Uncertainty Analysis of the GeoPEARL Pesticide Leaching Model

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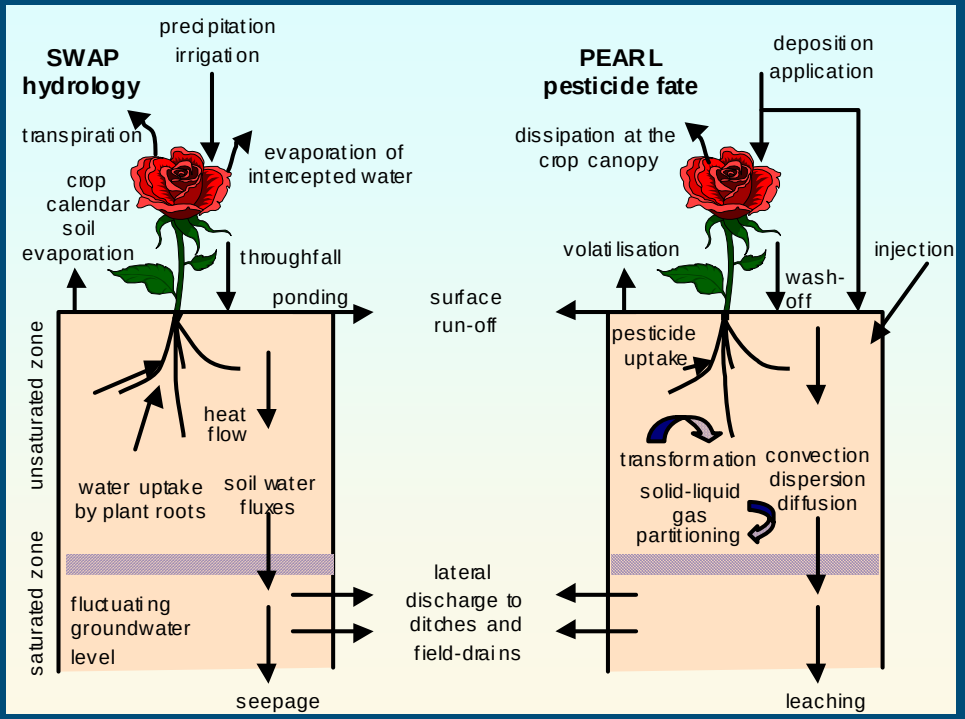
The GeoPEARL model

- 1D-model describing the fate of pesticides in the soil-plant system
- Calculates drainage of pesticides into surface water and leaching to groundwater
- Applied at grid nodes to create spatial images
- Used to verify the Dutch Pesticide Authorisation procedure



