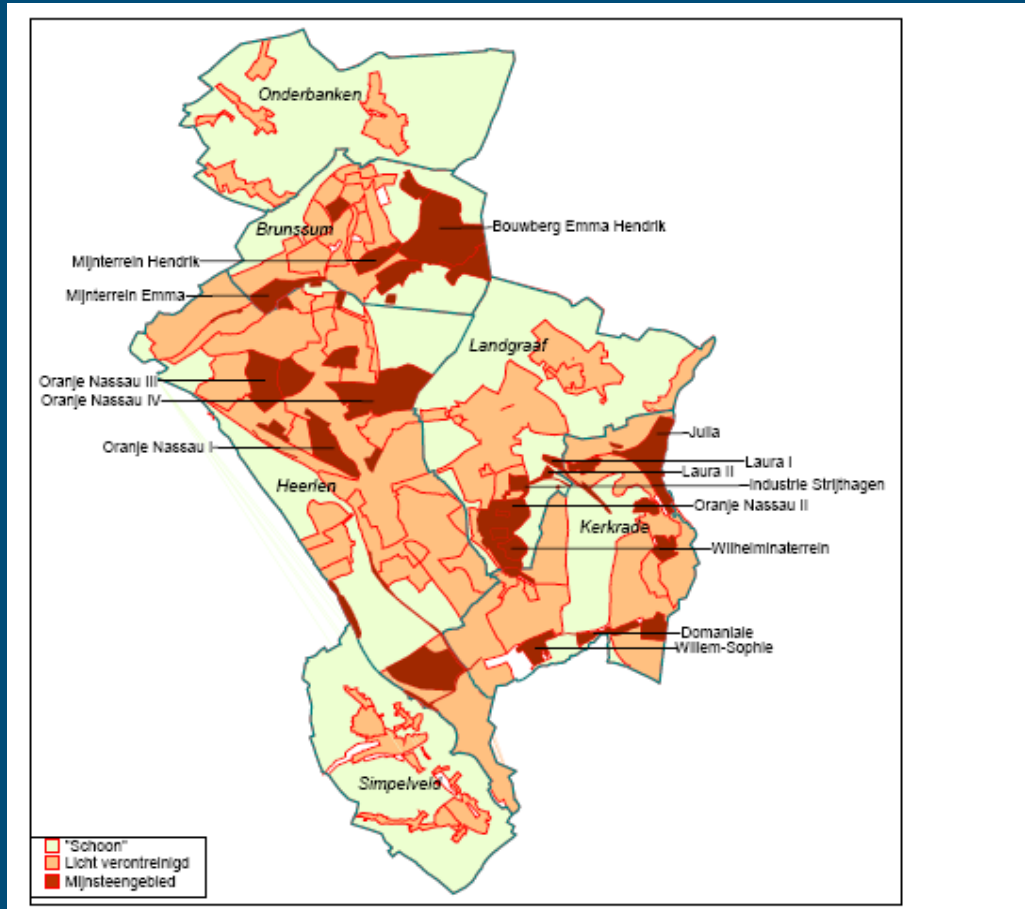
brown field within city limits, polluted soil, impact on water quality

Treatment:

1. Excavation of polluted soil, replacing by clean soil
2. Creation of yachting area

- CASE 1: Redevelopment of former mining area

Redevelopment of former mining area



Mining: 1900 – 1975

13 coal mines in the area

Redevelopment of former mining area



© Heemkunde Vereniging Landgraaf

Redevelopment of former mining area



© Heemkunde Vereniging Landgraaf

Redevelopment of former mining area



Redevelopment of former mining area

Public concern about human health:
presence of mine waste in private gardens



Redevelopment of former mining area

Public concern about human health: safety of home-grown food?



Redevelopment of former mining area

And the role of the media.....



Redevelopment of former mining area

- Major issues:
 1. How to redevelop the area?
 2. What are risks of mining waste?

Risk Assessment of PAH's in soil

Problem:



Contaminated waste may lead to
consumption of home

grown vegetables
based by science!

(Show us that it is safe!)

Risk Assessment of PAH's in soil

Experiments:

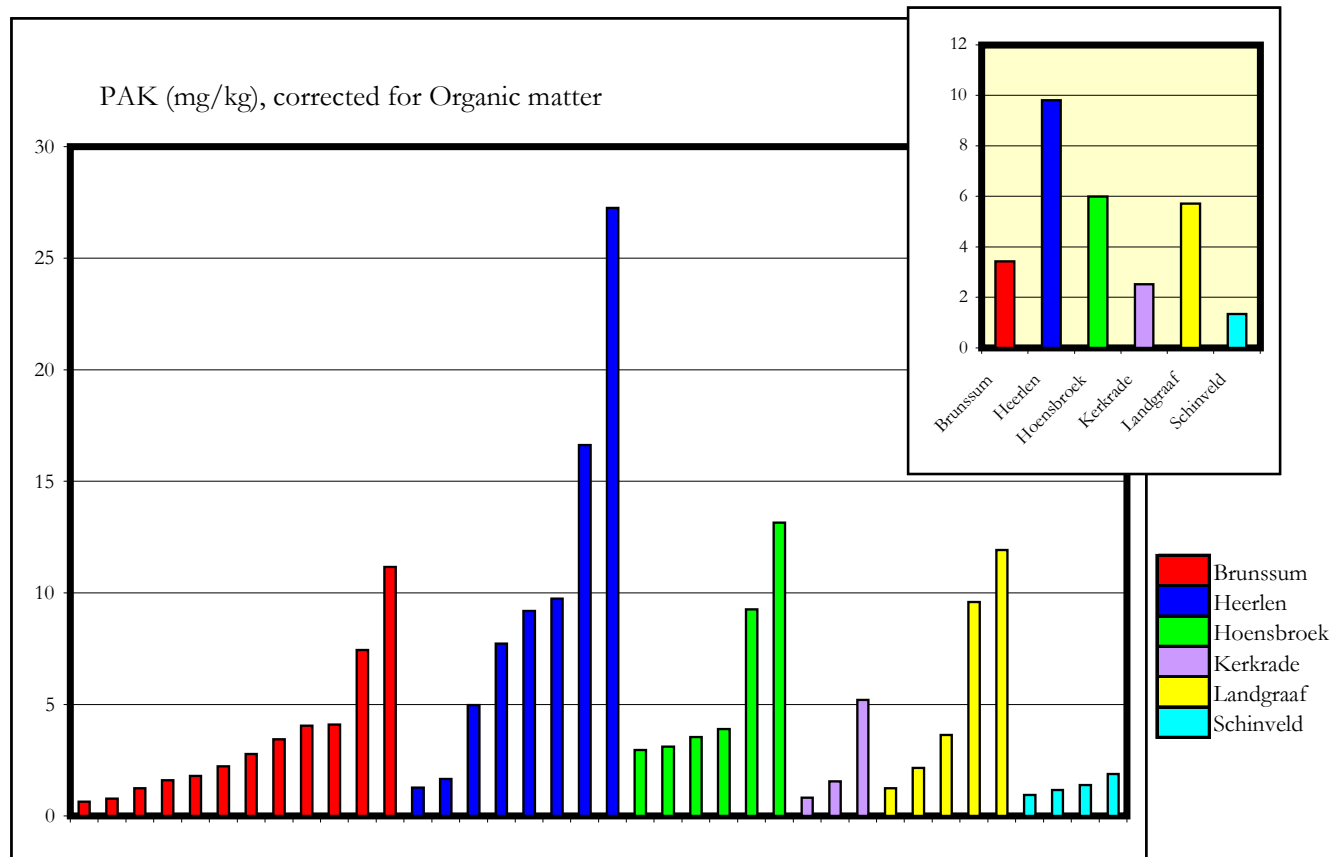
- Measurement of PAH in existing gardens (soil/crop) with different degree of pollution
- Setting up new gardens on extremely polluted soil (not used as private garden)
- Measurement of PAH uptake in pot experiment (well controlled)

Risk Assessment of PAH's in soil

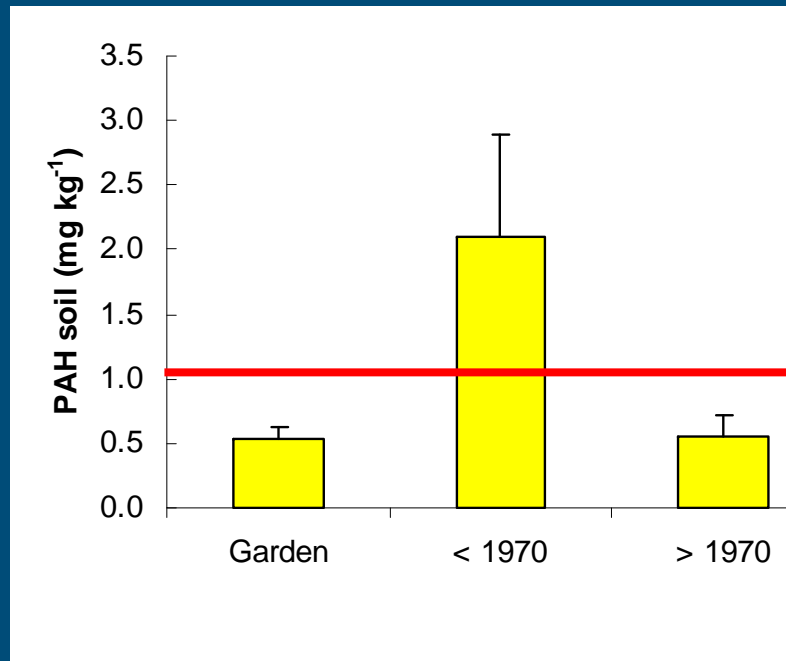
Experimental “garden” next to railroad



Risk Assessment of PAH's in soil



Risk Assessment of PAH's in soil

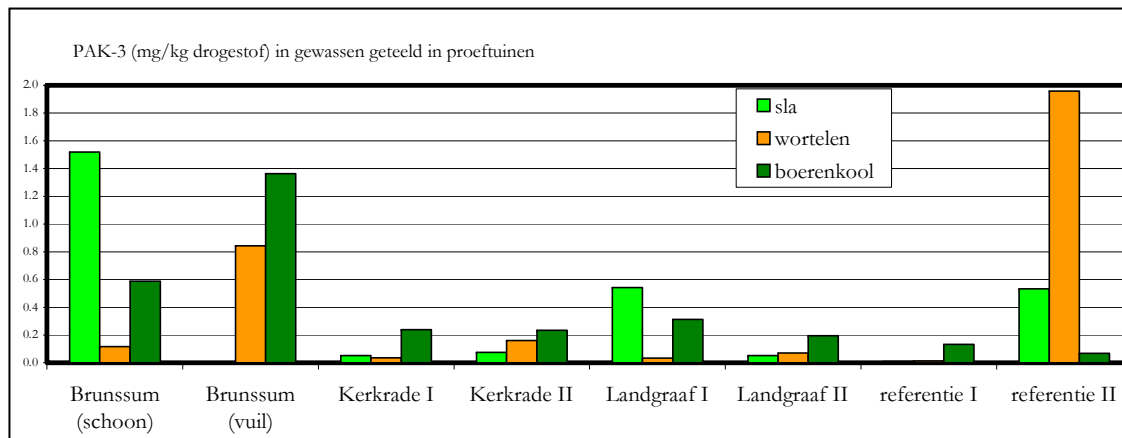


Risk Assessment of PAH's in soil

■ Results:

- Soil pollution not very serious
- Uptake by crops not related to PAH level in soil

Risk Assessment of PAH's in soil



Risk Assessment of PAH's in soil

■ Results:

- Soil pollution not very serious
- Uptake by crops not related to PAH level in soil
- Effect of “dust” is very large (and washing also)
- No further measures are needed
- Public concern was taken away by “real” data from their own environment (risk perception!)

