Netherlands Environmental Assessment Agency (PBL)

Impact of macroporosity on pesticide losses from tile-drained soils in the Netherlands

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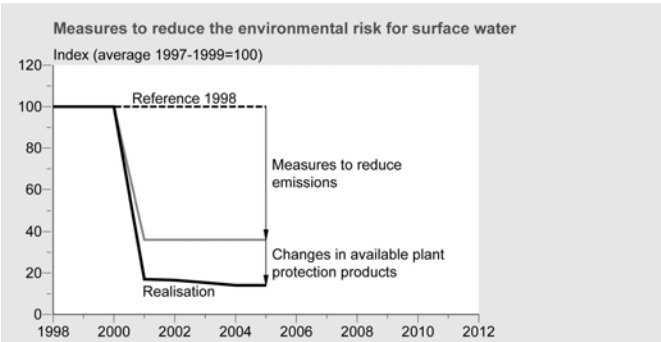
Pesticide Behaviour in Soils, Water and Air, 14 September 2009

The Dutch Policy Plan on Sustainable Crop Protection

- Dutch Policy Plan on Sustainable Crop Protection
  - 95% reduction of calculated environmental risk for surface water by pesticides between 1998 and 2010
  - Water quality standards not exceeded by the year 2010
- Interim evaluation by PBL – reduction of risk primarily achieved by:
  - Drift-reducing techniques
  - Pesticide authorisation (substitution of harmful substances by less harmful substances)



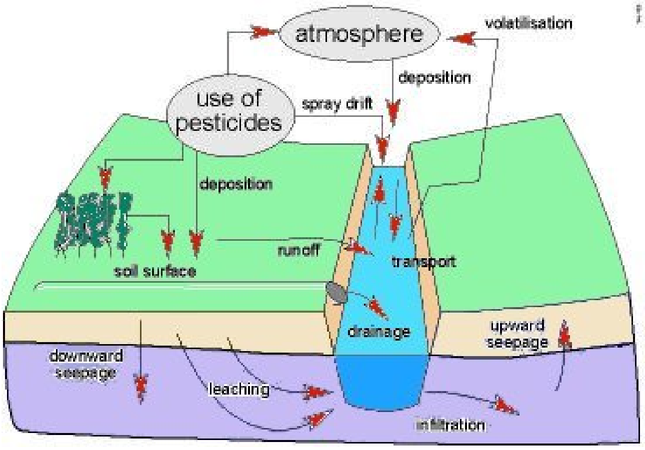
Source: PBL

Pesticide authorisation important, but not all loss pathways considered

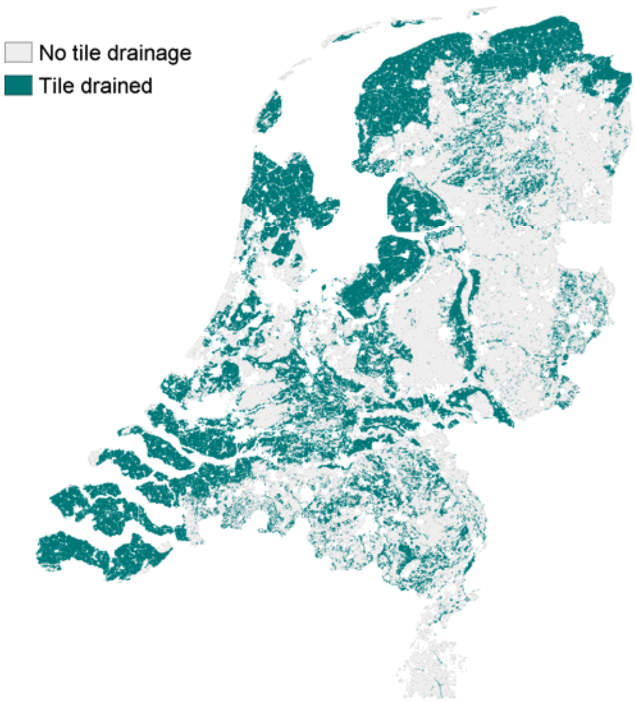
- Dutch authorisation procedure considers only one pathway to the surface water, i.e. drift

- Drift reduced, so other pathways (runoff and drainage) become relatively more important

- Political call to introduce other pesticide loss pathways (including drainage) into Dutch Pesticide Authorisation Procedures

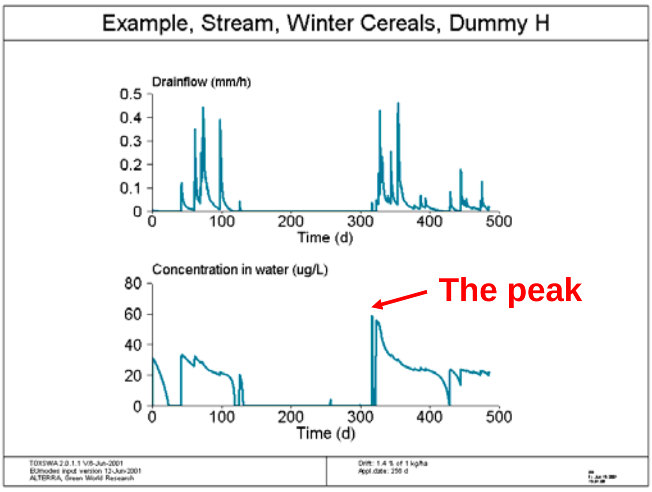


40% of Netherlands is tile drained



Peak concentration ecotoxicologically most relevant

- First step in exposure assessment: identify which concentration type gives the best correlation with ecotoxicological effects
- Ecotox workgroup:
  The peak concentration gives the best correlation with effects