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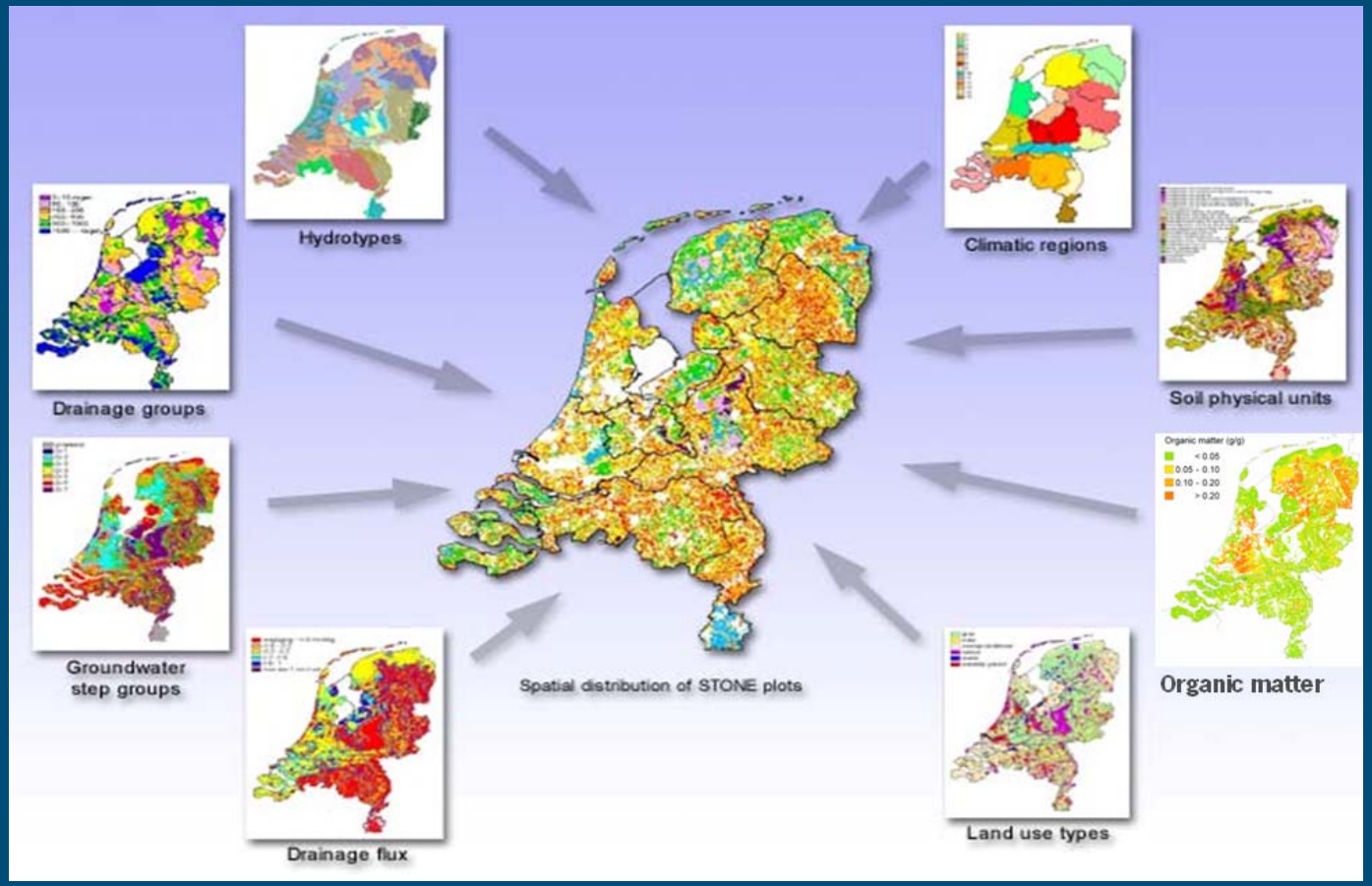
GeoPEARL has many inputs, mainly soil, landuse, climate and hydrology



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Why uncertainty analysis of GeoPEARL?

- Authorities must know how accurate the results of the model are if these results are to be used in legislation and policy making
- Information about uncertainty can be used to take better decisions (i.e., risk analysis)
- It provides insight into how best to improve results or save costs without deteriorating the results

This study

- Considered only the propagation of uncertainty in soil and pesticide properties (for three characteristic pesticides, named A, B and D)
- Used a Monte Carlo simulation approach
- Also quantified the contribution of individual error sources to the output
- Model output is defined as the 90 percentile of the spatial distribution of the temporal median of the leaching concentration at 1m depth

Uncertain soil properties

For each horizon:

- Thickness – *truncated normal, parameters derived from Soil Information System (SIS)*
- Texture – *triplet {clay-silt-sand}, truncated normal, parameters from SIS, cross-correlated*
- Organic matter content – *truncated lognormal, parameters from SIS*
- Hydraulic conductivity – *random sampling from Staring series per soil type*
- Water retention characteristic – *random sampling from Staring series per soil type*