Redevelopment of former mining area

- Spatial Planning of the area:
 - Consider risks in relation to use;
 - Heavily polluted areas – extensive use (light industry)
 - Moderately polluted areas – redesign, covering
 - Non polluted areas – parks, redesign (fishing ponds)
 - Activities for local/regional population

Redevelopment of former mining area



And now

More conventional recreation opportunities

Green oasis in a highly urbanised area:

Zoo

Flower theme park

Horse racing track

Skiing arena

Fish ponds

Hiking/biking trails

Museum for industrial heritage



Redevelopment of former mining area



View from the top of the re-designed waste dump
(race track, multi-event arena (pop concerts))

Redevelopment of former mining area



Indoor ski slope
(with FIS license!)

Redevelopment of former mining area



Redevelopment of former mining area



Flower & Garden
Theme-park
“Gaia-Park”

Redevelopment of former mining area



- Case 2 Kempen Area

The Kempen area: its famous inhabitants

Vincent van Gogh was born 150 years ago. He lived some years in The Kempen area.



Before.....

Zn and Cd smelter near Budel

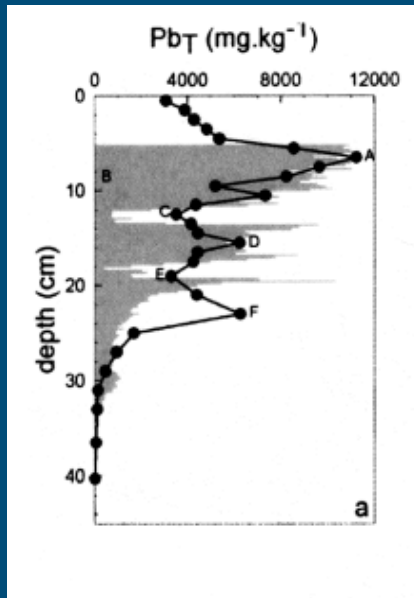


Cd (mg / kg soil)

- $350 \text{ km}^2 > 1,0$
- $2,5 \text{ km}^2 > 2,5$

Kempen area

- The problem: emission of Cd, Pb and Zn from ore treatment plants in B and NL:



Development of Pb levels in sediments of natural peat bogs

Kempen area

- The effects:
 1. Approx. 450 km² affected (soil cadmium levels > 1 ppm where 0.1 to 0.3 is normal)
 2. Increased levels of cadmium in arable products
 3. Elevated cadmium and zinc levels in ground- and surface waters as well as sediments (> 50 ppm)
 4. Increased occurrence of lung cancer (Nawrot et al., 2006) due to dust inhalation and exposure