Peak concentration affected by fast transfer pathways

- Overland flow (surface run-off)

- Preferential flow through the soil towards tile drains

Pesticide authorisation: risk assessment for realistic worst-cases

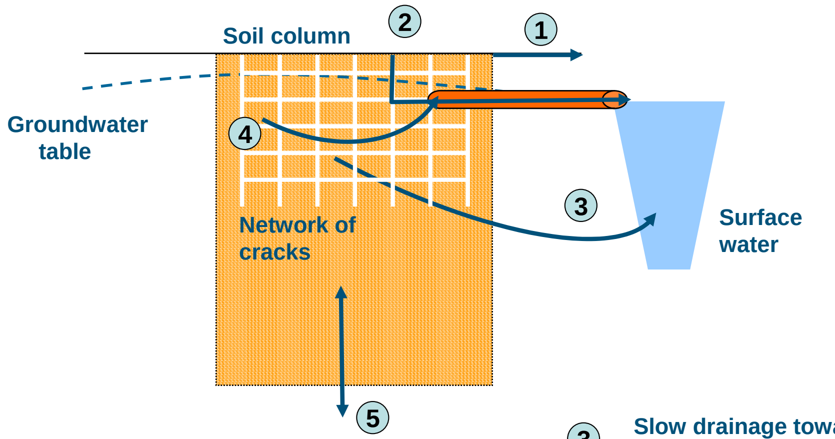
- Risk assessment is performed for a (series of) realistic worst case condition(s)
- Risk management decision: worst-case is defined as the 90th spatial percentile of the Ecotoxicologically Relevant Concentration (i.e. the peak concentration) in ditches adjacent to tile drained soils
- Spatially-distributed model needed to find the location where these realistic worst-case conditions occur

Exposure models must deal with these fast transfer pathways

- So exposure models must consider preferential flow
- Indication that surface runoff is another important pathway, even in delta areas
  - But scientific research on surface runoff in flat areas is still going on
  - Two field experiments carried out by two PhD students (Alterra, Deltares)
- A version of PEARL with preferential flow has been developed

Conceptual model for macropore flow: Flow pathways

Main flow pathways in a macroporous soil column



1. Hortonian and saturation excess runoff
2. Rapid drainage through drainpipes due to macropore flow
3. Slow drainage towards the ditch due to matrix flow
4. Slow drainage through drainpipes due to matrix flow
5. Interaction with the regional groundwater

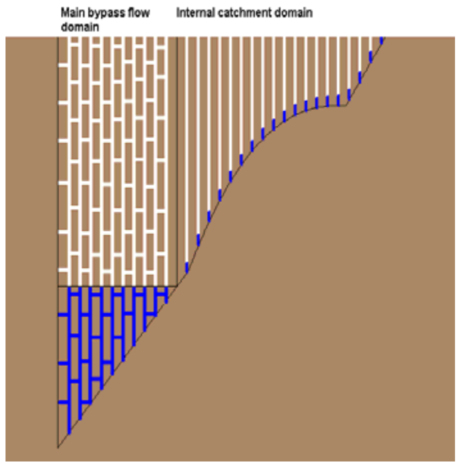
Conceptual model for macropore flow: Continuity and Persistency

- (Geo)PEARL* uses preferential flow concept of the SWAP model
- Macropore geometry important part of concept
  - Macropores are divided on the basis of continuity and persistency

**) GeoPEARL is the spatially-distributed version of PEARL*
See http://www.pearl.pesticidemodels.eu for details

Continuity: bypass domain versus internal catchment domain

- Main bypass domain
  - Network of continuous, horizontally interconnected macropores
  - Penetrate deep in the soil
  - Most important flow domain for rapid drainage to surface water
- Internal catchment domain
  - Non-connected macropores that end at various depths
  - Water must re-infiltrate in the matrix
  - Less important for rapid drainage

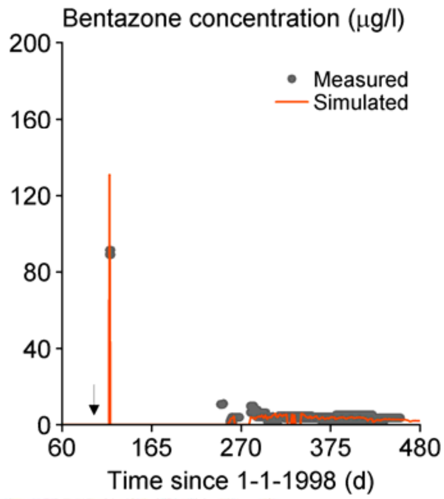


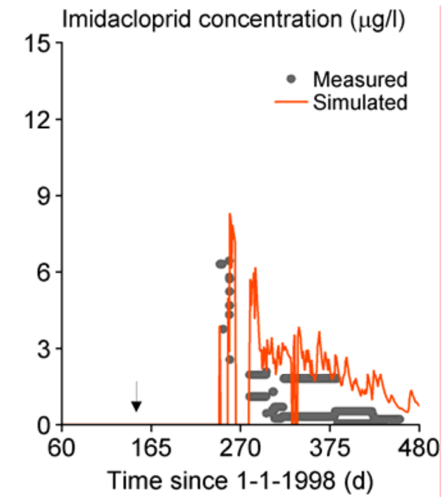
Persistence: static versus dynamic macropores

