Risk Assessments and Mass Balances

Andreas Huber, Environmental Safety and Exposure Assessments, Basel

How to Evaluate Environmental Exposure ?

Potential uses of a compound

- Greenhouse vegetables, foliar
- In-furrow applications
- Broadcast application to paddy rice
- Seed treatment
- Application with drip irrigation
- Stem paintings
- etc.....

Is the compound safe under worst-case conditions ?

Risk Assessment

What is the total exposure of environmental compartments associated with normal use of the compound ?

Mass Balance

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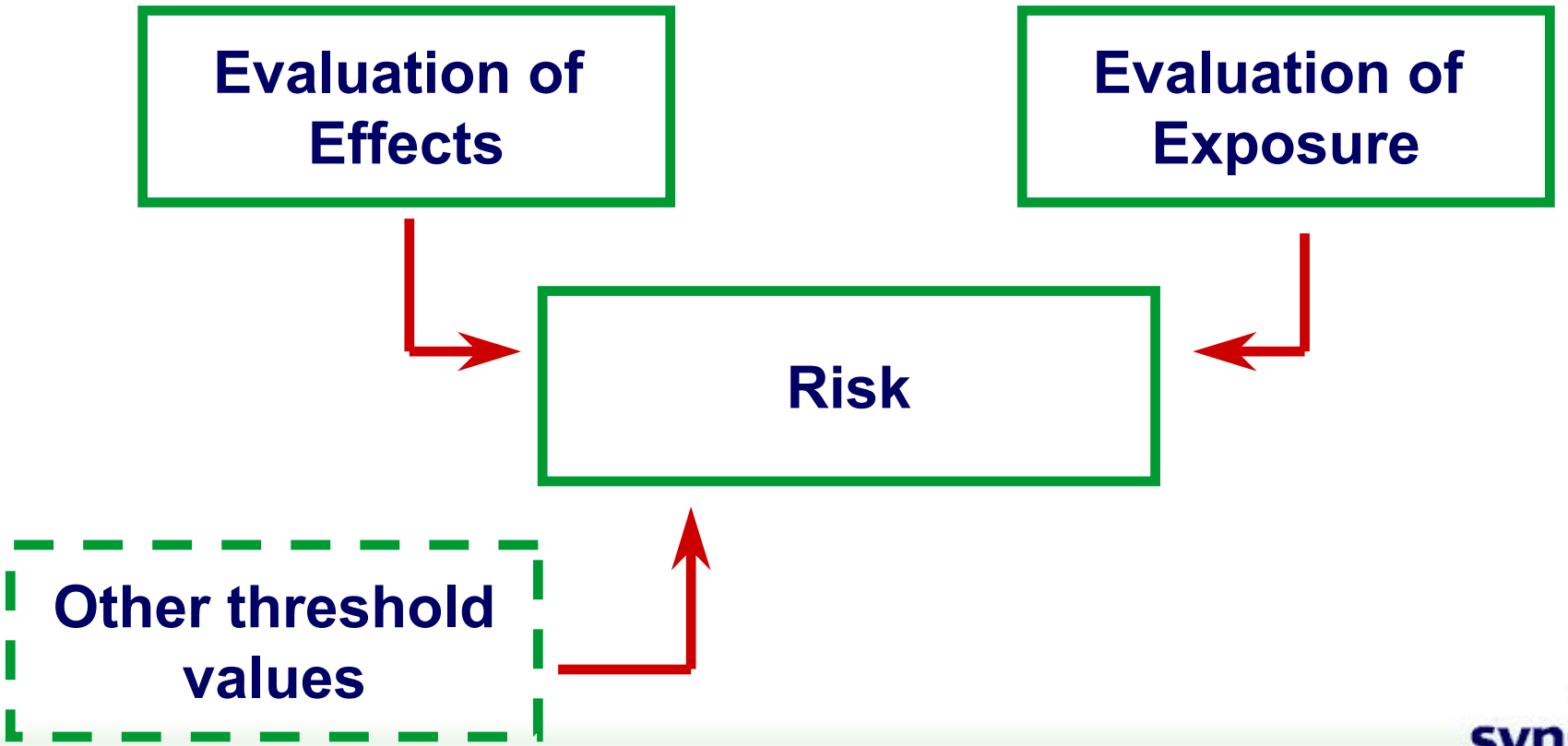
The principle of risk assessments

- The prediction of risk for different environmental compartments is a crucial part of the registration process for active ingredients in OECD countries



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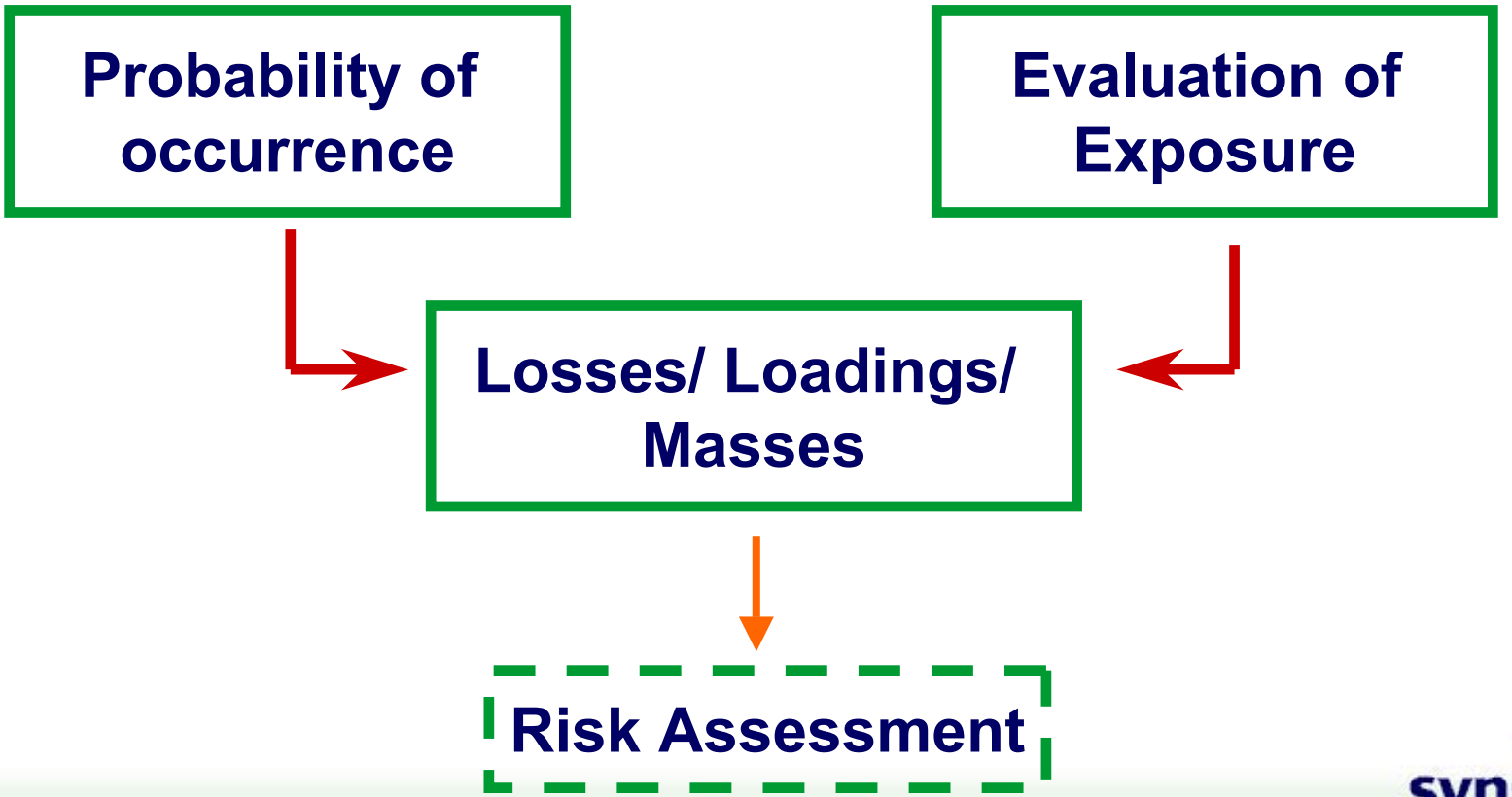
The principle of mass balances

- A mass balance aims to elucidate the real exposure of environmental compartments in relation to the use of an active ingredient



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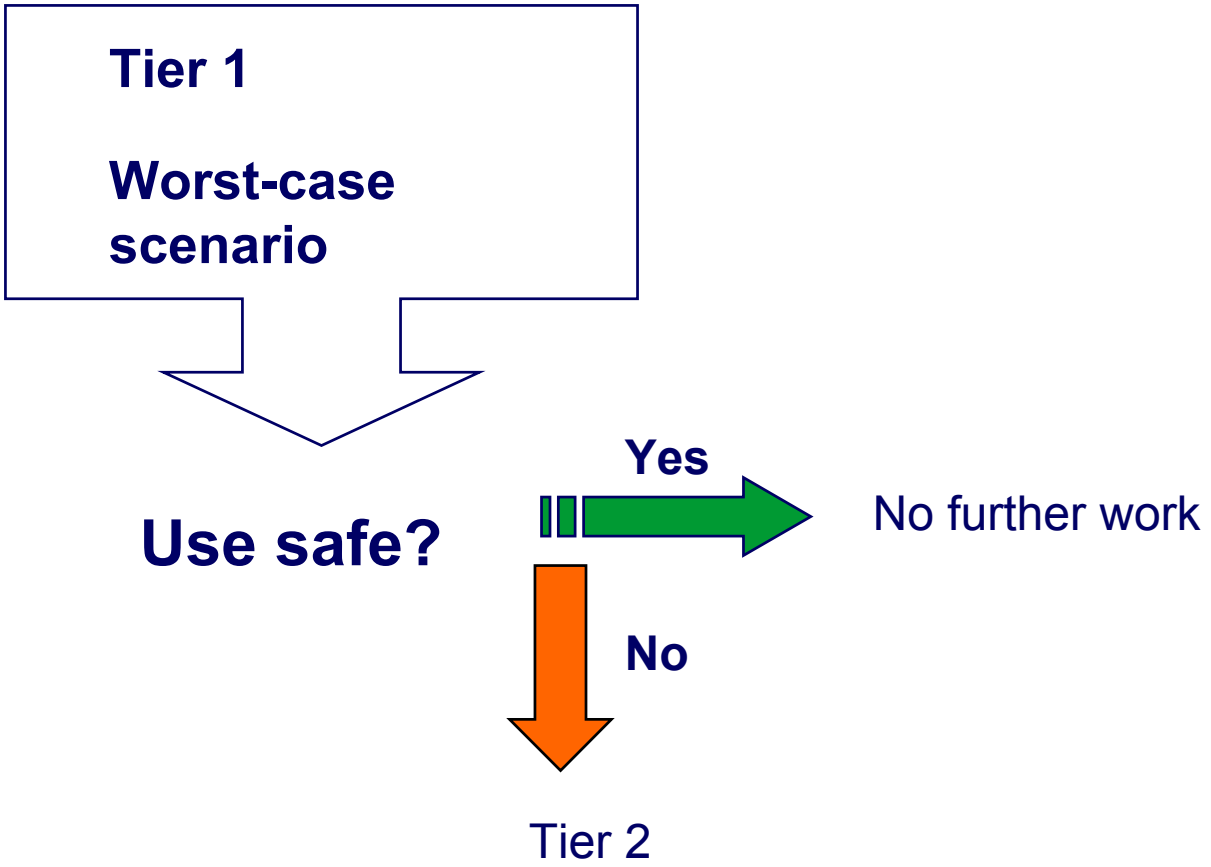
Examples for Risk Assessments (1)

- Surface Water

Assessment of surface water exposure

Idealized worst-case scenario with a large margin of safety



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Example for Tier-I assessments: UK drainage model

If K_{OC} < 74 => **1.9 %** of applied material is lost and further diluted in 130.000 L of drainflow and surface water

