

Considering Variability in Groundwater Exposure to Pesticides in LCA

Georg Geisler, Simon Liechti, Stefanie Hellweg, Konrad Hungerbühler

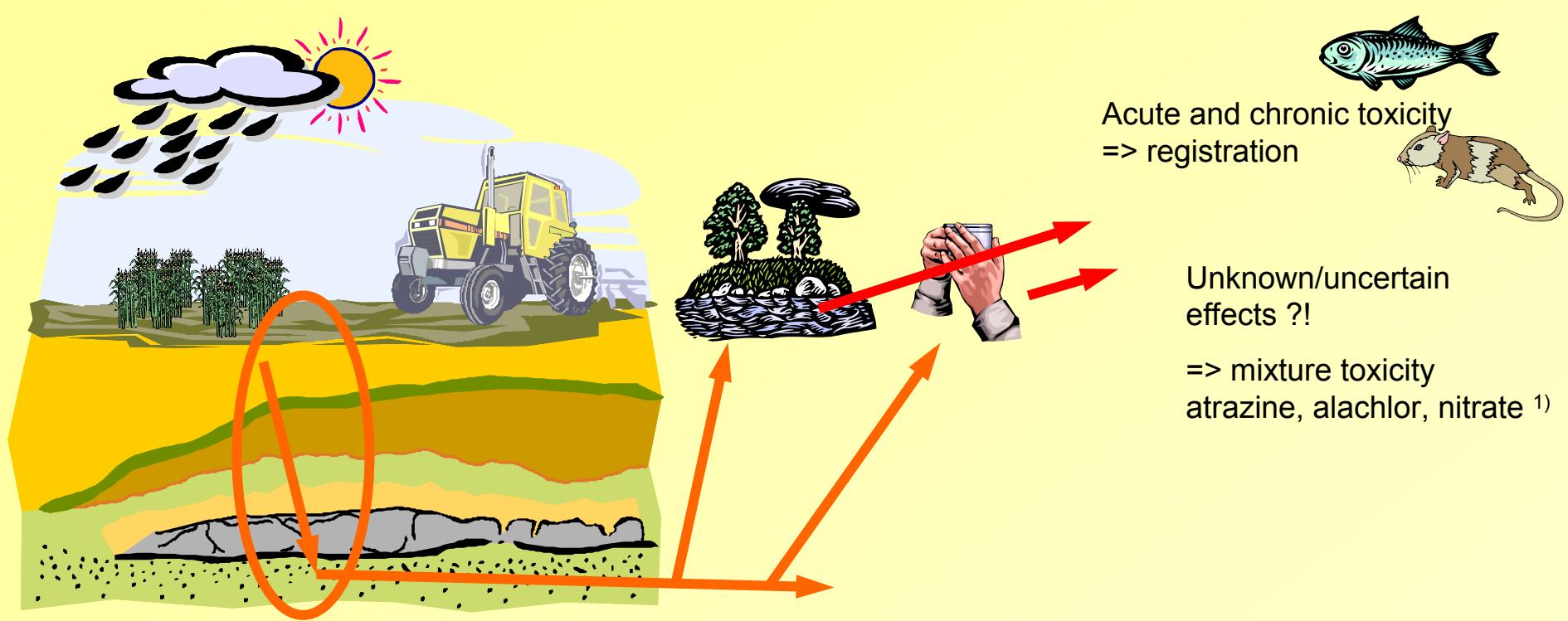
Safety and Environmental Technology Group,
Swiss Federal Institute of Technology (ETH), Zürich

Method of incorporating
variability in LCA

Case study of
pesticide leaching

Relevance of
pesticide leaching

Groundwater Exposure to Pesticides



- => Highly variable exposure and uncertain/unknown impacts on local scales
- => Precautionary approach: groundwater as safeguard subject