- Static (i.e. permanent) macropores
  - Structural shrinkage cracks, biopores
- Dynamic macropores
  - Due to swelling and shrinking of clay
  - Extremely important in clay soils with a large proportion of interlayered clay minerals (smectites and vermiculites)
  - All Dutch clay soils contain a large proportion of these interlayered clay minerals

Validation of conceptual model: Application of PEARL to Andelst clay-soil

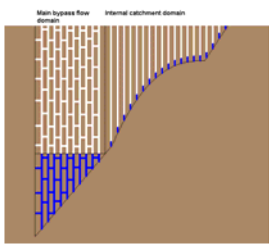
- Main conclusions
  - Fast response
  - Concentration in autumn high due to exchange between soil matrix and macropore domain

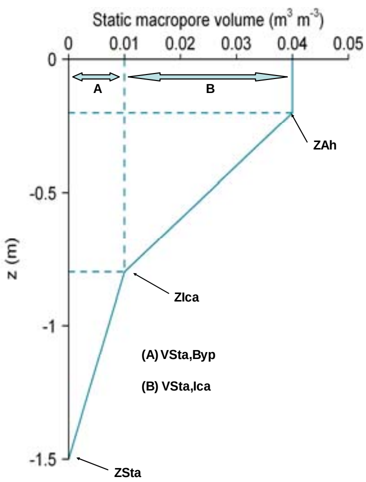




Regional scale: macropore parameters obtained with pedotransfer functions

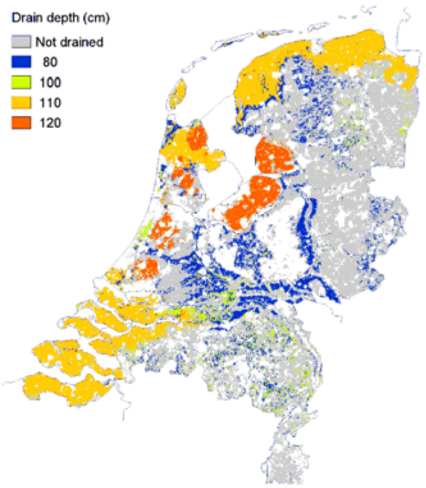
- Four parameters for macropore geometry
  - Volume of permanent macropores at soil surface (Vst0)
  - Depth of plough layer (ZAh)
  - Maximum depth of internal catchment domain (ZIca)
  - Maximum depth of all macropores (ZSta)

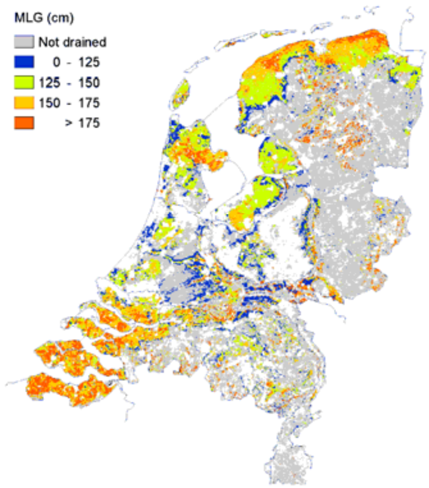




Maximum macropore depth equal to Mean Lowest Groundwater Level

- No ripening of clay below this depth, so no structural shrinkage cracks

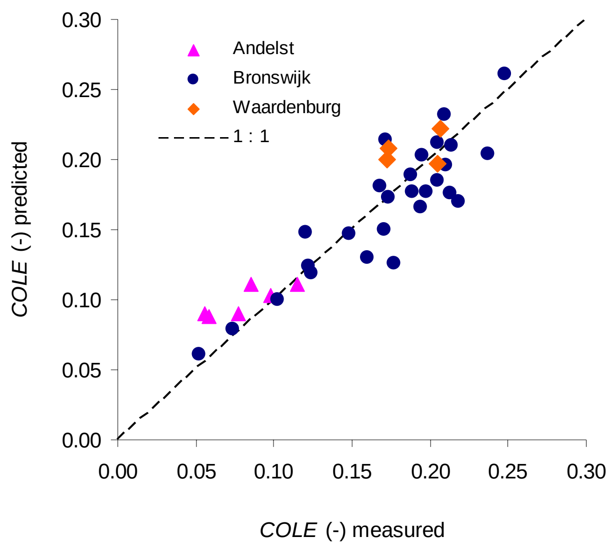




- Macropore depth usually deeper than tile drain depth, so rapid drainage is expected to be an important mechanism in most clay soils