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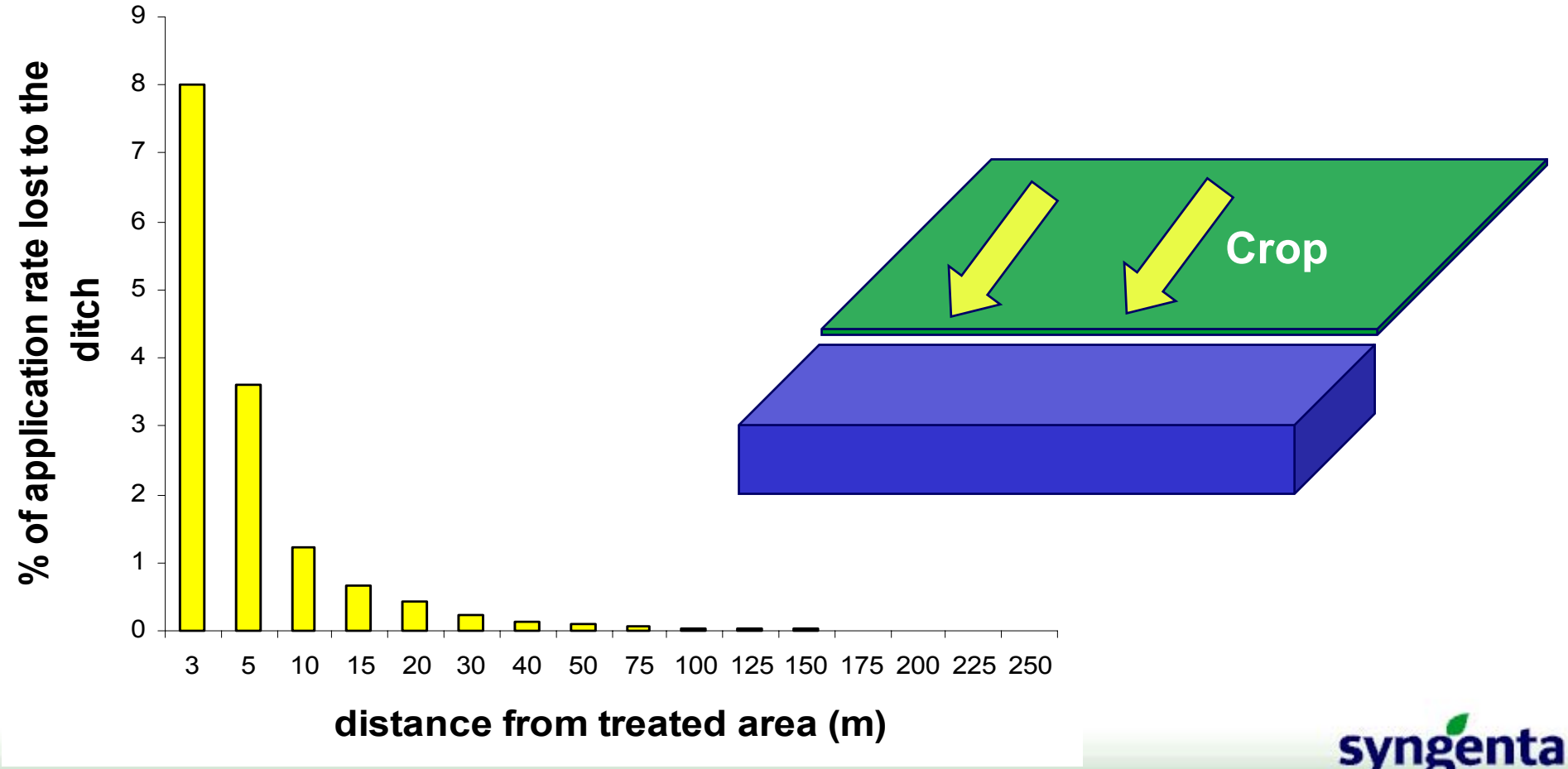
Example for Tier-I assessments: German drift model

Loadings of a ditch with 30 cm depth (example: vinejards)



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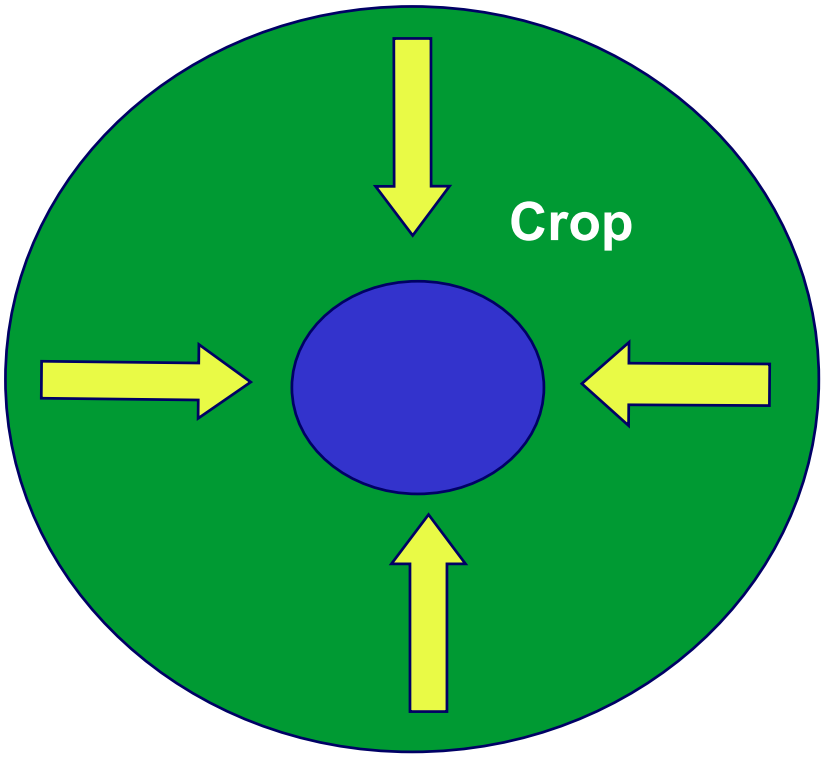
Example for Tier-I assessments: U.S. surface water exposure model

10 % of product applied to a 10 acre field enters a 1 acre pond which is 1.8 m deep



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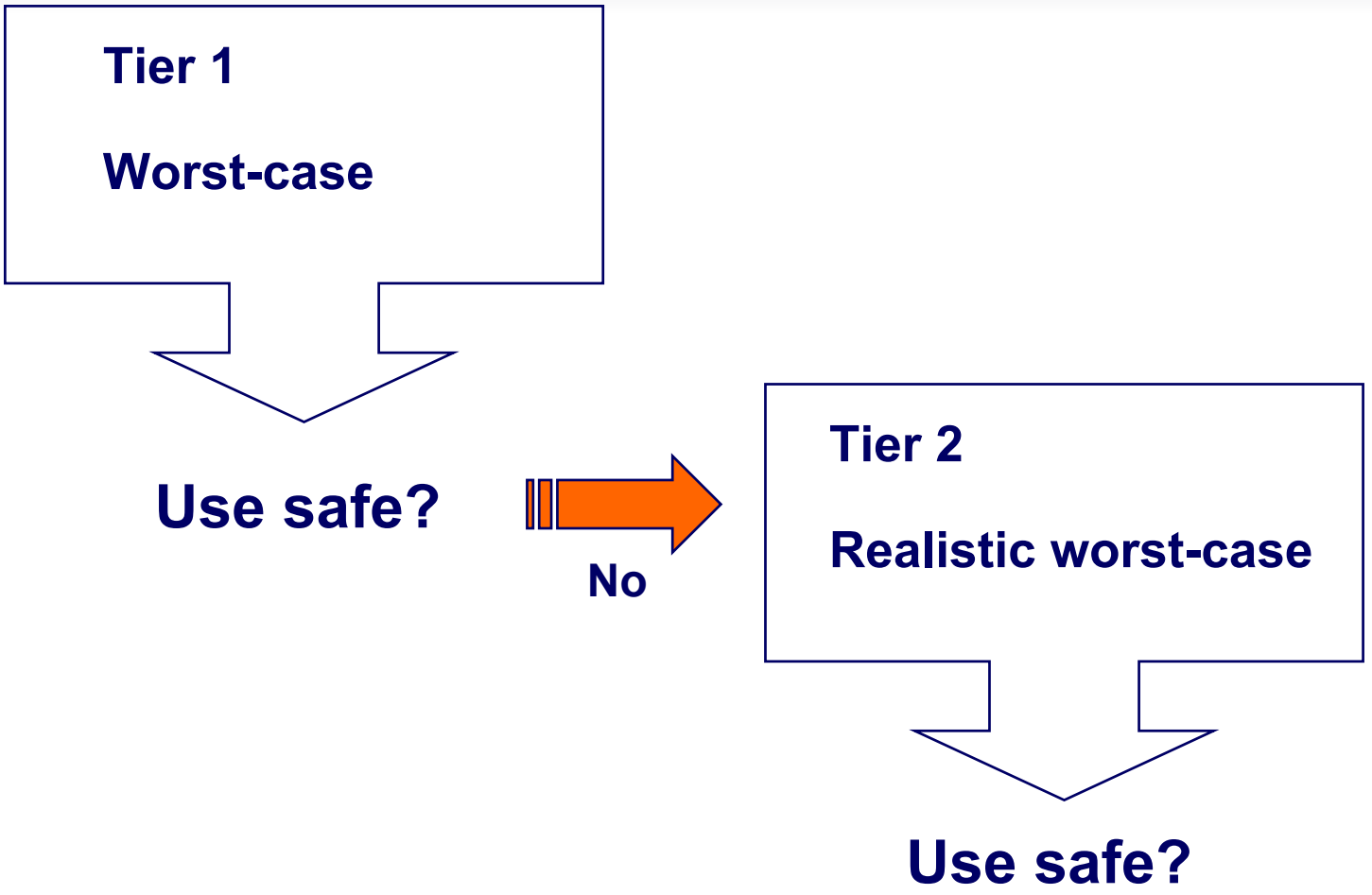
Assessment of surface water exposure: Tier-II



Spatial variation of surface water exposure by spray drift

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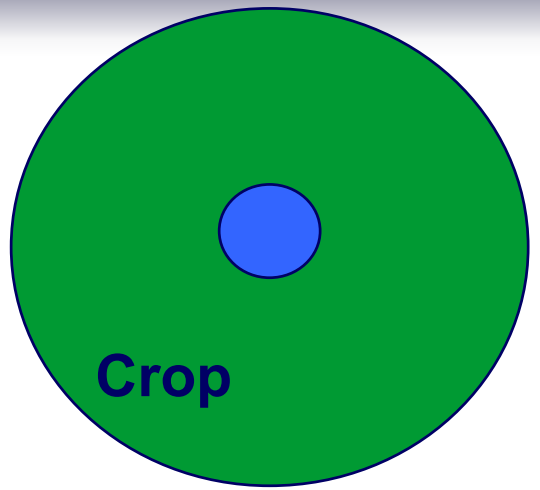
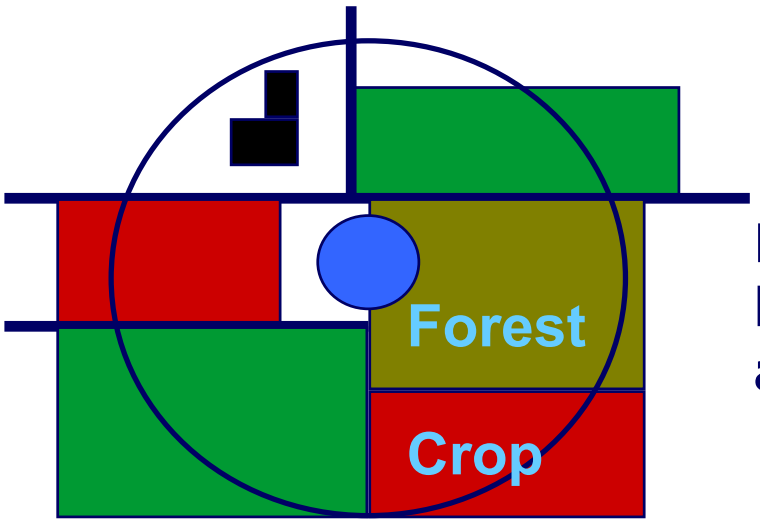
Worst case → Reality

Worst case scenario



→No buffer between crop and water
→100% cropped
→Drift from all directions
→95%ile wind velocity
→90%ile deposition
→No degradation
→All organisms affected

Reality



Models and field studies help to reflect real agricultural conditions.