Uncertain pesticide properties

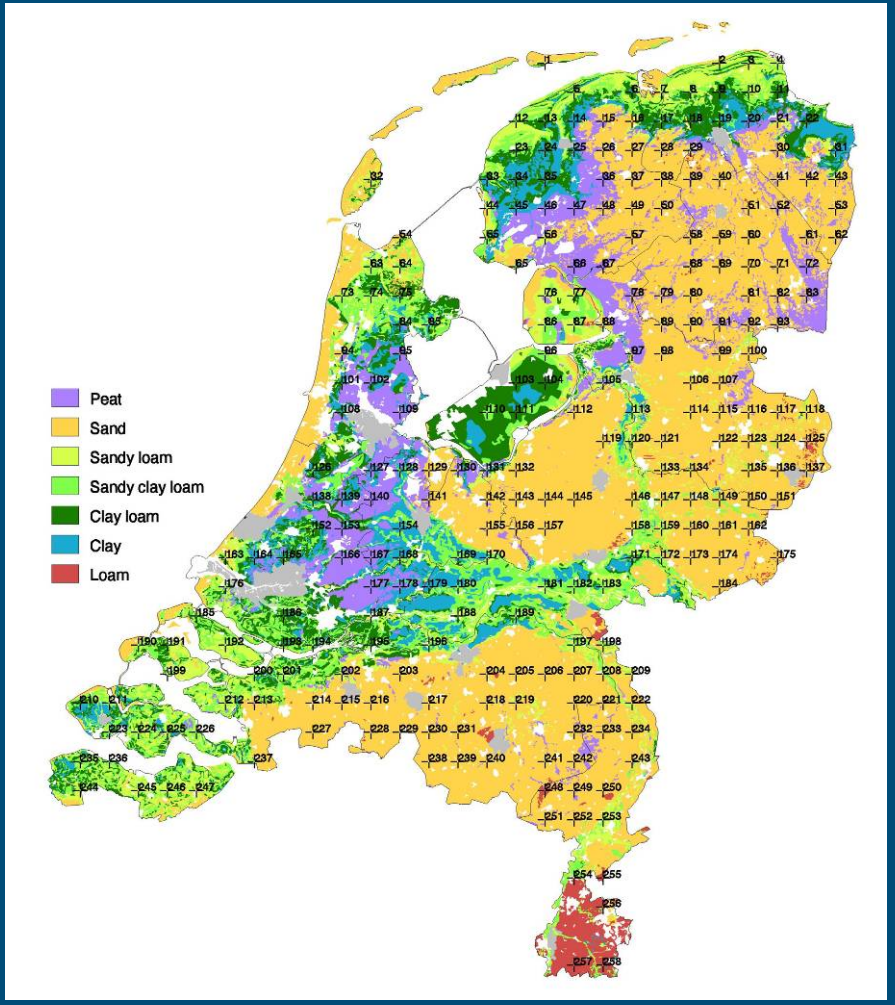
- Half-life of transformation in soil – *lognormal, parameters from literature*
- Coefficient of sorption on organic matter – *lognormal, parameters from literature*

Summary of Monte Carlo method

- Repeat many times (in our case 1000 times):
  - Simulate a possible reality from the probability distribution of the uncertain inputs
  - Run model with simulated input and store result
- Compute and report statistics of the stored results (e.g. mean, standard deviation, proportion that exceeds critical threshold)

Systematic spatial sample of 258 grid points

- Sampling error was considered negligible (but this was not checked!)
- At each point 1000 Monte Carlo runs of GeoPEARL
- Next 90 percentile (P90) of 258 GeoPEARL outputs computed for each of the 1000 runs
- Variability in the 1000 P90 values conveys uncertainty about true P90