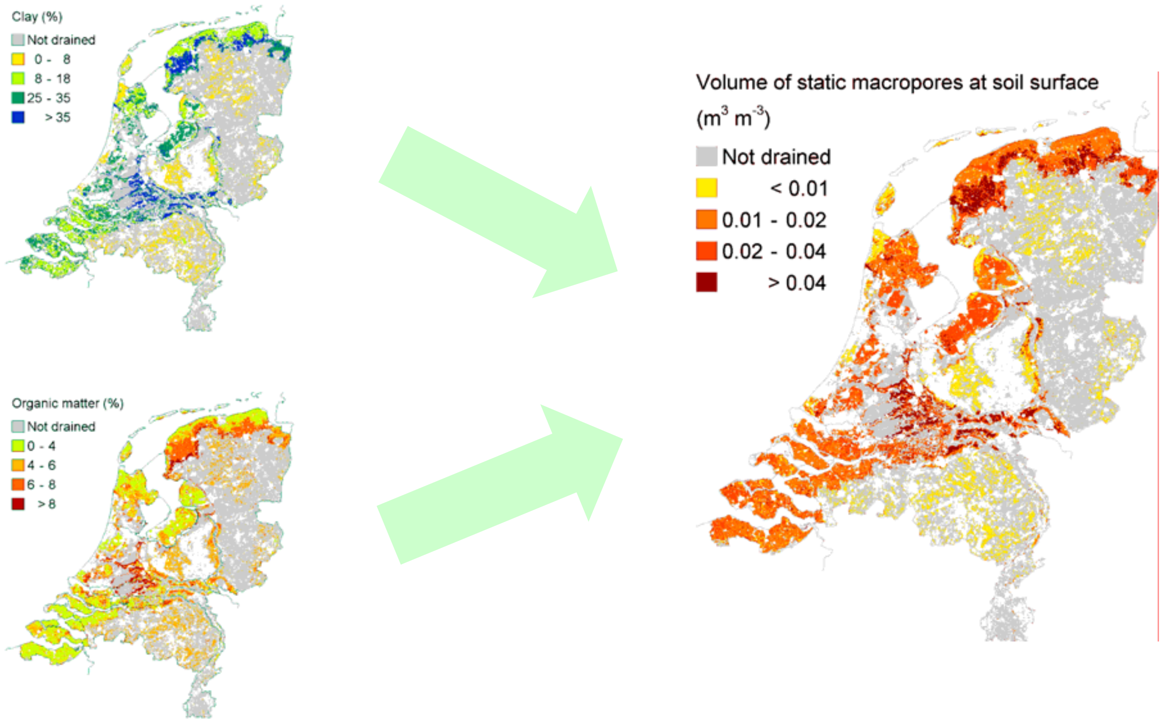
Volume of static macropores at soil surface related to COLE

- Assumption:
  - All static macropores are structural shrinkage cracks due to ripening of clay
  - Volume of static macropores related to Coefficient of Linear Extensibility
  - COLE related to organic matter and clay content



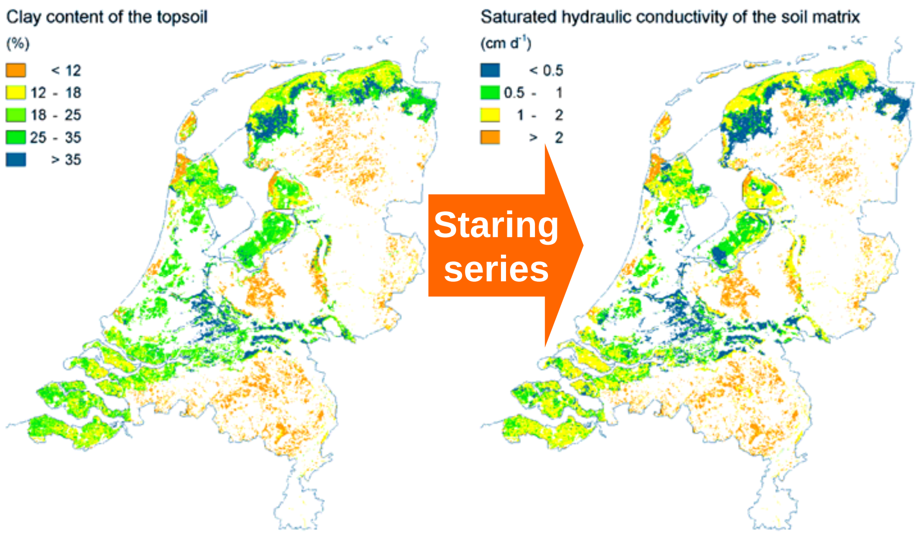
$$COLE = -0.02094 + 0.003311 f_{clay} + 0.009051 f_{om} \qquad (N = 37;\ R^2 = 0.81)$$

Static macropore volume at soil surface

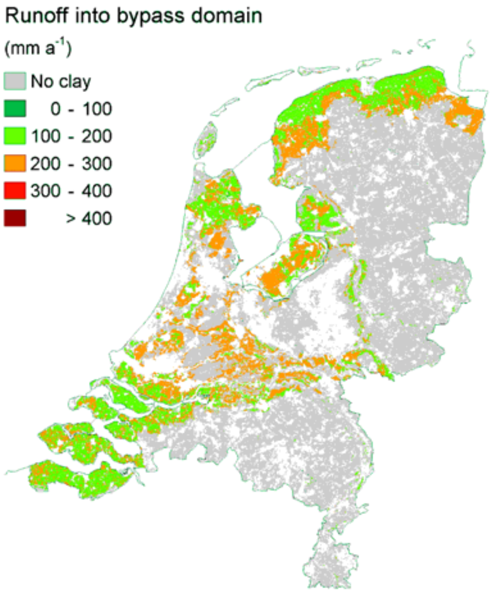


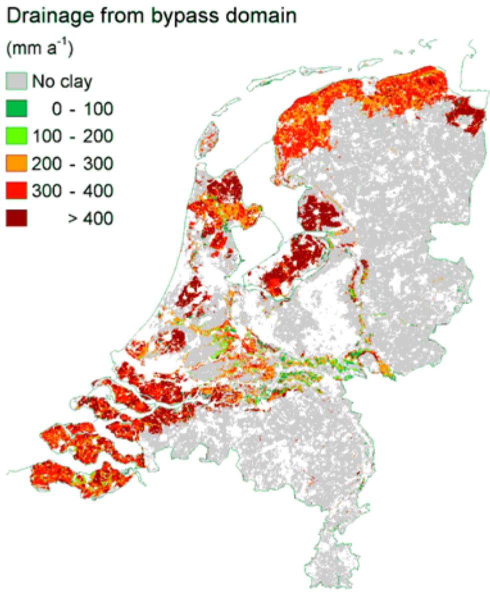
Additional soil physical parameters

- Parlanges sorptivity
- Hydraulic conductivity at boundary pressure head
  (*h* = -5 cm corresponding to a pore diameter of 0.5 mm)