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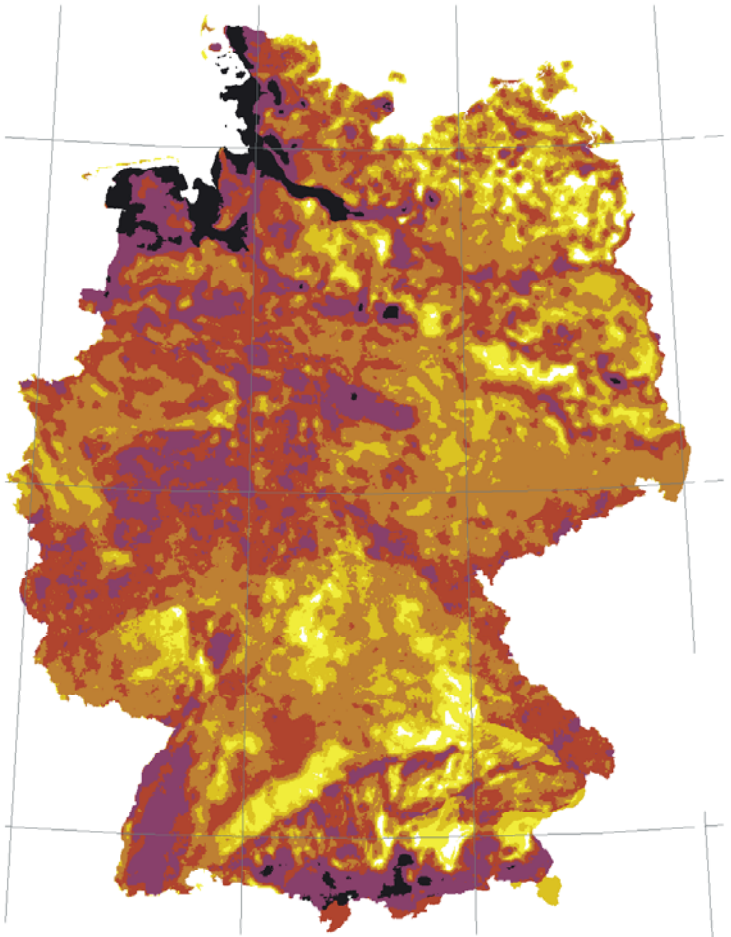
Density of surface water network (km/km^2) in Germany



Drainage Density in Germany

in km km^{-2}

- 0
- 0,01 - 0,45
- 0,45 - 0,95
- 0,95 - 1,70
- 1,70 - 2,65
- 2,65 - 5,00
- > 5,00

sources:
digital data on natural river network (HAD, 1998); various studies in different catchments

200 0 km

N

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"Pollution of Surface Waters with Pesticides in Germany" a project funded by the Federal Environment Agency, Berlin
(project no. 107 01 34)

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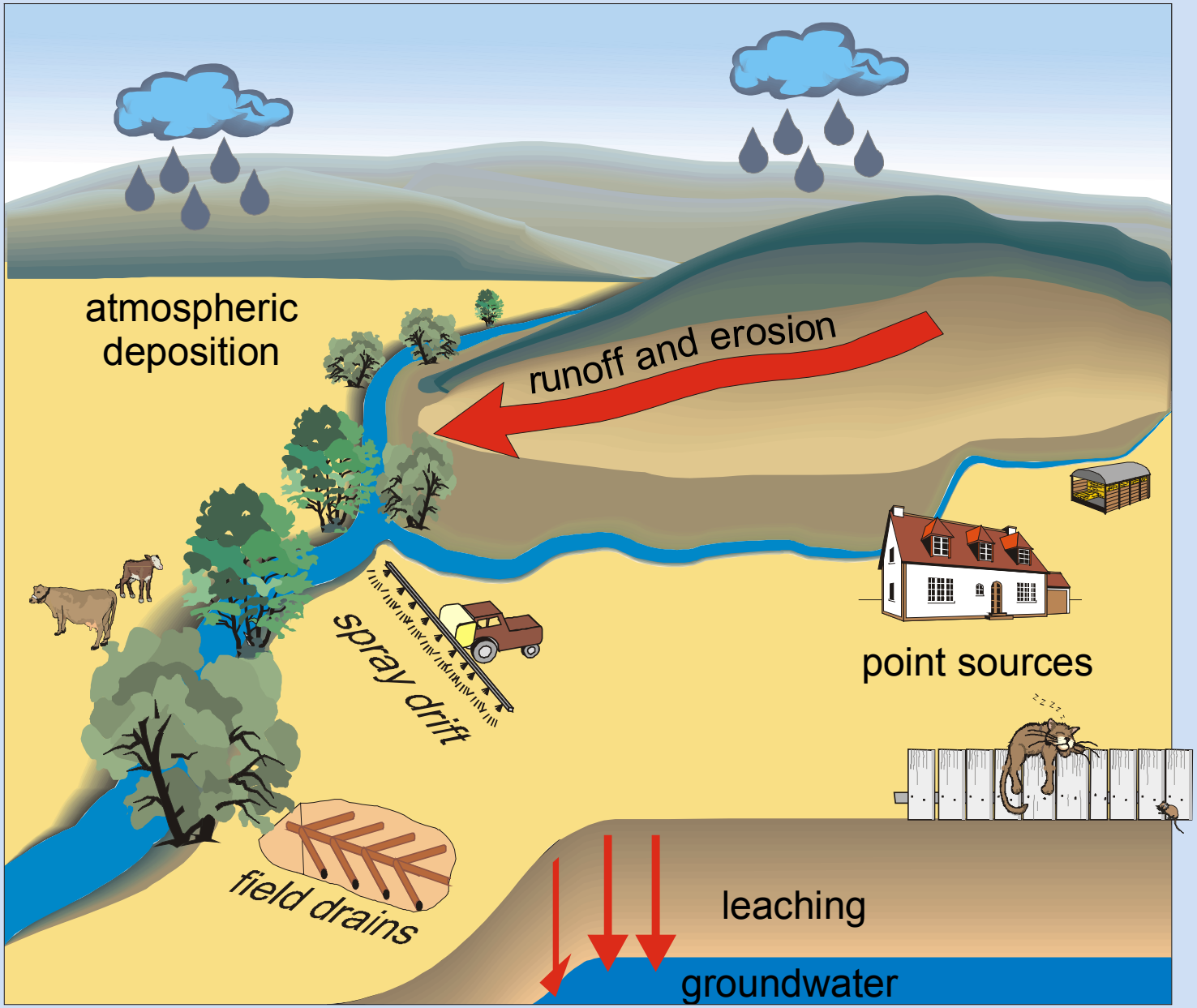
Potential Paths of Entry into Surface Water



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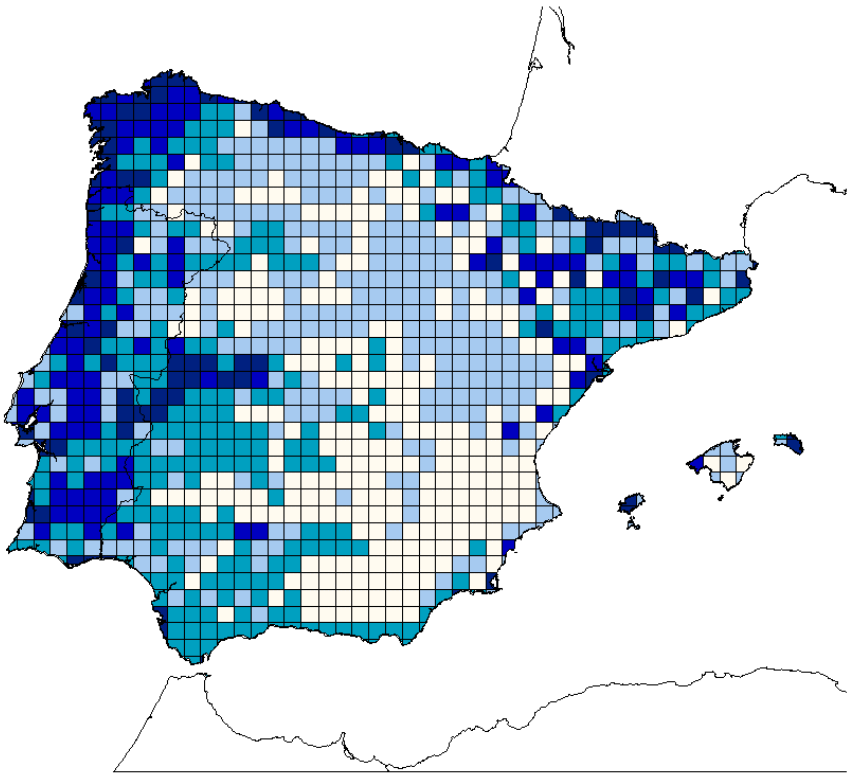
Identification of a realistic worst-case situation for runoff and erosion

Probability of occurrence of runoff producing rainfalls

(> 10 mm in 24 h)

Percentiles

- 10th
- 25th
- 50th
- 75th
- 90th



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Identification of a realistic worst-case situation for runoff and erosion

Soils vulnerable towards runoff and erosion

=> Fine textured soils with low infiltration rates, slopes, low organic matter content

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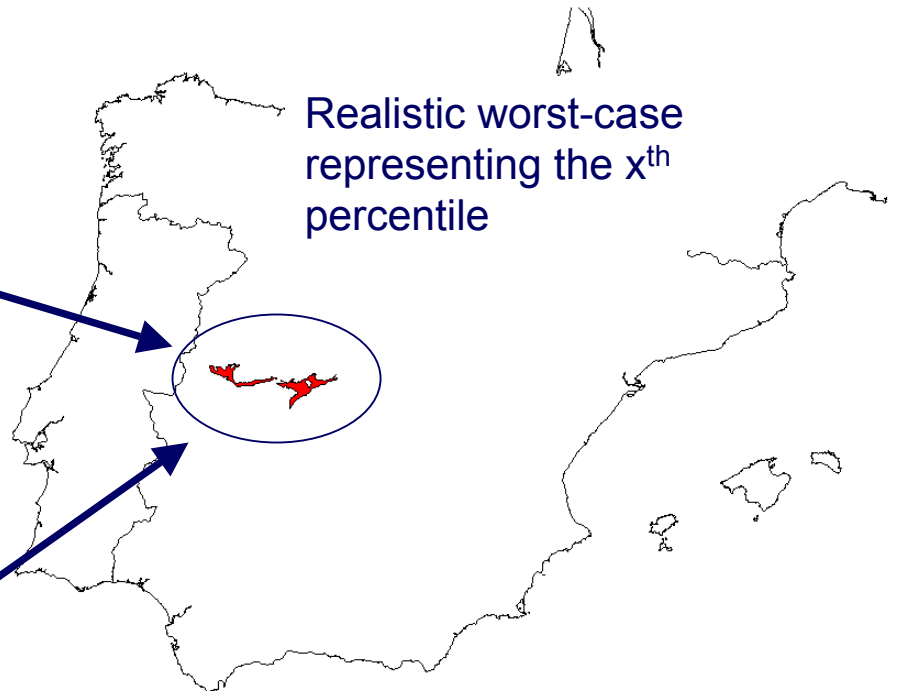
Identification of a realistic worst-case situation for runoff and erosion

Soil properties

Horizon	Sand	Silt	Clay	Organic matter	…
	(%)	(%)	(%)	(%)	…
0 - 30	20	32	48	1.2	…
30 - 50	35	28	37	0.3	…
	…	…	…	…	…

Weather record

Date	Rain	Temp min	Temp max	ETpot	…
	(mm)	(°C)	(°C)	(mm)	…
1/1/1998	0	-2	9	0.3	…
1/2/1998	5.6	5	11	0.8	…
…	…	…	…	…	…