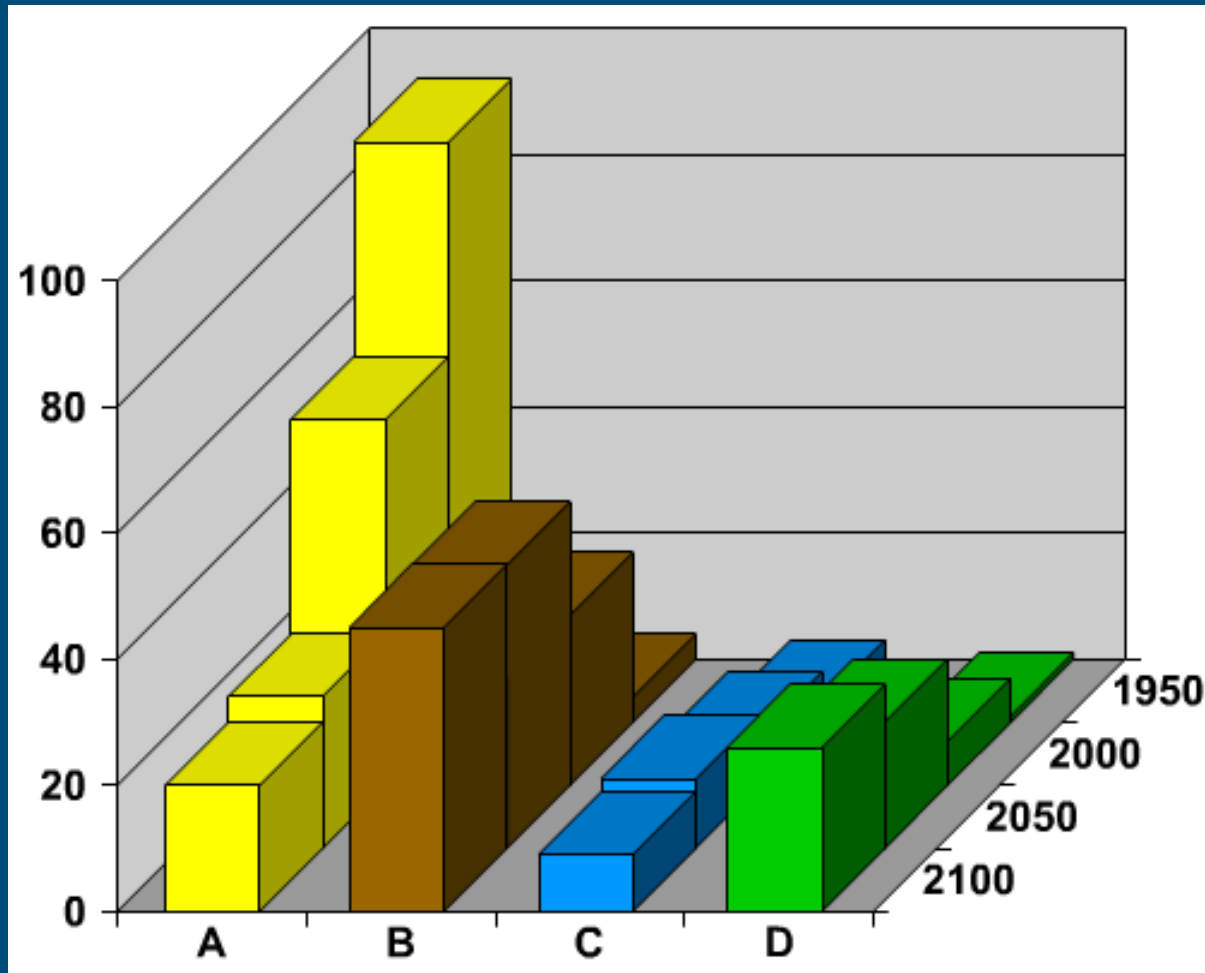
Kempen: an integrated regional approach

- Divide problem into pieces that can be managed:
 - Zink ash distribution
 - Peoples gardens (food crops)
 - Polluted sediments along rivers (Dommel)
 - Groundwater
 - Agriculture
 - Nature

Kempen: an integrated regional approach

- Establish degree of risk
- Find out what is happening (process knowledge)
- Determine need to clean or treat or manage
- Design specific action plans for different fields
- Communicate with local stakeholders (farmers) and civilians (owners of gardens)
- Make action plan (and stick to it!)

Identification of sources and pathways



A: Topsoil

B: subsoil (adsorbed)

C: sub-soil in
waterphase

D: Flux towards
sediments

Presence of zinc ashes

Presence of highly polluted ashes throughout the region.



Used for roads and
pavement of yards near
houses

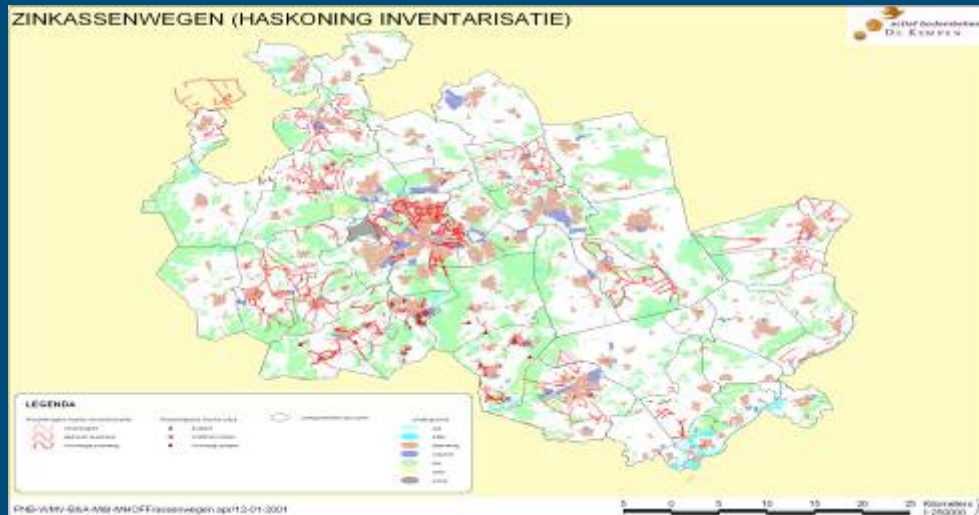
Cd: > 50 ppm

Zn: > 5000 ppm

Presence of zinc ashes

Decision:

1. Very high risk
2. Complete removal
3. 60% paid by national government, 0% - 40% by community, depending on use
4. People have own responsibility (step approach)



Clean up of ashes from private gardens

1. Gain information
2. Apply for soil test & testing
3. Analysis of results by local/regional government
4. Decision of need for clean-up
 - Flower garden = 100% compensation
 - Food production = 60% compensation
5. Signing of agreement
6. Preparation and execution of clean-up