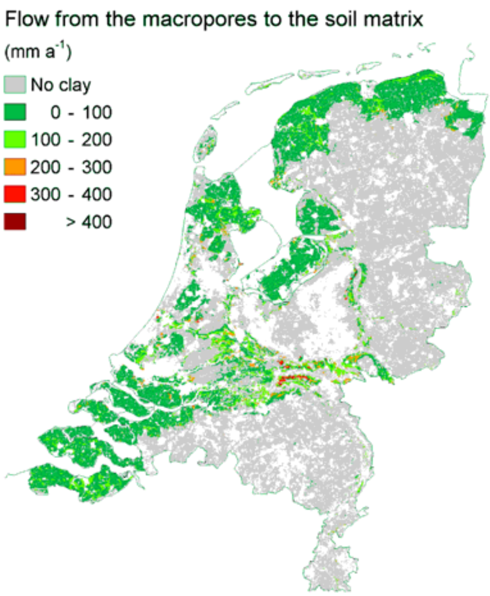
Water balance of the macropore domain: Runoff and drainage from the macropores

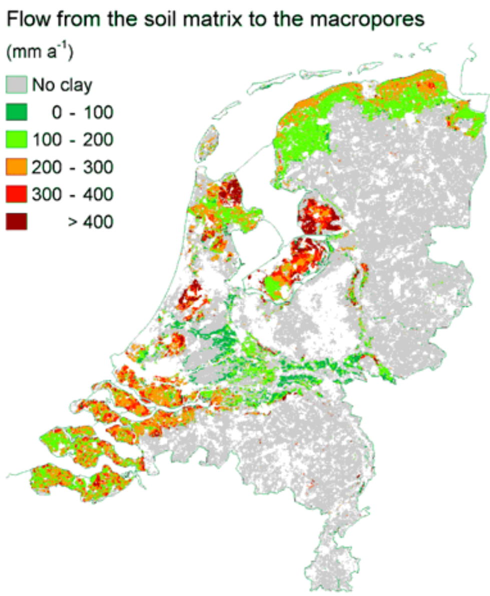




- Drainage >> Runoff
- What is happening?

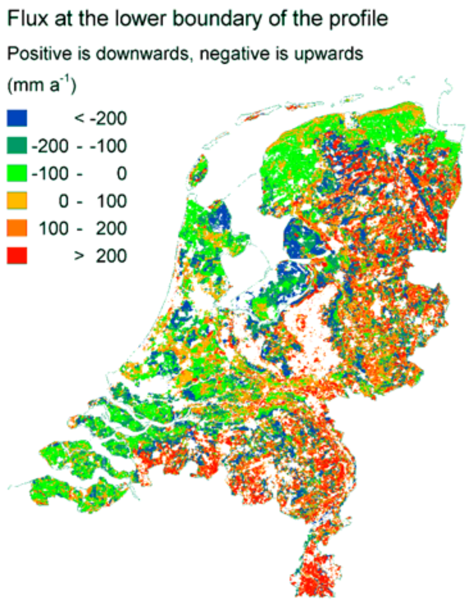
Water balance of the macropore domain: Exchange between matrix and macropores

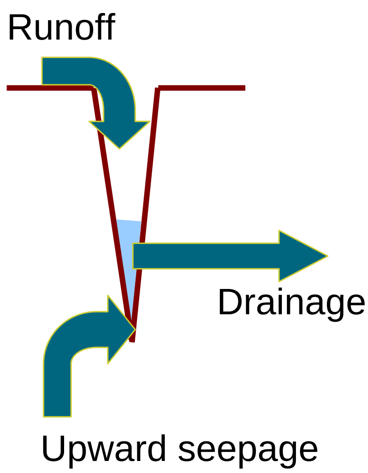




- Input from the soil matrix dominant term in large part of the country

Upward seepage from regional groundwater equally important as runoff!

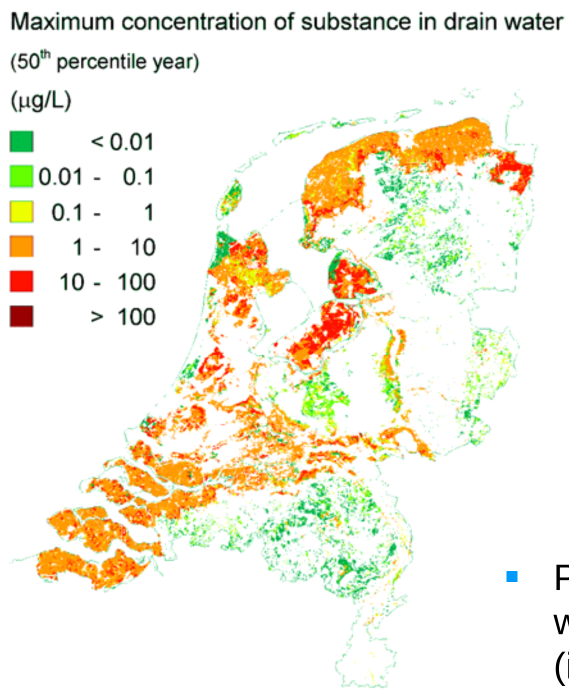




(source: National Ground Water Model)