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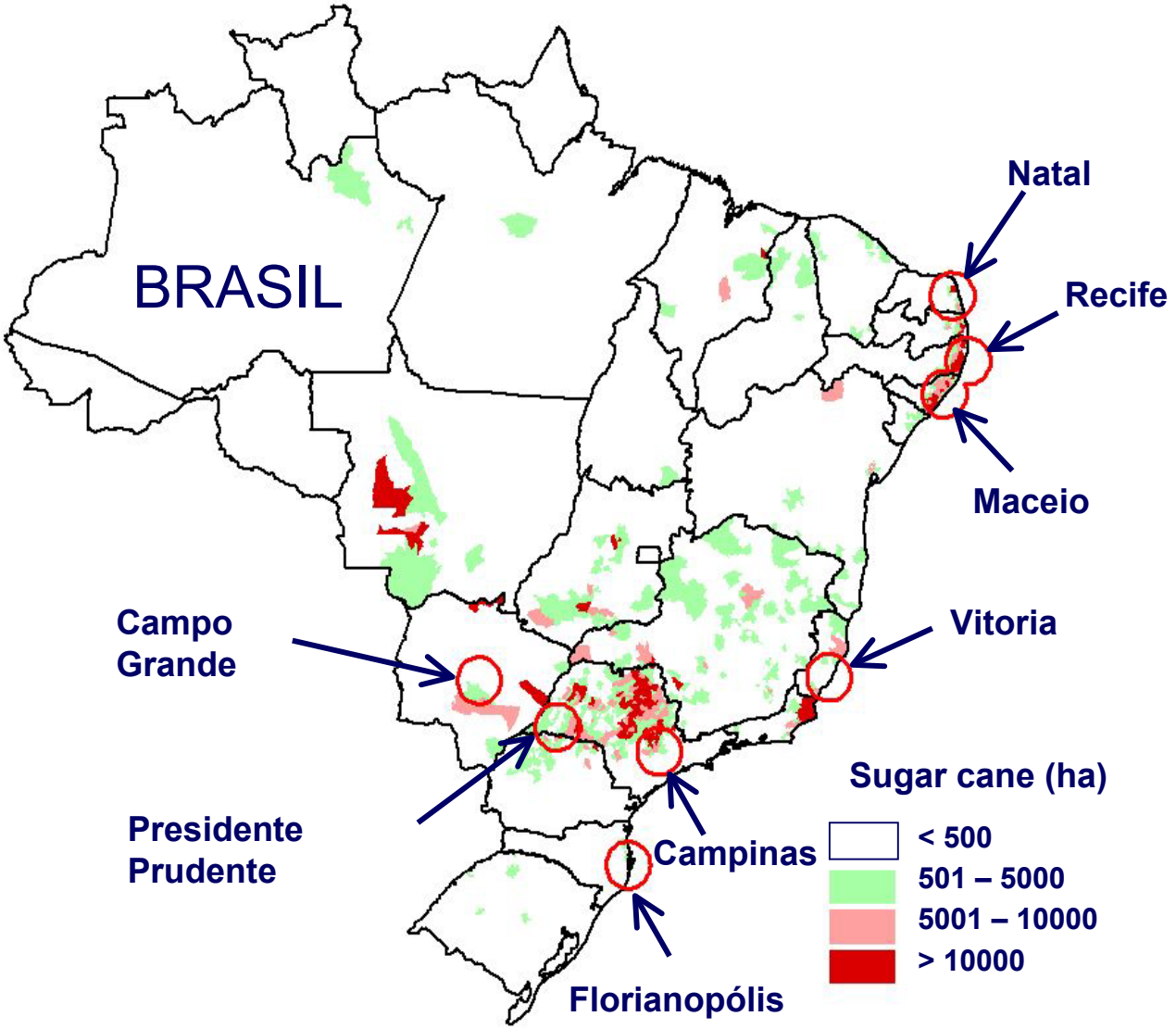
Spatial variation of surface water exposure



- Rainfall re-occurrence probabilities vary from one region to another
- Vulnerable soils might be more frequent in some parts of a country

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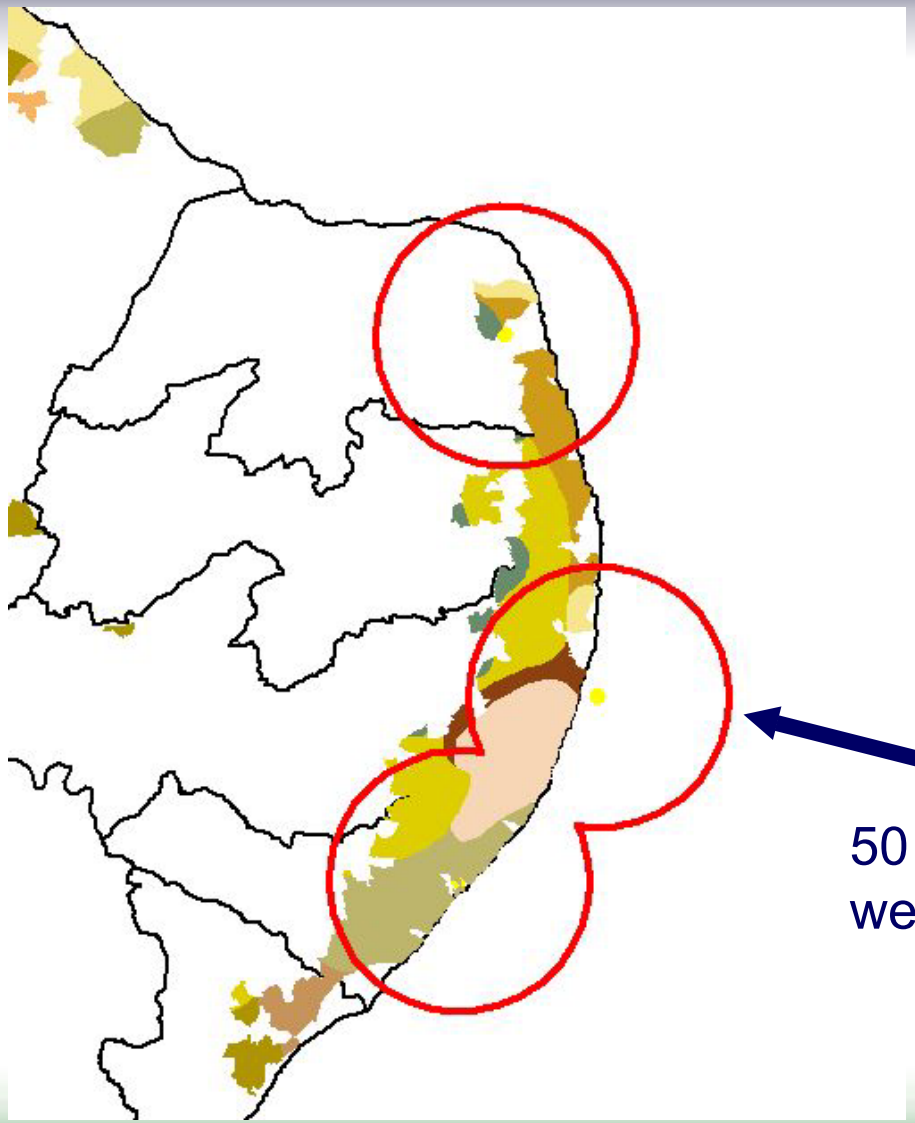
Spatial variation of surface water exposure



Each combination of soil and weather provides a scenario for pesticide loss to a surface water body

50 km radius around weather stations

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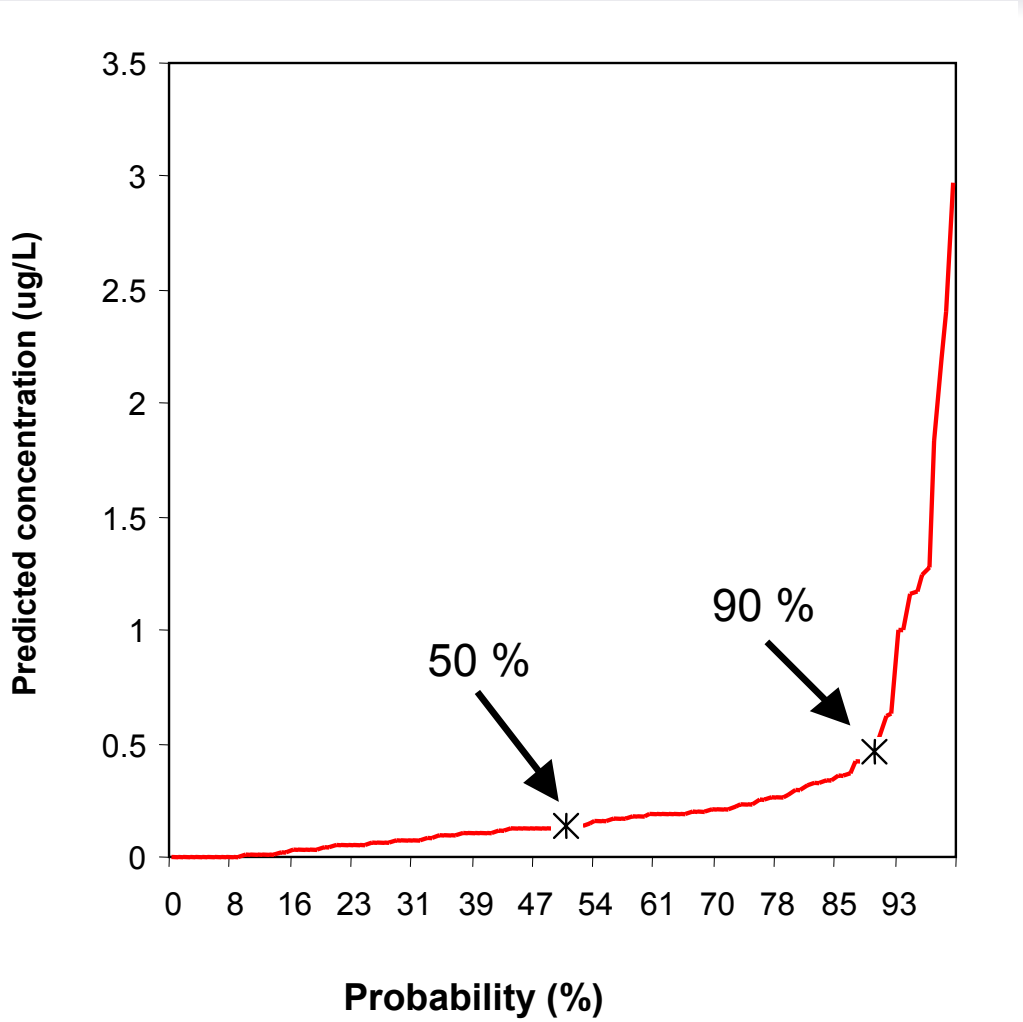
How to assess exposure estimates ?



Variation of surface water exposure with time

Due to the variability of various factors which govern pesticide loss to surface waters the simulations should be carried out for several years

=> Is a critical exposure level exceeded once every 5 years or once every 100 years?