Risks for agriculture

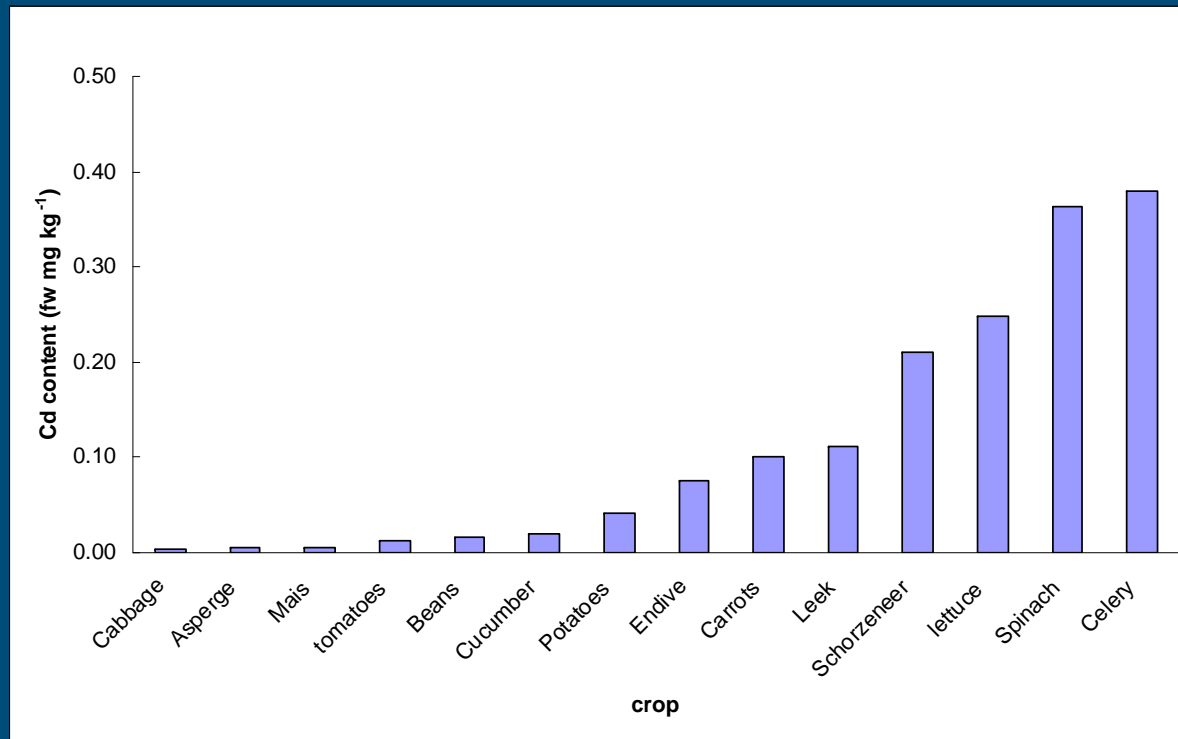
■ Problem

- Crops do not meet EU food safety regulations

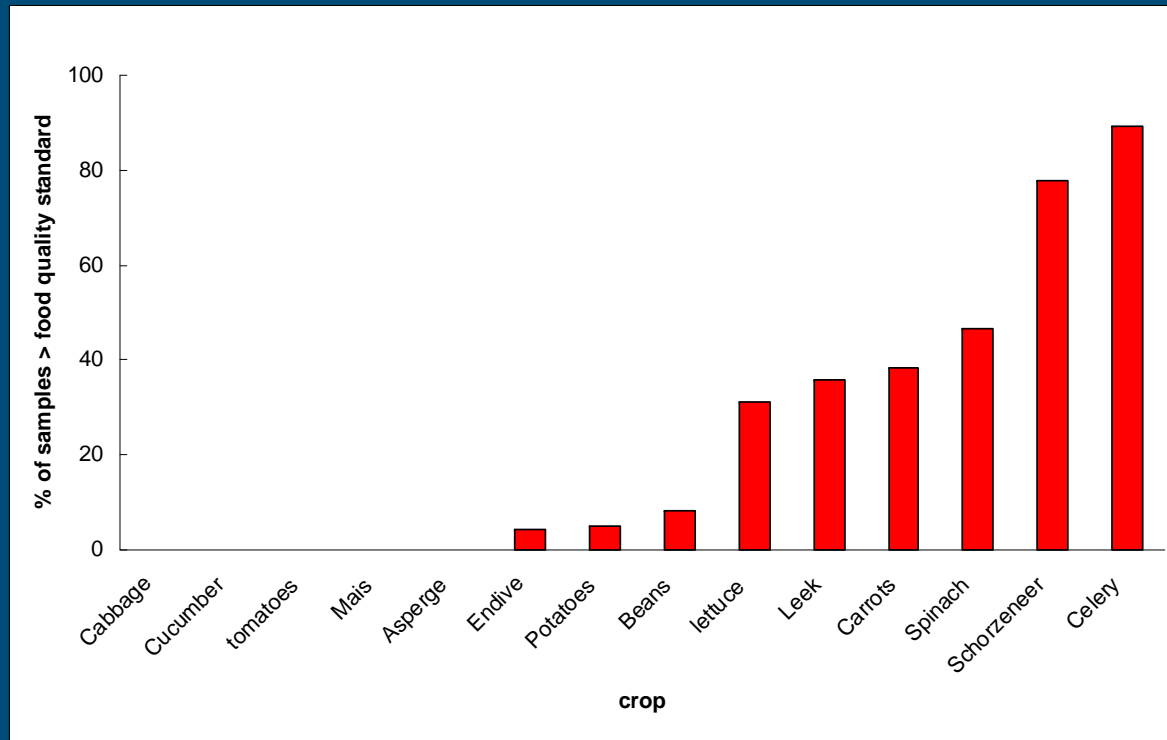
■ Approach:

- Determine levels in soil and crop
- Measure other soil properties (pH, organic matter)
- Establish relationship between soil and crop cadmium levels
- Derive measures to reduce uptake by crops

Cadmium levels in field grown crops (1)



Cadmium levels in field grown crops (2)



Cadmium in crops

- Reason for high cadmium levels in crops:
 - low pH (4 – 5.5)
 - Low organic matter content (< 5%)
 - Low clay content (< 4%)
- Solution: increase pH of the soil!
 - No removal of cadmium -> soil management
- Make “look-up tables” for farmers

Look-up tables for animal fodder

MAIS

| bodemgehalten: | pH: | pH: | pH: | pH: | pH: | pH: |
|------------------|------|------|------|------|------|------|
| | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| [Cd]: 0.40 mg/kg | 0.30 | 0.21 | 0.15 | 0.11 | 0.08 | 0.06 |
| [Cd]: 0.80 mg/kg | 0.52 | 0.37 | 0.26 | 0.19 | 0.14 | 0.10 |
| [Cd]: 1.20 mg/kg | 0.71 | 0.51 | 0.36 | 0.26 | 0.19 | 0.13 |
| [Cd]: 1.60 mg/kg | 0.89 | 0.63 | 0.45 | 0.32 | 0.23 | 0.17 |
| [Cd]: 2.00 mg/kg | 1.05 | 0.75 | 0.54 | 0.39 | 0.28 | 0.20 |
| [Cd]: 2.40 mg/kg | 1.22 | 0.87 | 0.62 | 0.45 | 0.32 | 0.23 |
| [Cd]: 2.80 mg/kg | 1.37 | 0.98 | 0.70 | 0.50 | 0.36 | 0.26 |
| [Cd]: 3.20 mg/kg | 1.52 | 1.09 | 0.78 | 0.56 | 0.40 | 0.29 |
| [Cd]: 3.60 mg/kg | 1.67 | 1.19 | 0.85 | 0.61 | 0.44 | 0.31 |
| [Cd]: 4.00 mg/kg | 1.81 | 1.30 | 0.93 | 0.66 | 0.47 | 0.34 |
| [Cd]: 4.40 mg/kg | 1.95 | 1.40 | 1.00 | 0.71 | 0.51 | 0.37 |
| [Cd]: 4.80 mg/kg | 2.09 | 1.49 | 1.07 | 0.76 | 0.55 | 0.39 |