- Dutch macroporous soils are generally in areas with upward seepage

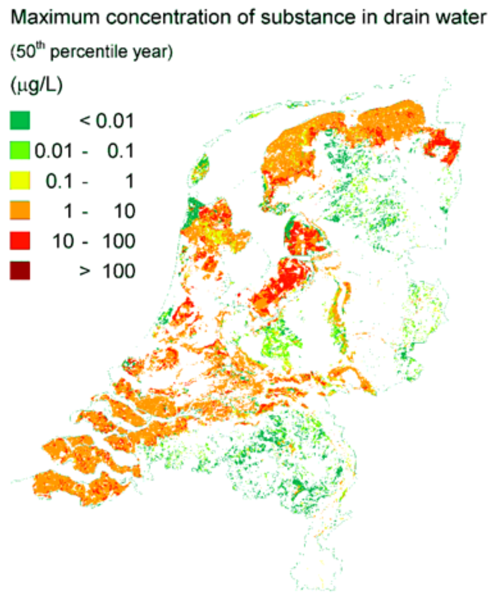
Peak concentration in drain water

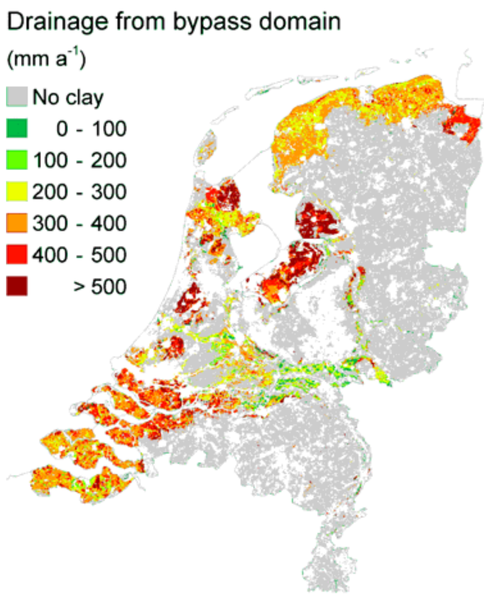


- Peak concentration highest in soils where preferential flow occurs (i.e. clay soils)

Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

Example output:
Peak concentration in drain water





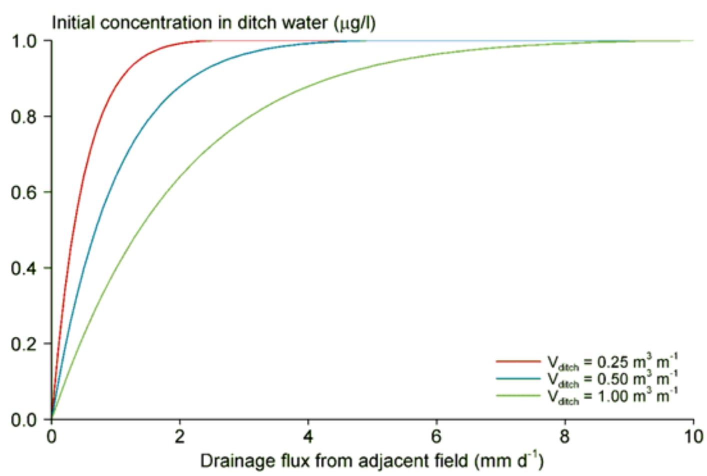
- Weak relation between drainage flux and concentration due to earlier observed effects!

Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

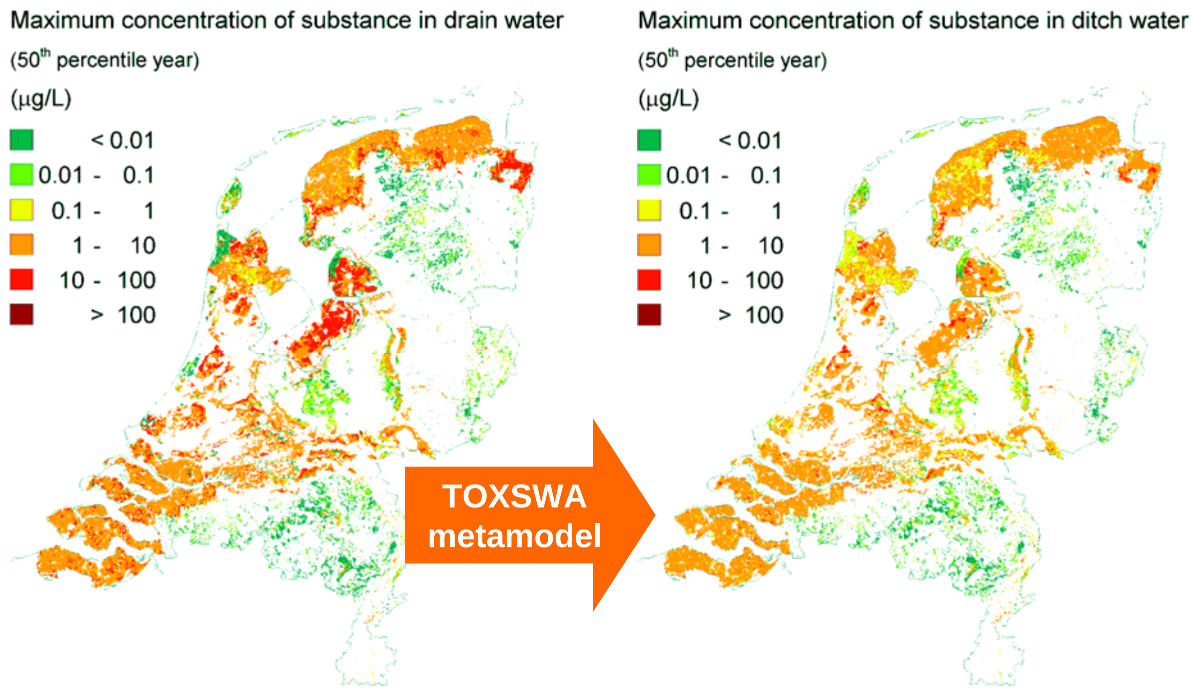
Scenario selection: we need the 90th percentile concentration in the ditch