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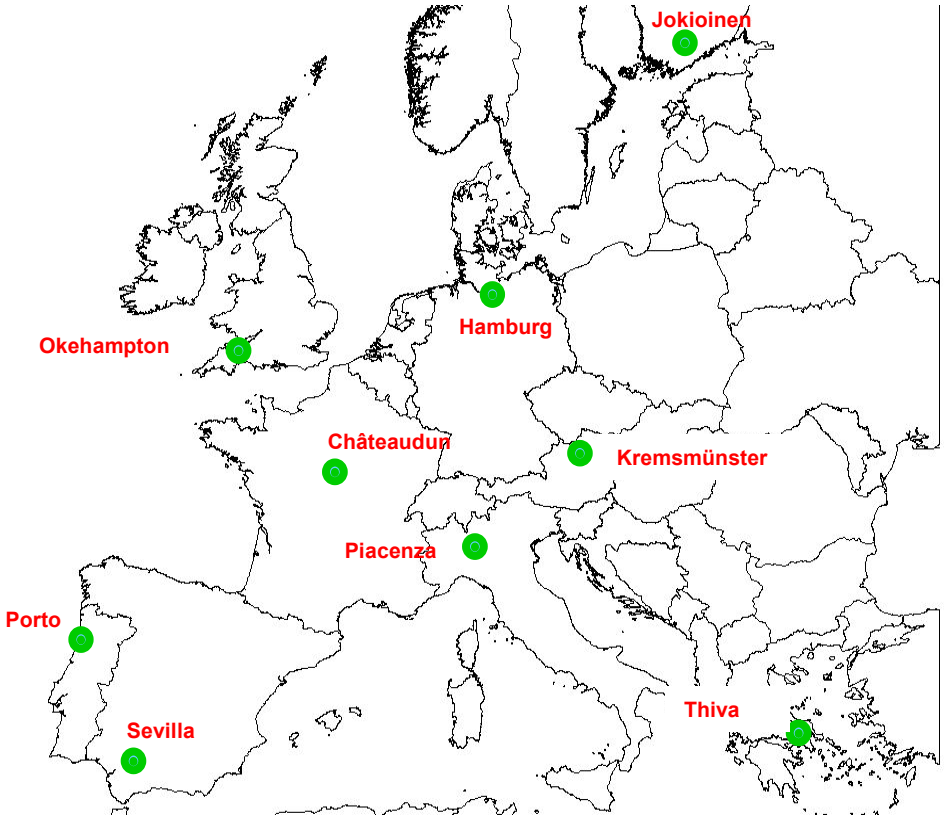
Examples for Risk Assessments (2)

- Groundwater

FOCUS standard scenarios



Requirements for Annex I listing:

„...The FOCUS scenarios collectively represent agriculture in the EU for the purposes of a Tier I EU level assessment of leaching risk ....“

„...scenarios which gave results less that 0.1 µg/L indicate the extent of safe uses.....and could then be used to guide local assessments of leaching risk at the member state level.“

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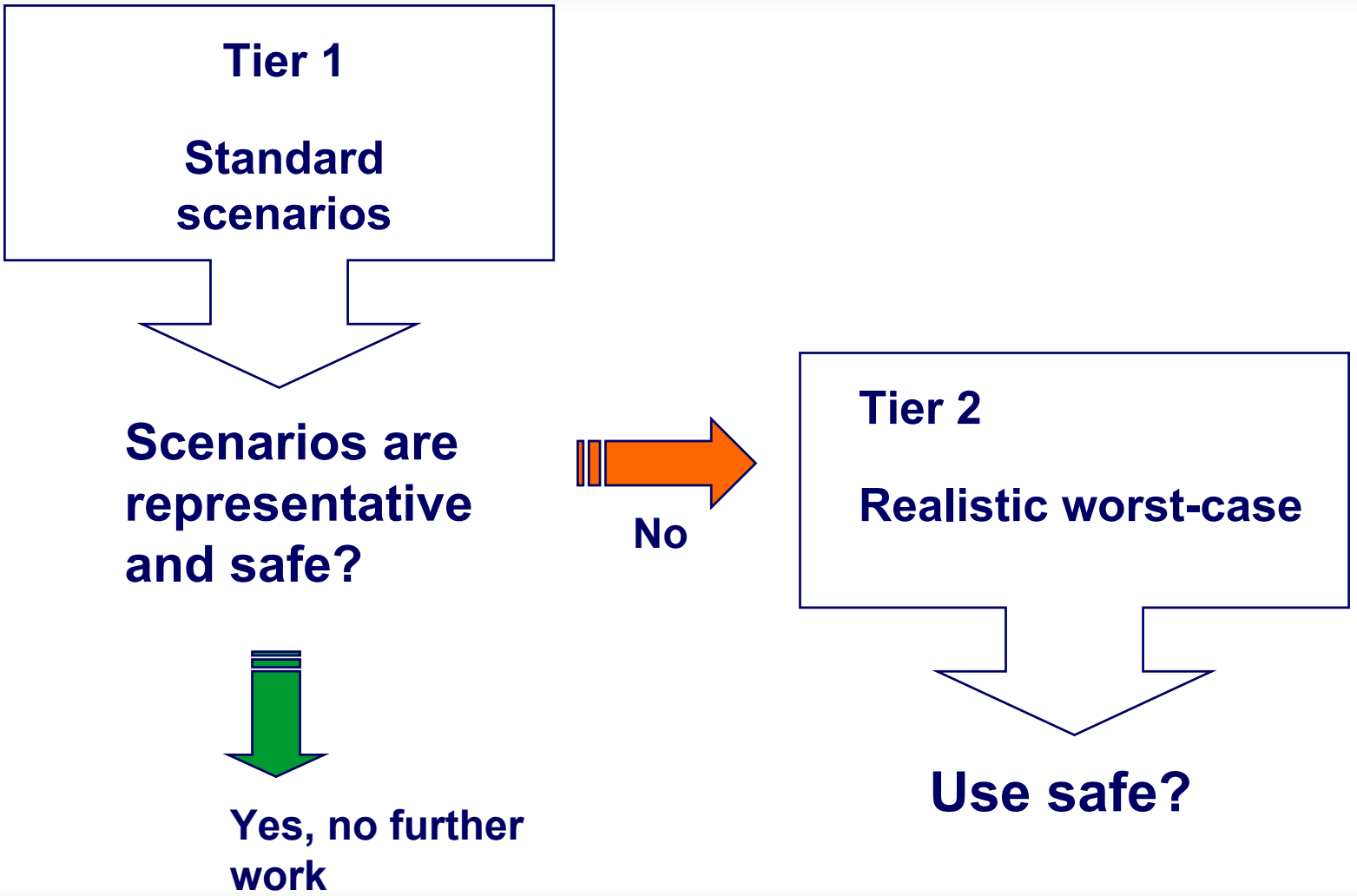
Assessment of groundwater exposure



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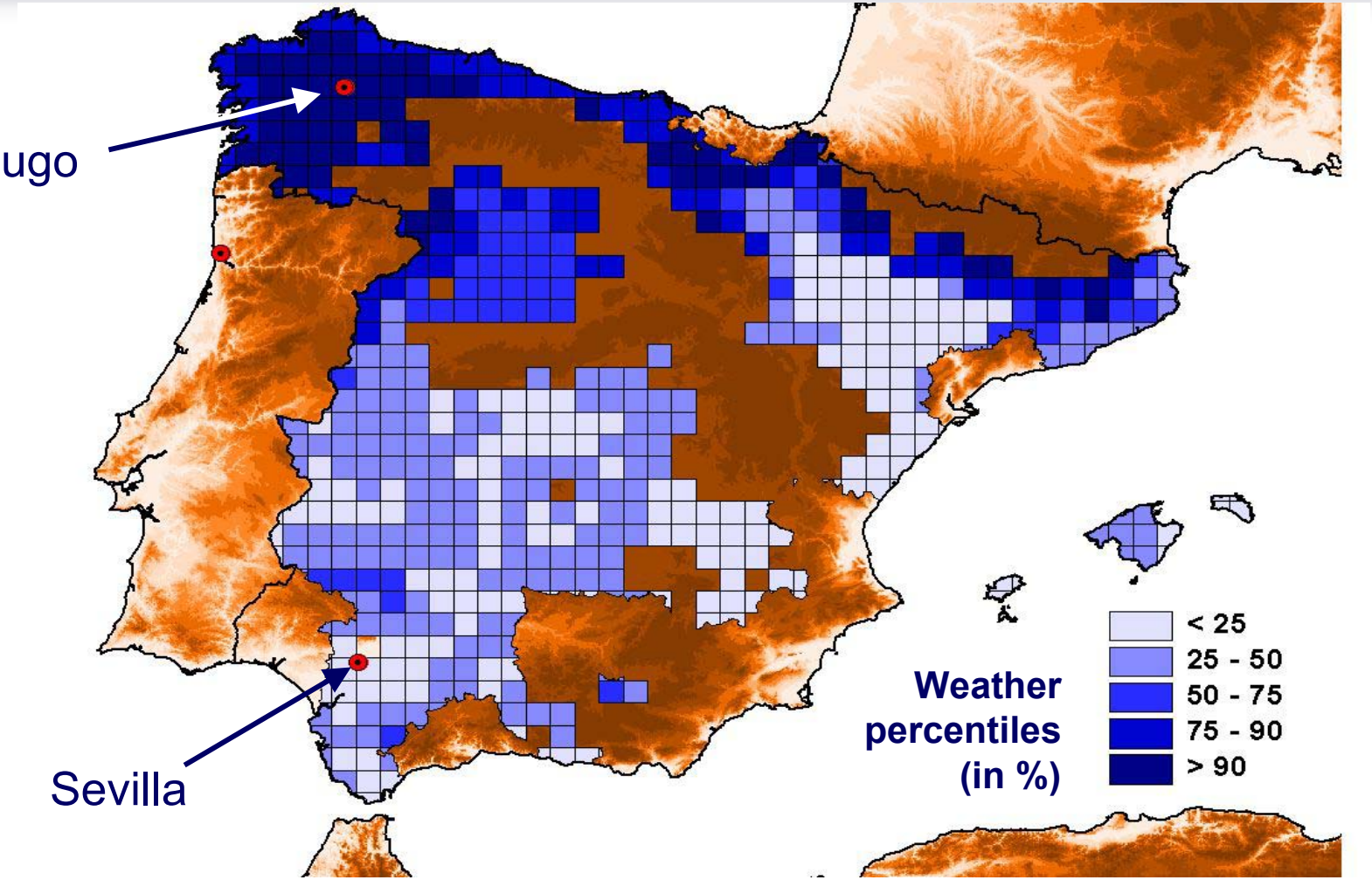
Derivation of realistic worst-case scenarios



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Examples for Risk Assessments (3)

- Soil Persistence

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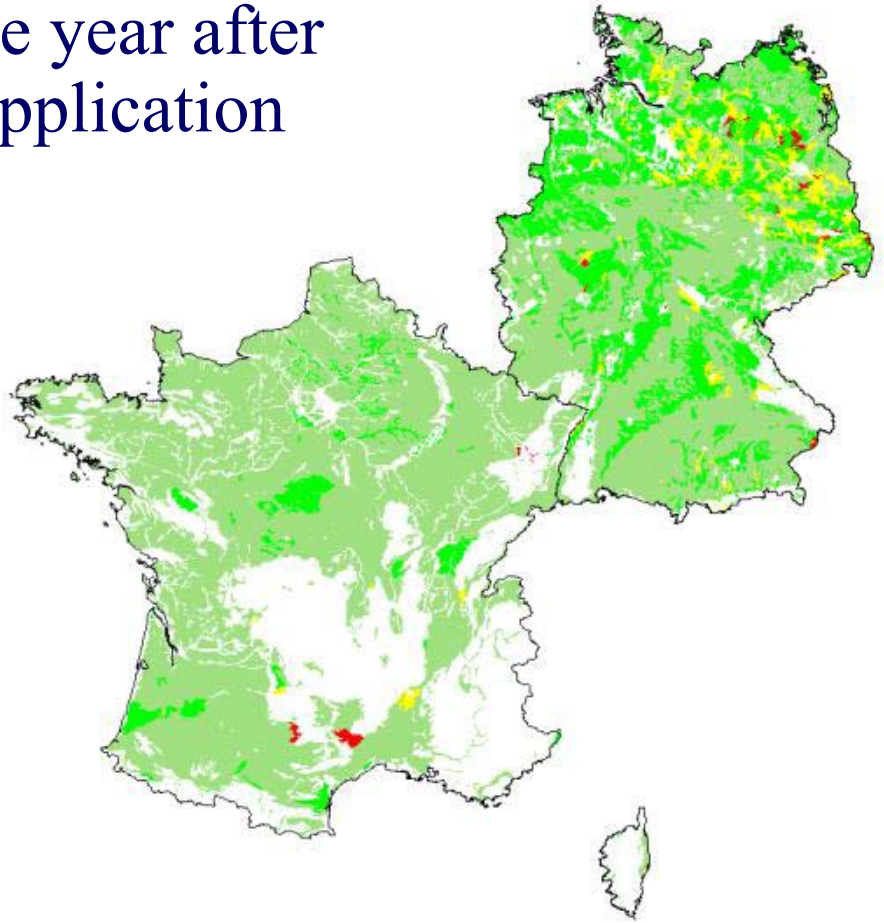
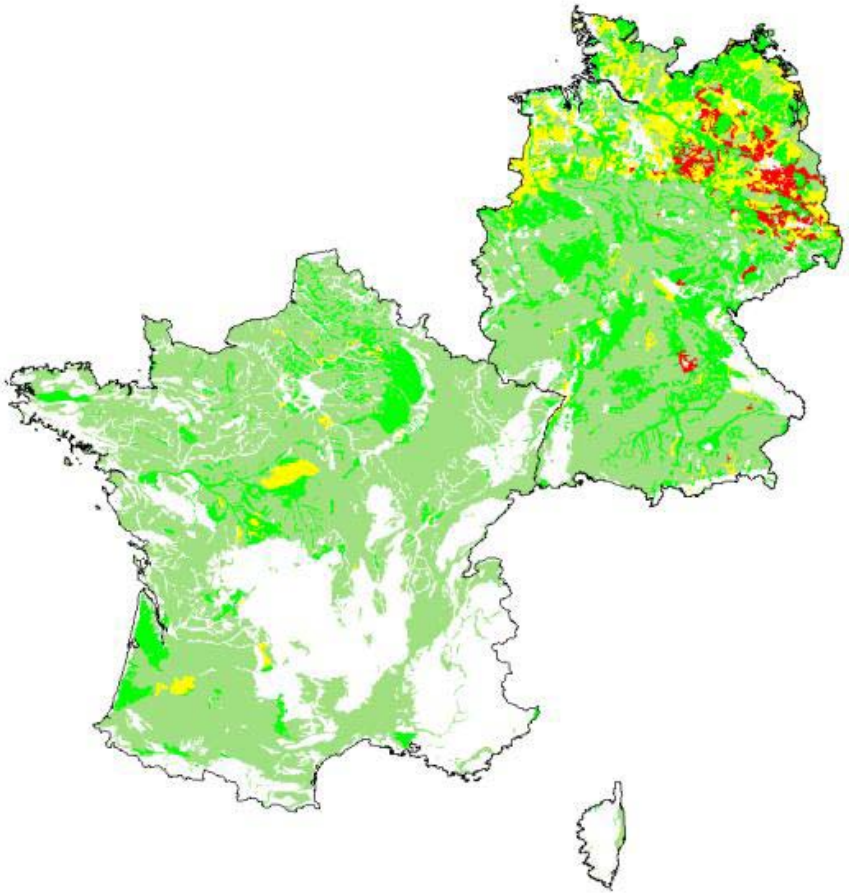
Concentration in topsoil one year after application