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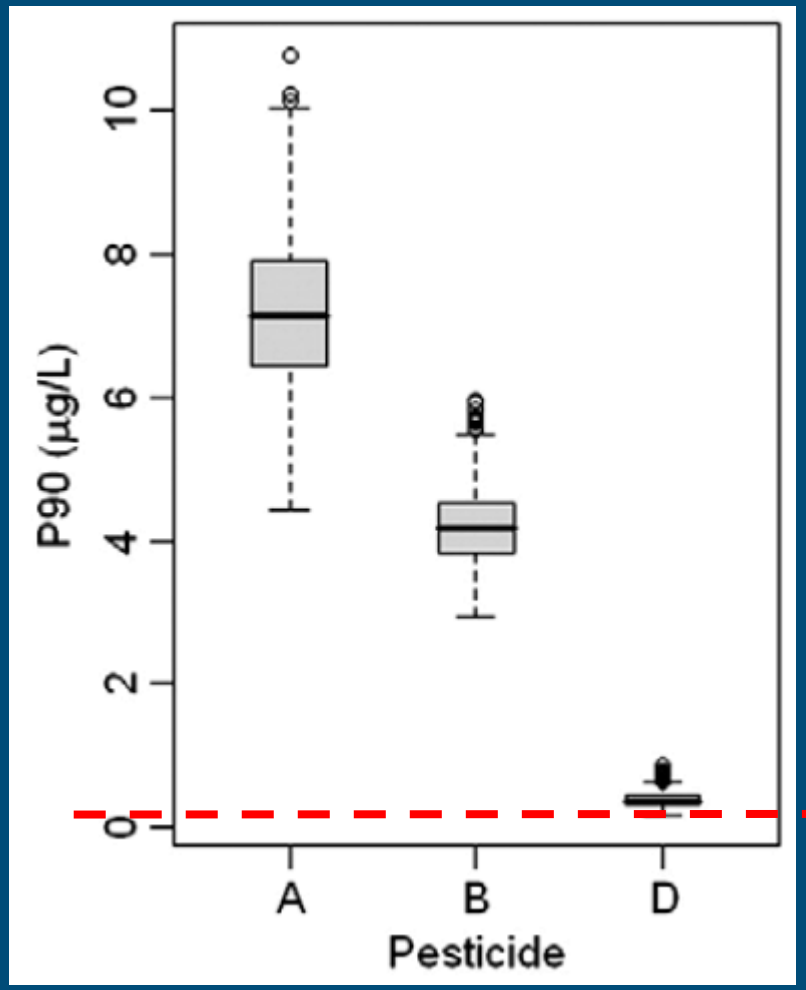
Results: uncertainty in GeoPEARL output

- Large uncertainty in P90, particularly for substance A
- Box-plots all above regulatory limit of 0.1 $\mu g \cdot L^{-1}$
- Reject all three pesticides with certainty