MAIZE

| bodemgehalten: | pH: | pH: | pH: | pH: | pH: | pH: |
|-----------------|------|------|------|------|------|------|
| | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| [Zn]: 50 mg/kg | 357 | 219 | 134 | 82 | 50 | 31 |
| [Zn]: 100 mg/kg | 584 | 358 | 220 | 135 | 83 | 51 |
| [Zn]: 150 mg/kg | 779 | 477 | 293 | 180 | 110 | 68 |
| [Zn]: 200 mg/kg | 955 | 586 | 359 | 220 | 135 | 83 |
| [Zn]: 250 mg/kg | 1119 | 686 | 421 | 258 | 158 | 97 |
| [Zn]: 300 mg/kg | 1273 | 781 | 479 | 294 | 180 | 110 |
| [Zn]: 350 mg/kg | 1421 | 871 | 534 | 328 | 201 | 123 |
| [Zn]: 400 mg/kg | 1562 | 958 | 587 | 360 | 221 | 135 |
| [Zn]: 450 mg/kg | 1698 | 1041 | 639 | 392 | 240 | 147 |
| [Zn]: 500 mg/kg | 1830 | 1122 | 688 | 422 | 259 | 159 |
| [Zn]: 550 mg/kg | 1958 | 1201 | 736 | 452 | 277 | 170 |
| [Zn]: 600 mg/kg | 2082 | 1277 | 783 | 480 | 295 | 181 |

GRASS

| bodemgehalten: | pH: | pH: | pH: | pH: | pH: | pH: |
|------------------|------|------|------|------|------|------|
| | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| [Cd]: 0.40 mg/kg | 0.36 | 0.23 | 0.15 | 0.10 | 0.06 | 0.04 |
| [Cd]: 0.80 mg/kg | 0.85 | 0.54 | 0.35 | 0.23 | 0.15 | 0.09 |
| [Cd]: 1.20 mg/kg | 1.39 | 0.89 | 0.57 | 0.37 | 0.24 | 0.15 |
| [Cd]: 1.60 mg/kg | 1.97 | 1.27 | 0.82 | 0.52 | 0.34 | 0.22 |
| [Cd]: 2.00 mg/kg | 2.58 | 1.66 | 1.07 | 0.69 | 0.44 | 0.29 |
| [Cd]: 2.40 mg/kg | 3.23 | 2.08 | 1.34 | 0.86 | 0.55 | 0.36 |
| [Cd]: 2.80 mg/kg | 3.90 | 2.51 | 1.61 | 1.04 | 0.67 | 0.43 |
| [Cd]: 3.20 mg/kg | 4.59 | 2.95 | 1.90 | 1.22 | 0.79 | 0.51 |
| [Cd]: 3.60 mg/kg | 5.30 | 3.41 | 2.19 | 1.41 | 0.91 | 0.58 |
| [Cd]: 4.00 mg/kg | 6.02 | 3.88 | 2.49 | 1.61 | 1.03 | 0.67 |
| [Cd]: 4.40 mg/kg | 6.76 | 4.35 | 2.80 | 1.80 | 1.16 | 0.75 |
| [Cd]: 4.80 mg/kg | 7.52 | 4.84 | 3.12 | 2.01 | 1.29 | 0.83 |

GRASS

| bodemgehalten: | pH: | pH: | pH: | pH: | pH: | pH: |
|-----------------|------|------|------|------|------|------|
| | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| [Zn]: 50 mg/kg | 269 | 174 | 112 | 72 | 47 | 30 |
| [Zn]: 100 mg/kg | 438 | 283 | 182 | 117 | 76 | 49 |
| [Zn]: 150 mg/kg | 583 | 376 | 242 | 156 | 101 | 65 |
| [Zn]: 200 mg/kg | 714 | 460 | 297 | 191 | 123 | 80 |
| [Zn]: 250 mg/kg | 835 | 539 | 347 | 224 | 144 | 93 |
| [Zn]: 300 mg/kg | 950 | 612 | 395 | 255 | 164 | 106 |
| [Zn]: 350 mg/kg | 1058 | 682 | 440 | 284 | 183 | 118 |
| [Zn]: 400 mg/kg | 1163 | 750 | 483 | 312 | 201 | 130 |
| [Zn]: 450 mg/kg | 1263 | 814 | 525 | 339 | 218 | 141 |
| [Zn]: 500 mg/kg | 1360 | 877 | 566 | 365 | 235 | 152 |
| [Zn]: 550 mg/kg | 1455 | 938 | 605 | 390 | 251 | 162 |
| [Zn]: 600 mg/kg | 1547 | 997 | 643 | 415 | 267 | 172 |

Management of natural areas: flooded river plains



Management of natural areas: flooded river plains

Problem: high levels of cadmium, zinc and lead in flooded river soils "Malpiebeemden" (n=26): natural area!

| | pH | OM | Cd | Pb | Zn |
|--------|-----|------|-------------|-----|------|
| Min | 4.3 | 3.6 | 5.0 | 31 | 115 |
| Median | 5.2 | 10.5 | 22.0 | 157 | 395 |
| Max | 6.4 | 29.3 | 123 | 472 | 1992 |