application 1996

very low
low
moderate
high



application 1997

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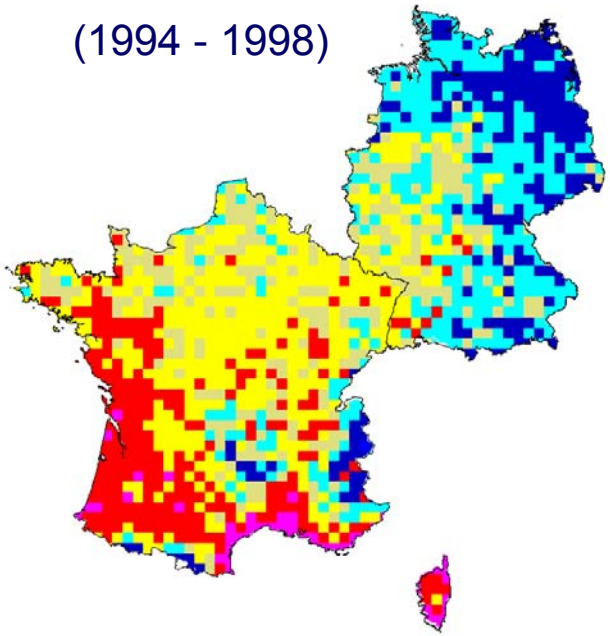
Climatic risk areas for damage to rotational crops

minimum temperature in April

(1994 - 1998)

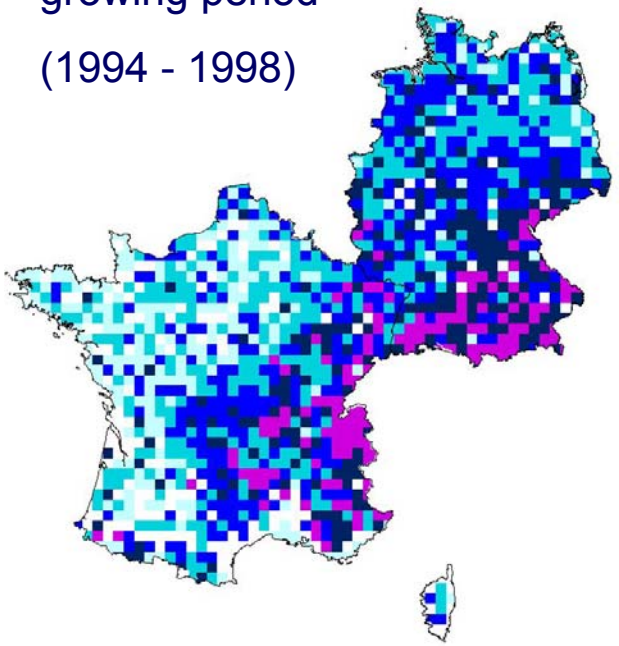


10th percentile

100th percentile

minimum rainfall during growing period

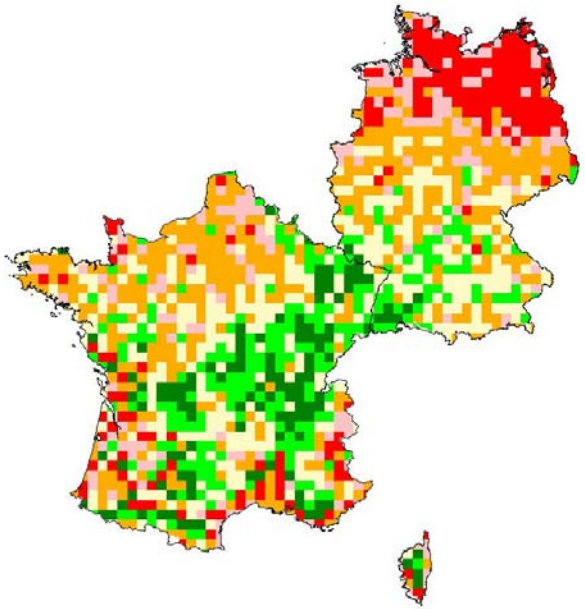
(1994 - 1998)



10th percentile

100th percentile

climatic risk areas



10th percentile

100th percentile

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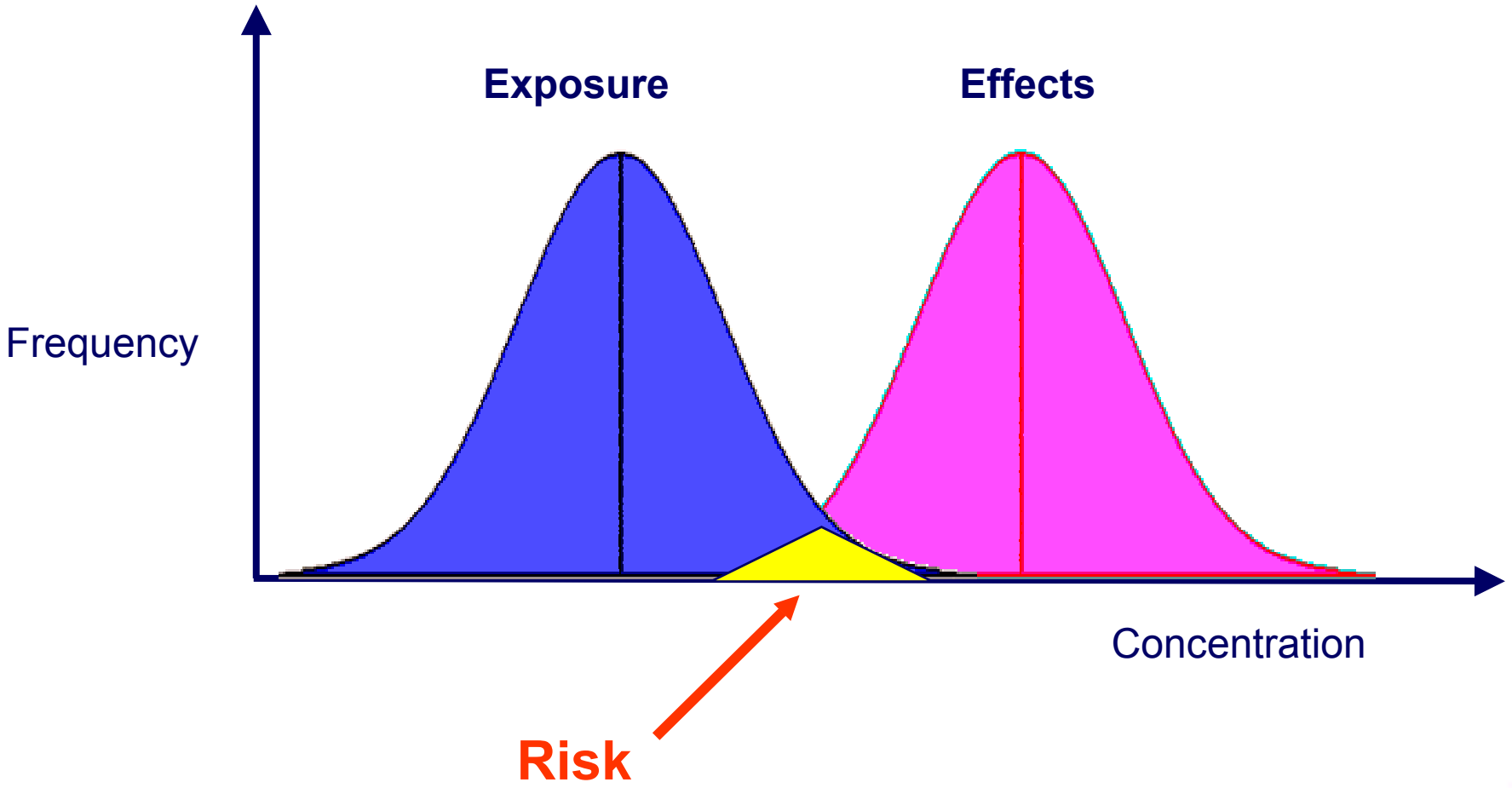
From prediction of exposure to prediction of risk



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Characteristics of risk assessments for pesticide losses to the environment

- Risk assessments operate with scenarios, even on a higher tier (e.g. assumption that a maximum use rate is applied)
- Worst-case estimates are used for parameters which are unknown or subject to high uncertainty
- Risk assessments are performed to evaluate the safety of a compound but do not reflect the real longterm exposure situation in a region or country.

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Characteristics of mass balances for pesticide losses to the environment

- Mass balances are used to quantify loadings but usually cannot be used to calculate concentrations (e.g. in surface water)
- Mass balances should avoid the use of scenarios and are used to provide a correct representation of the longterm exposure situation in a country considering normal agricultural practice
- Mass balances are an attempt to consider all potential use and exposure situations
- Mass balances for the exposure to pesticides are usually done for larger spatial units (e.g. regions, countries)

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Example for a regional mass balance

Annual use of compound X = **1200 t**

Survey data, agricultural census etc...

Annual loss to surface water = **0.2 – 0.4 %**

-Runoff
-Erosion
-Field drains
-Drift etc.....