1000 Monte Carlo runs was sufficient

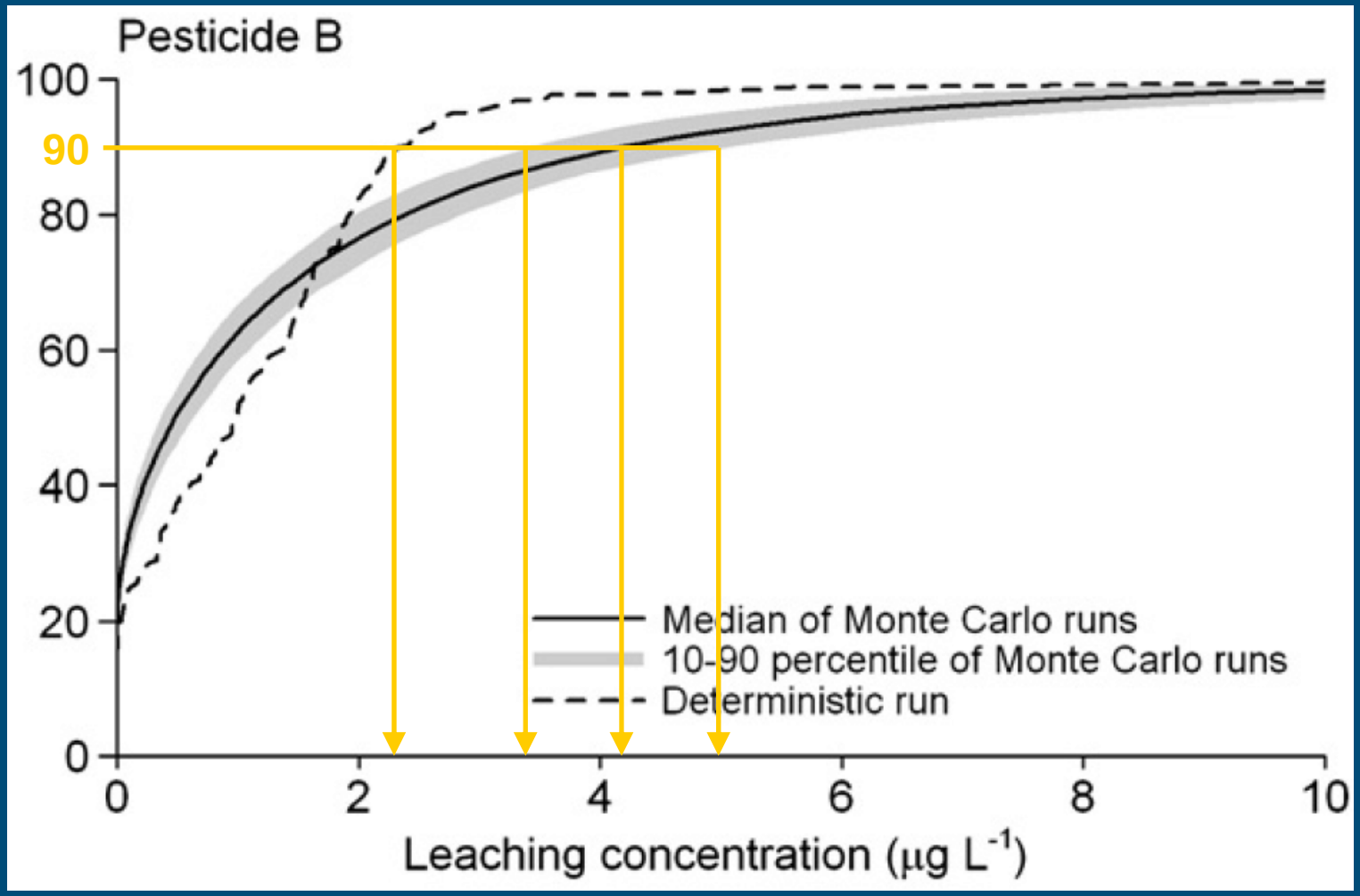
$$var(m_{P90}) = \frac{\sigma^2_{P90}}{N}$$

$$var(S^2_{P90}) = \frac{1}{N}\left(\tau^4_{P90} - \sigma^4_{P90} \cdot \frac{N-3}{N-1}\right)$$

Table 2
Estimated mean and variance of P90 and associated sampling error standard deviations.

Pesticide	Mean of P90 (µg/L)		Variance of P90 $(\mu g/L)^2$	
	Mean	$\widehat{SD}$	Mean	$\widehat{SD}$
A	7.168	0.033	1.063	0.045
B	4.202	0.016	0.258	0.012
D	0.3922	0.0034	0.0119	0.0007

Including uncertainty causes a systematic shift in P90



What is the main source of error?

Percentage variance explained by uncertain inputs

	Organic matter	Other soil properties	Half-life	Sorption
Substance D	0	0	60	20
Substance A	7	1	54	41
Substance B	7	0	87	10

Conclusions

- Uncertainty in 90 percentile of the spatial distribution of pesticide leaching concentration is very large
- However, when the regulatory limit of 0.1 $\mu g \cdot L^{-1}$ is used, then uncertainty does not impair decision-making
- Pesticide properties (notable the half-life) are a much greater source of uncertainty than soil properties
- Accuracy improvement of GeoPEARL output must be achieved by reducing the uncertainty about pesticide properties
- Reducing uncertainty about pesticide properties is difficult because this requires extensive experiments and modelling of the interaction between soil and pesticides

Thank you

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