Management of natural areas: flooded river plains

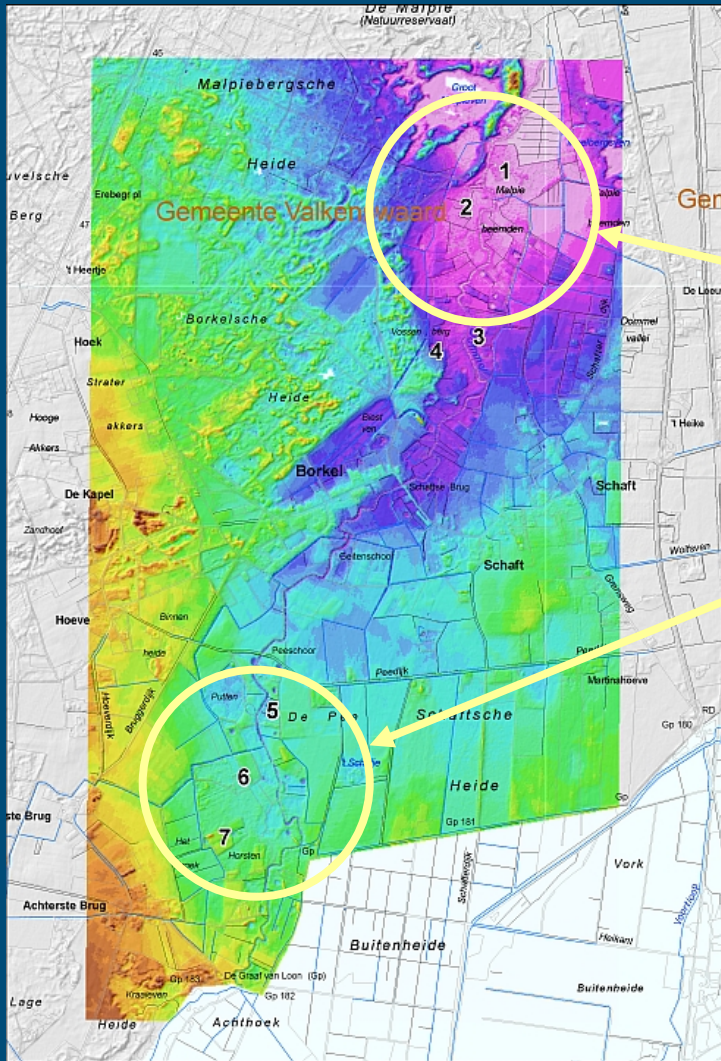
■ Problem

- Heterogeneous soil pollution
- High content of cadmium in grass (> EU fodder regulation)
- Intake of cows too high, accumulation of Cd in kidney

■ Approach

- Measure levels in grass in relation to deposition level (low, medium, high)
- Calculate Cd levels in kidney
- Allow cows in higher areas only
- Remove kidney from foodchain

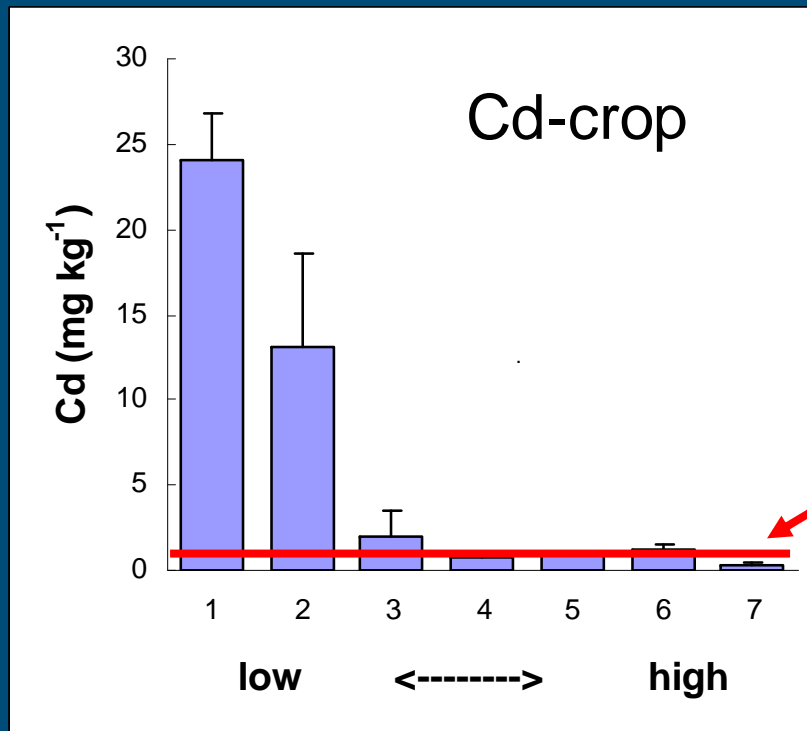
Management of natural areas: flooded river plains



Low lying areas
(frequently flooded)

Higher situated
areas (less
frequently flooded)