Annual loading of surface water bodies = **2.4 – 4.8 t**

Confidence interval

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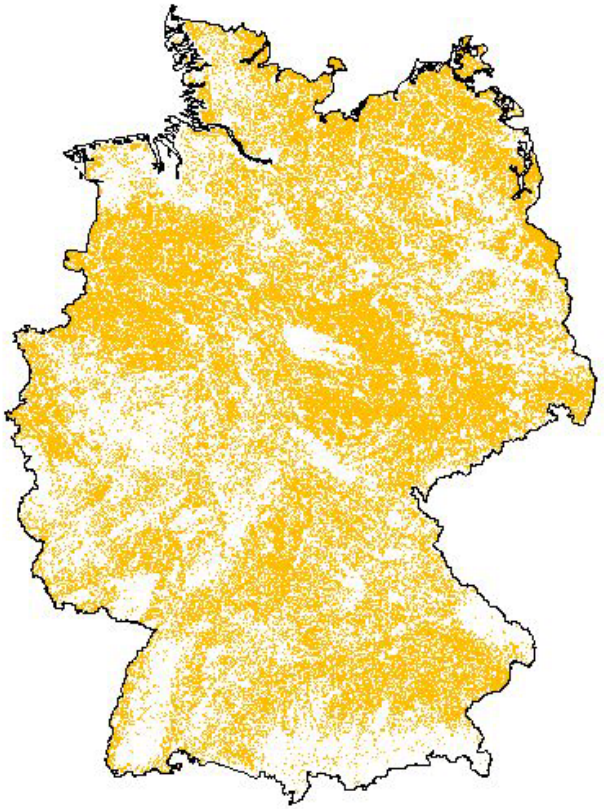
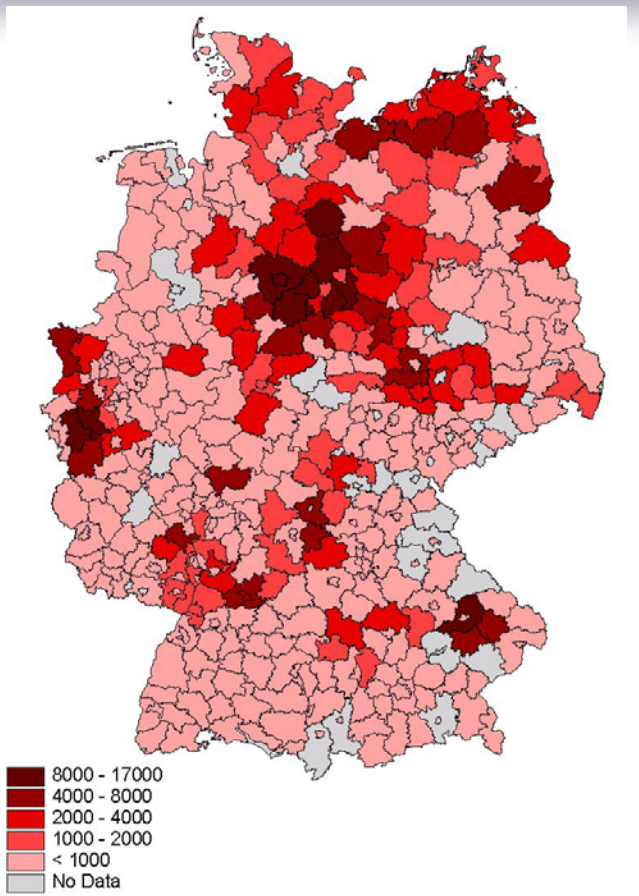
Mass balance: Use data





Where is the crop grown ?

Where was the chemical used in year X ?

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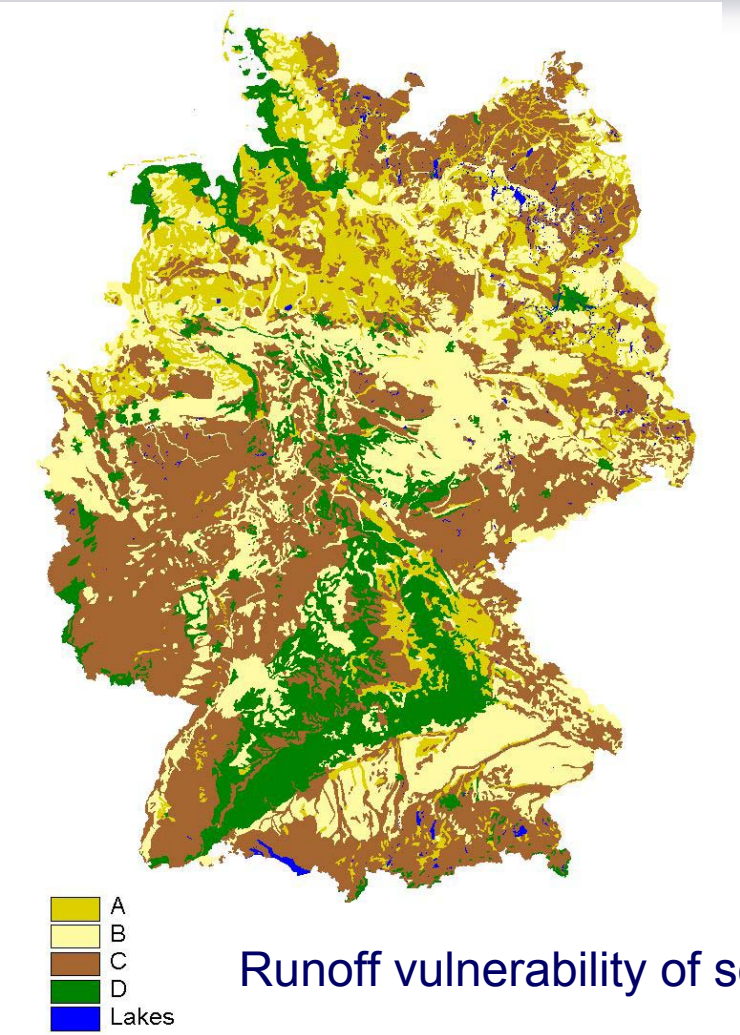
Calculation of longterm losses with runoff



Runoff vulnerability of soils

Which percentage would be washed off in a 10, 15, 20 ....mm/24 h event ?

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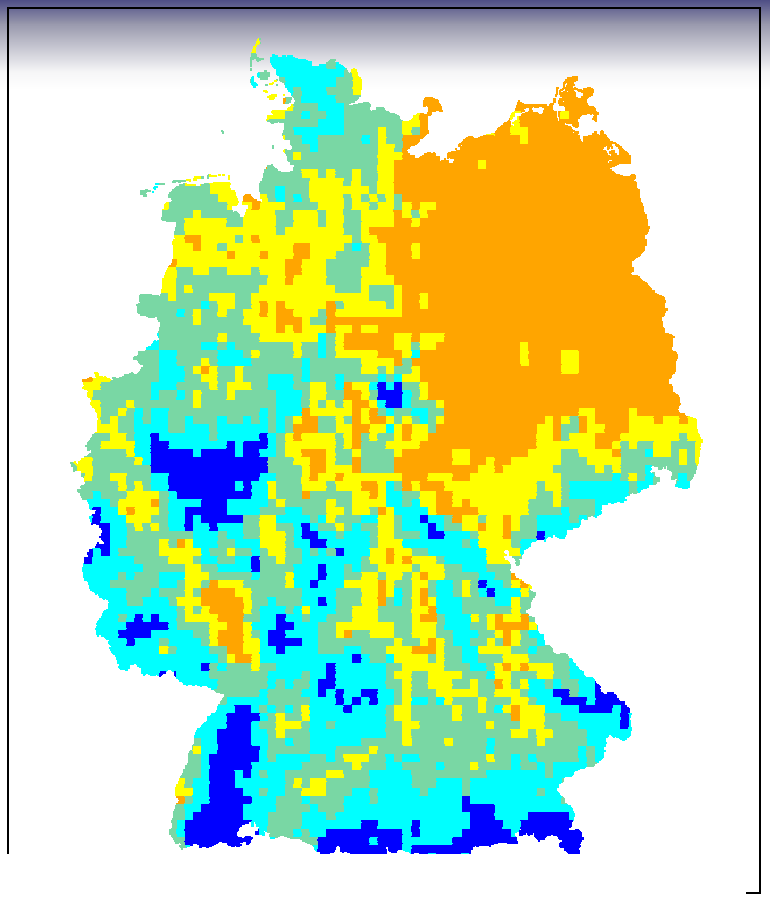
Mass balance: Rainfall probabilities



Re-occurrence intervals of significant events > 20 mm/d

- < 50 d
- 50 - 100 d
- 100 - 150 d
- 150 - 200 d
- > 200 d

How often do 10, 15, 20 ....mm/24 h events occur ?

What is the residue level at the beginning of a runoff event ?

The rainfall re-occurrence interval is a probability function rather than an absolute value !

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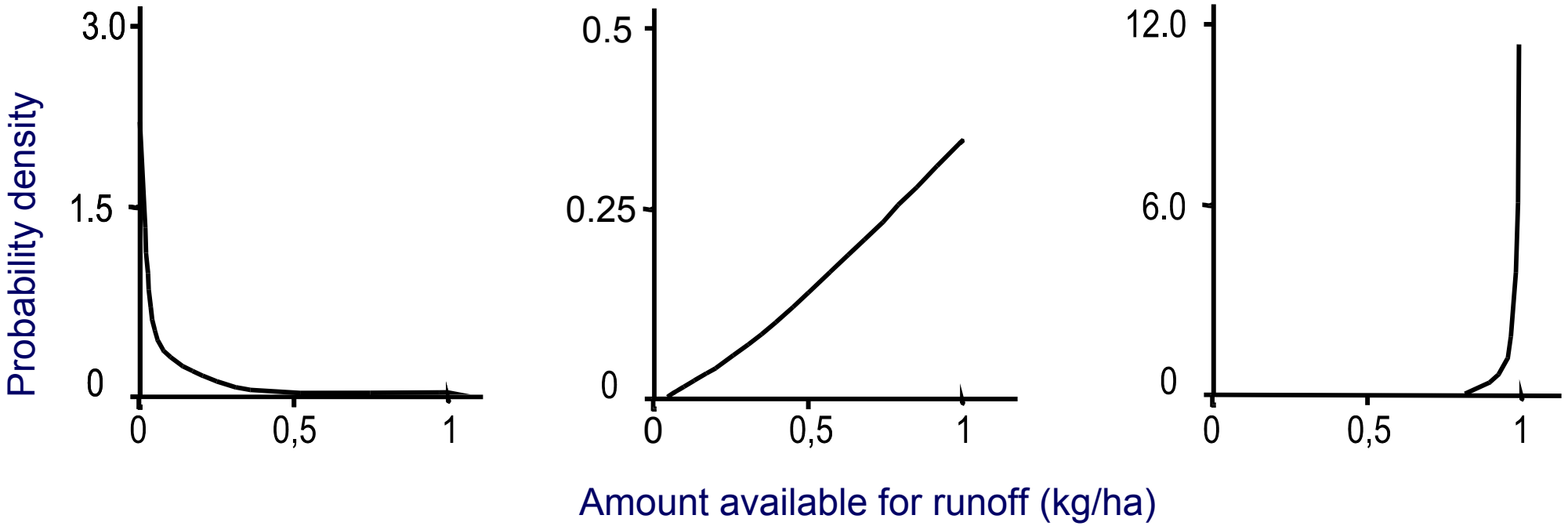
Probability density functions for amounts available for runoff for a given rainfall intervall