- A metamodel of TOXSWA, which calculates dilution of the drainpipe concentration based on:
  - Initial ditch volume
  - Daily volume of drainflow from the upstream catchment
  - Daily volume of drainflow from the adjacent field

- Drainage flux of 2 mm/d sufficient to refresh entire volume in small ditches

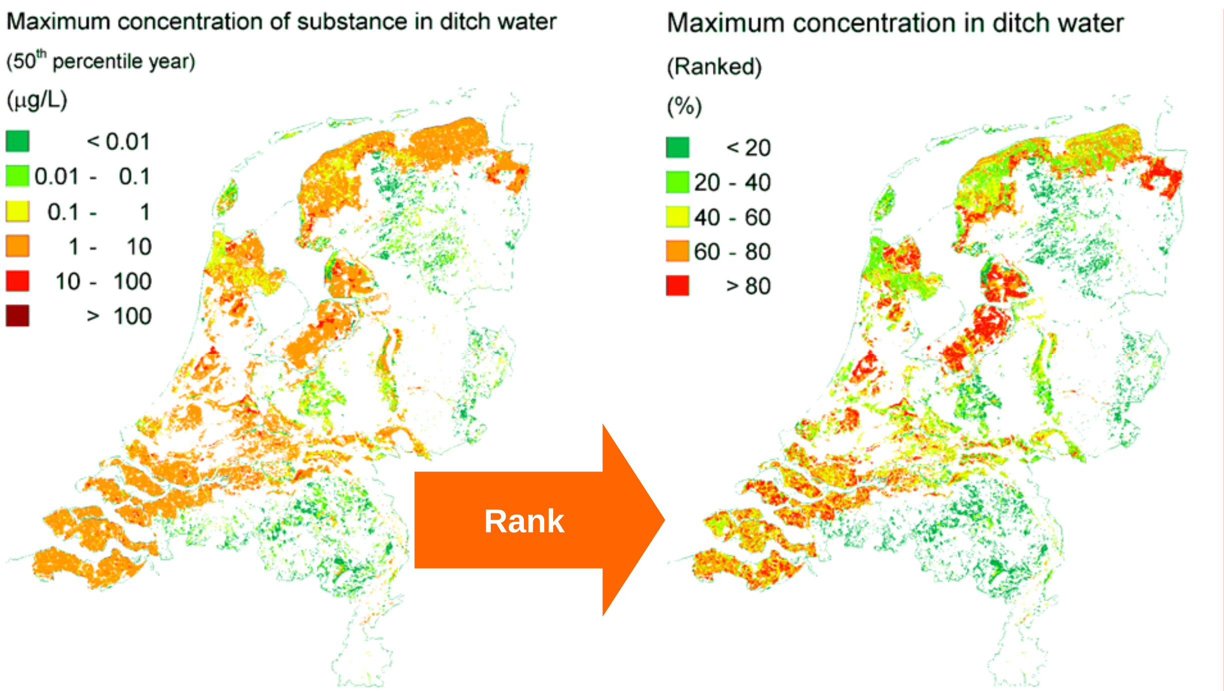


Peak concentration in ditch water



Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

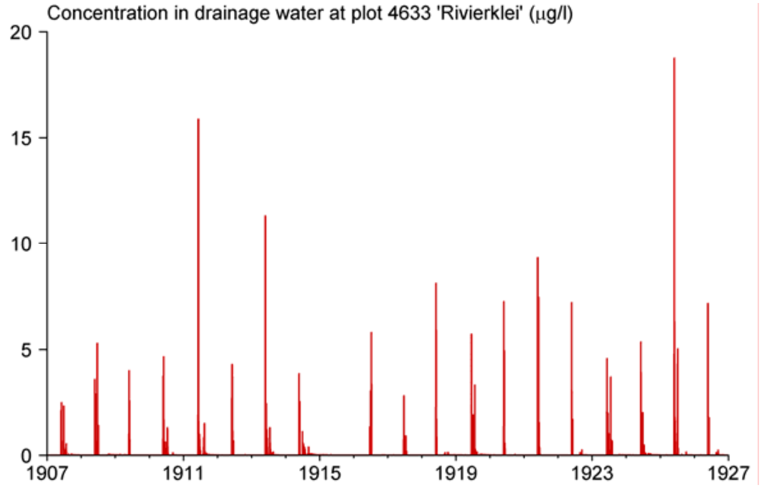
Scenario selection: rank the concentrations



Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

Both spatial variability and variability between years is important

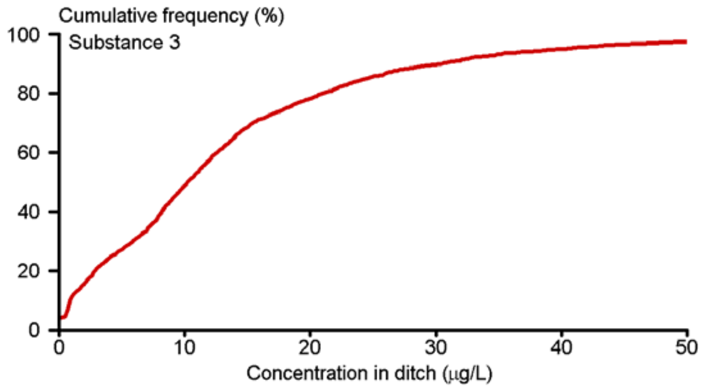
- 20 annual maximum concentrations simulated (weather series according to FOCUS ground water, including six warm-up years)



- For the previous example maps, we used the median value (i.e. mean of 10th and 11th highest year)

Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

In the scenario selection procedure, we use an overall frequency distribution



- Line exists of 20 (number of years) x 6405 (number of scenarios) points.
- GeoPEARL was run for multiple pesticides.
- The selected scenario conforms the approximate 90th overall vulnerability for all pesticides.

Kom = 50 L/kg; DegT50 = 50 d; 1 kg/ha annually

Main conclusions

- A series of pedotransfer functions could be developed to fully parameterise the preferential flow version of GeoPEARL.
- The pesticide peak concentration is highest in clay soils and is caused by rapid drainage through the main bypass domain.
- Water enters the macropores through runoff and upward seepage. For this reason, there is a weak relationship between drainage volume and the peak concentration.
- A drainage flux of 2 mm d^{-1} is sufficient to refresh the entire volume in small ditches. In these cases, the maximum concentration in ditches is equal to the concentration in drain water.

Main conclusions

- Because of the complex behaviour of pesticides in soils, spatially distributed models are indispensable tools to find worst-case locations used in pesticide authorisation.
- Because of the importance of the lower boundary flux, this model should have a link with a regional-groundwater model.
- A robust scenario selection procedure accounting for spatial variability and variability between years has been developed.

Netherlands Environmental Assessment Agency

More information at

http://www.pearl.pesticidemodels.eu

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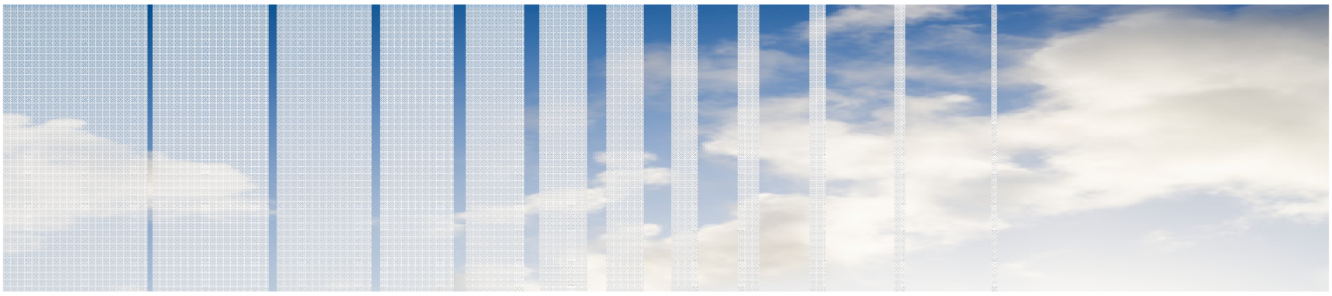
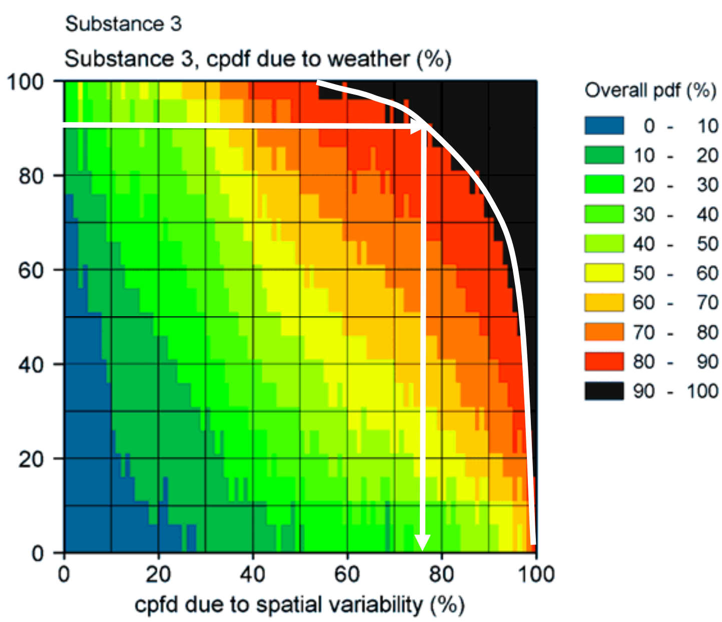


Overall 90th percentile results from variability in weather and spatial variability



- Many options available!