Management of natural areas: flooded river plains



EU fodder regulation

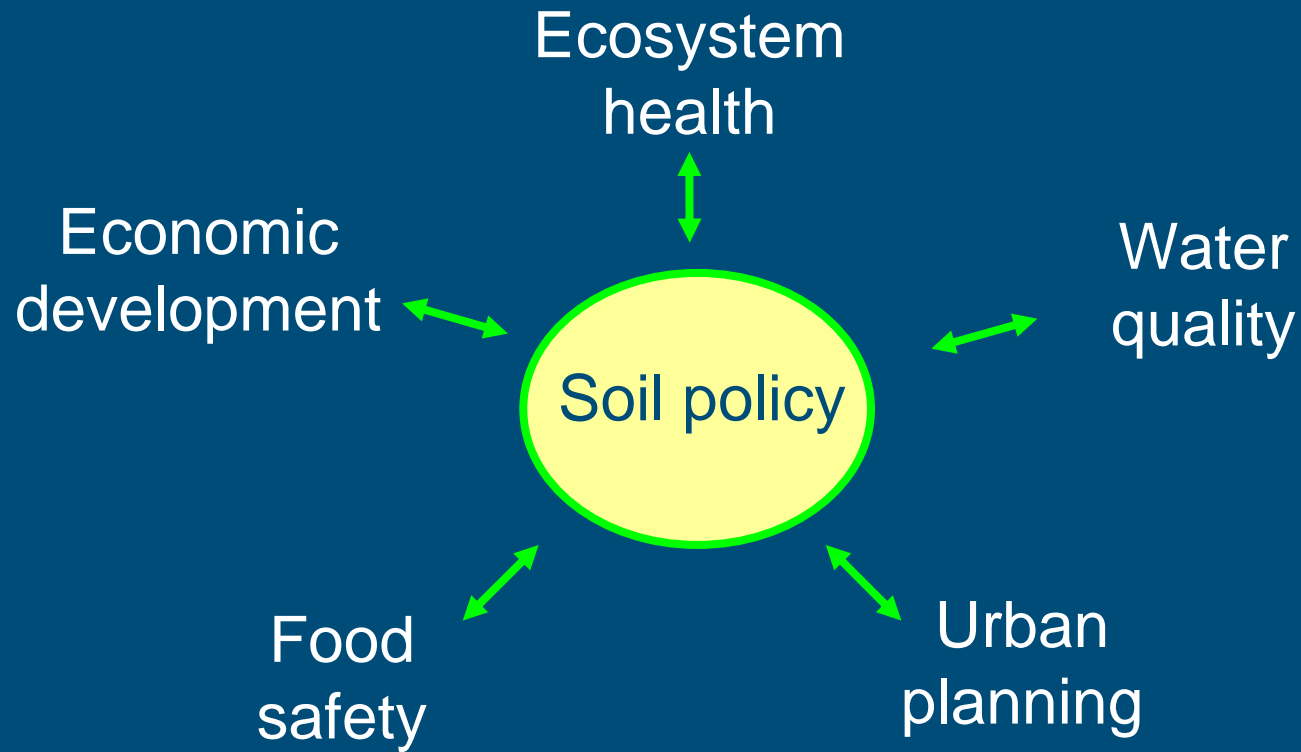
Are cows at risk?

- Cadmium-kidney:
 - soil + grass + additives = total intake
 - total intake * Biotransfer coefficient = Cd-kidney
- Cd-kidney 0.5 – 3.0 mg kg⁻¹ in higher plots (4 – 7)
- Cd-kidney 2.3 – 57 mg kg⁻¹ in low plots (1, 2, 3)
- EU food quality standard = 1.0 mg kg⁻¹
- toxic level for cows > 100 mg kg⁻¹

Management of natural areas: flooded river plains

- Decision of policy makers:
 - Cows and cow products not suitable for human consumption
 - Cows are allowed to graze in polluted areas (maintain grassland)
 - Careful monitoring for increased signs of toxicity (animal health)

In conclusion.....

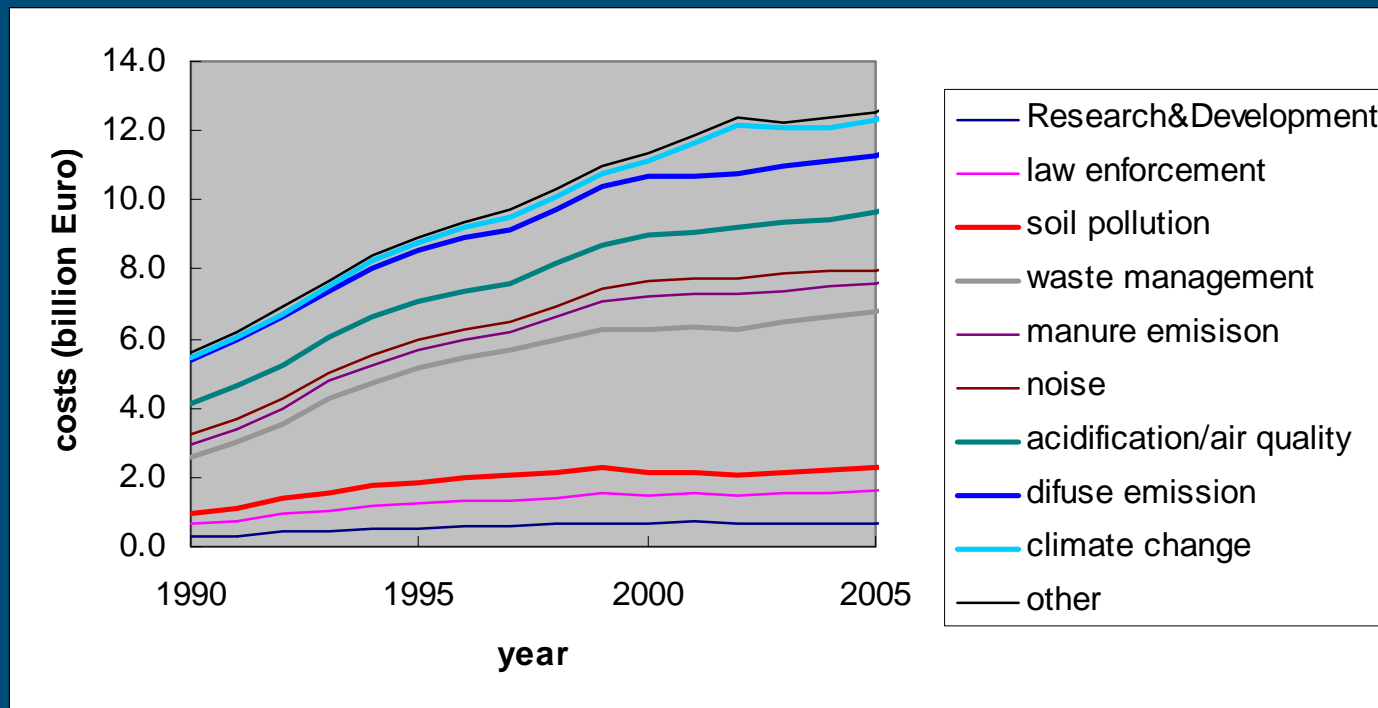


Soil policy: the essence

■ Soil policy:

- Keep clean what is clean *prevent risk*
- Clean up what really needs to be cleaned *remove risk*
- Manage the rest (re-use of polluted soil) *minimize risk*

But its not for free.....



Soil policy

But worth the effort!

Thank you!