DT50 < 10

10 < DT50 < 100

DT50 > 100

Mills and Leonard, 1984

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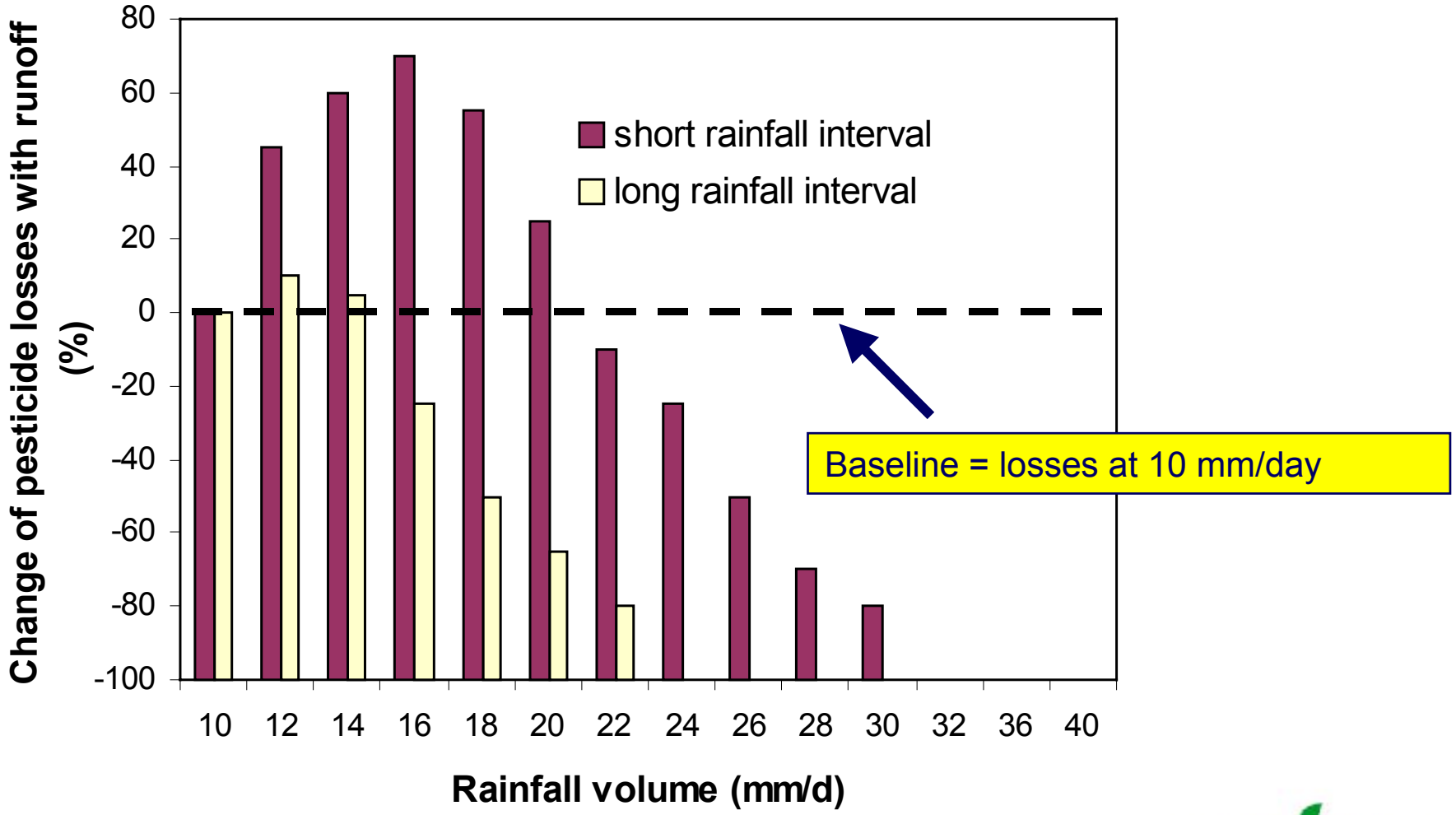
Predicted runoff losses for rainfall volumes and the respective re-occurrence intervals



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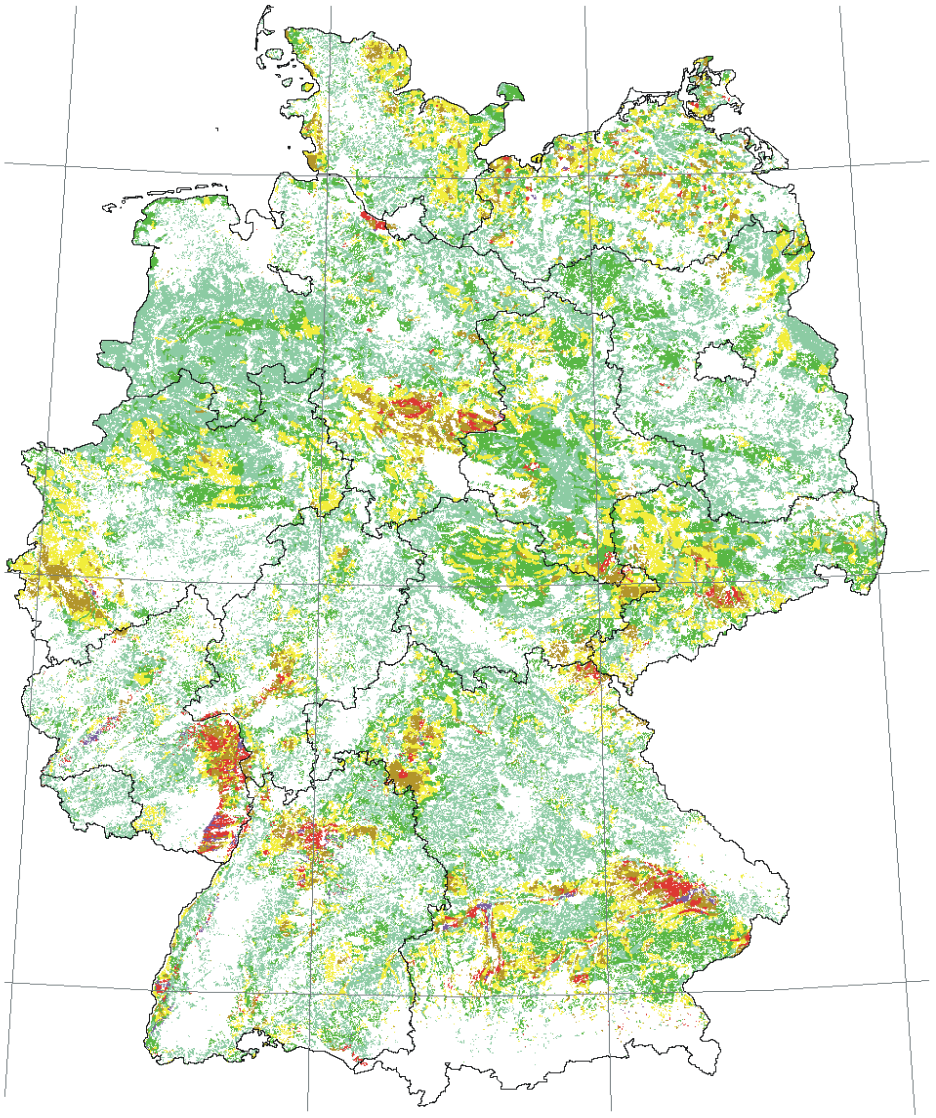

Pesticide Losses with Surface Runoff (42 active ingredients; 1993/94)

Losses in mg ha^{-1} $year^{-1}$

- no application
- no loss
- 1 - 300
- 301 - 600
- 601 - 1200
- 1201 - 2400
- 2401 - 4800
- > 4800

200 0 km

N

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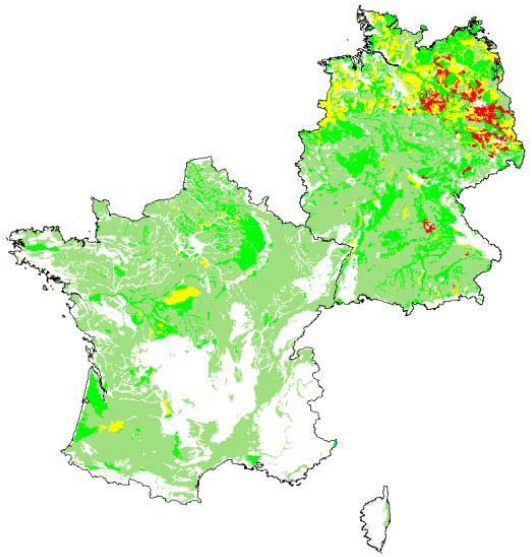
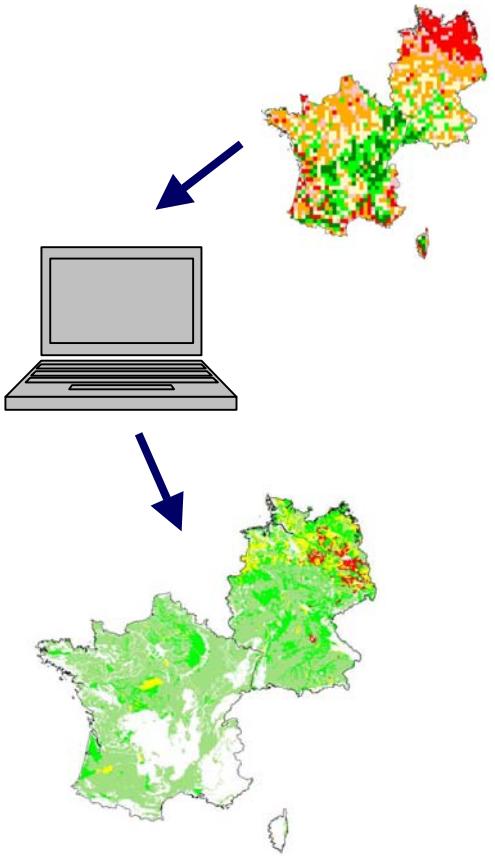
Landscape level exposure modeling

Option 1: GIS-model



Option 2: Link between GIS and e-fate models



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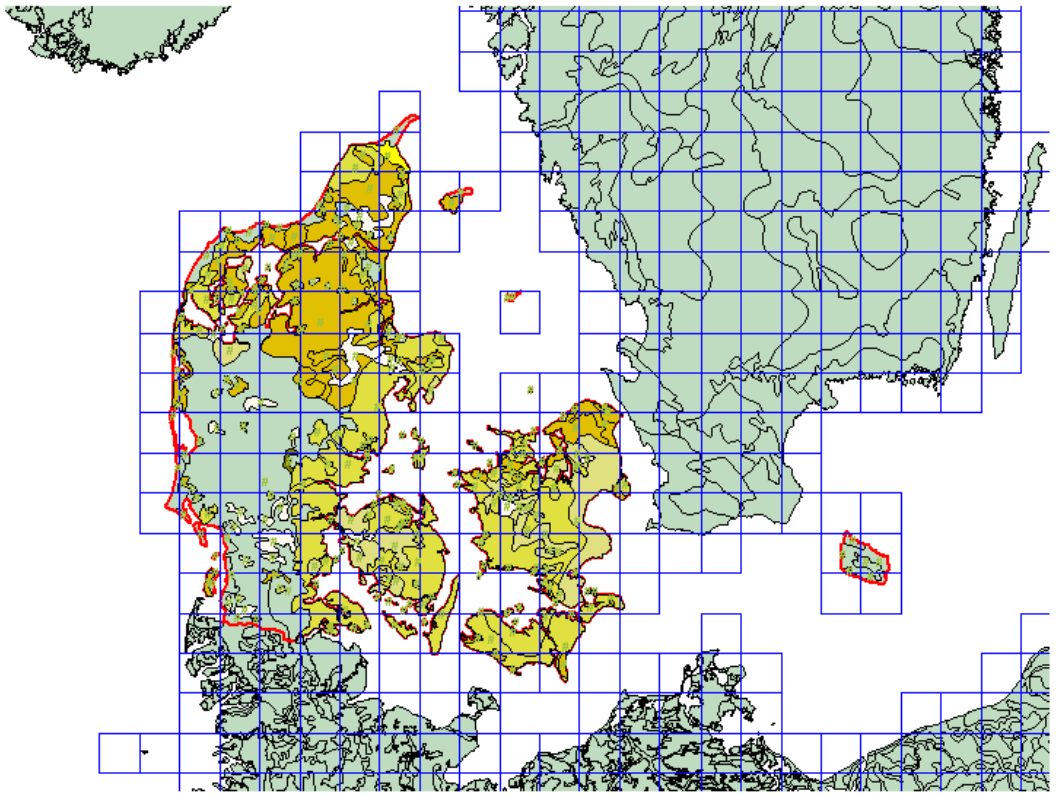
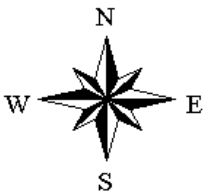
Spatial modeling



- 25 km grid

  (long term daily weather records)

The simulation of all possible use situations with real weather data is not unrealistic but requires still a considerable amount of resources.



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Conclusions

Risk Assessments

- Consist of specific scenarios
- Relate exposure with effects
- Include safety factors to address uncertainty issues
- Are used in regulatory assessment schemes

=> µg/L, **mg/kg** etc.

Mass Balances

- Try to include all possible use situations
- Cannot be related to effects
- Provide confidence intervals to address uncertainty issues
- Are used in environmental status reports

=> **t/year, kg/year** etc.

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