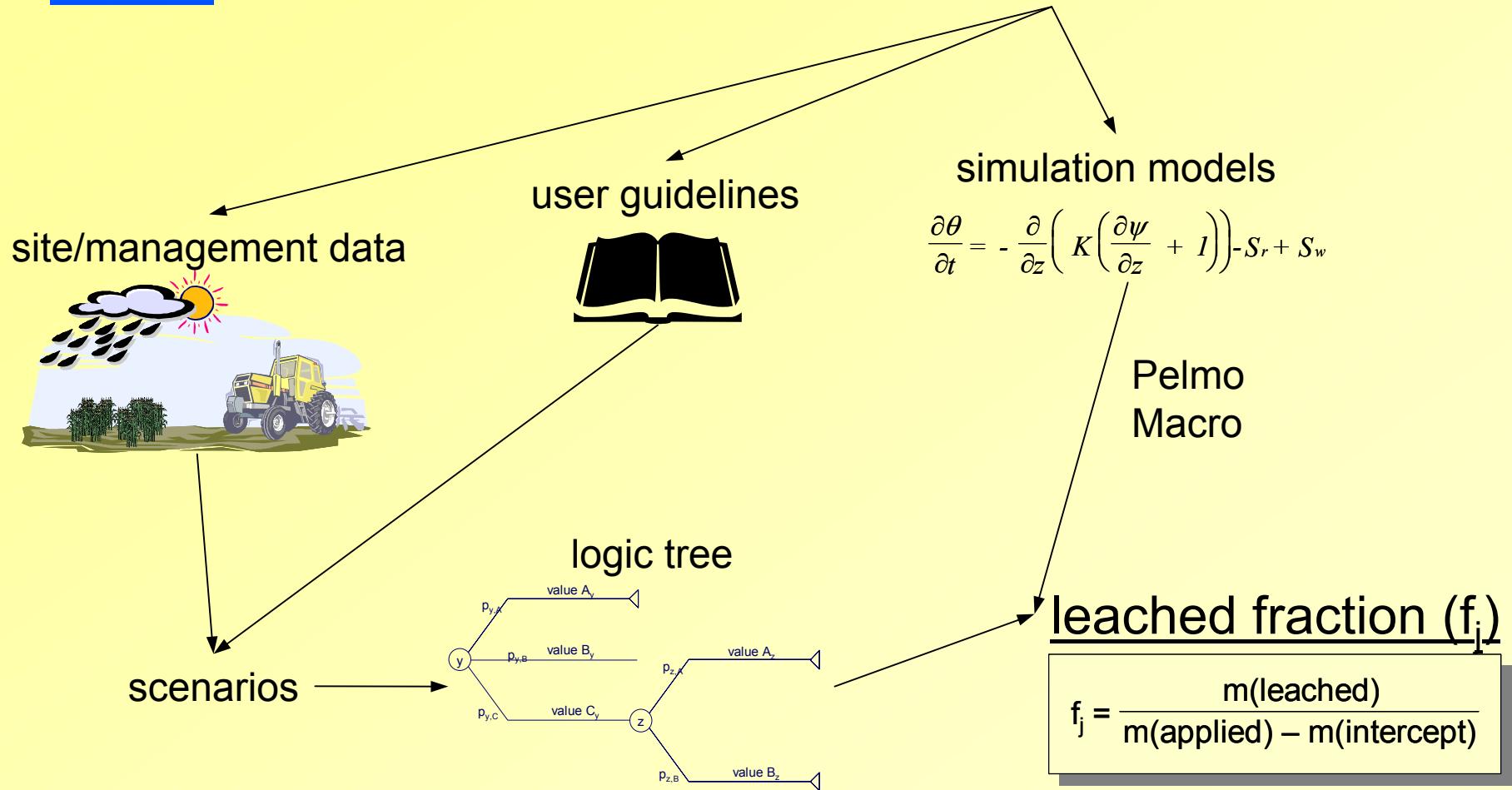
¹⁾ Jaeger et al. (1999)
Tox Indust Health 15 133-151

FOCUS Modelling Framework and Leached Fraction



Pesticide
Registration

FOCUS: harmonized modelling framework for
pesticide leaching assessment



Processes influencing Pesticide Leaching: Water Balance

Parameter in logic tree
(derived from FOCUS)

influencing factor

site: soil/weather combination

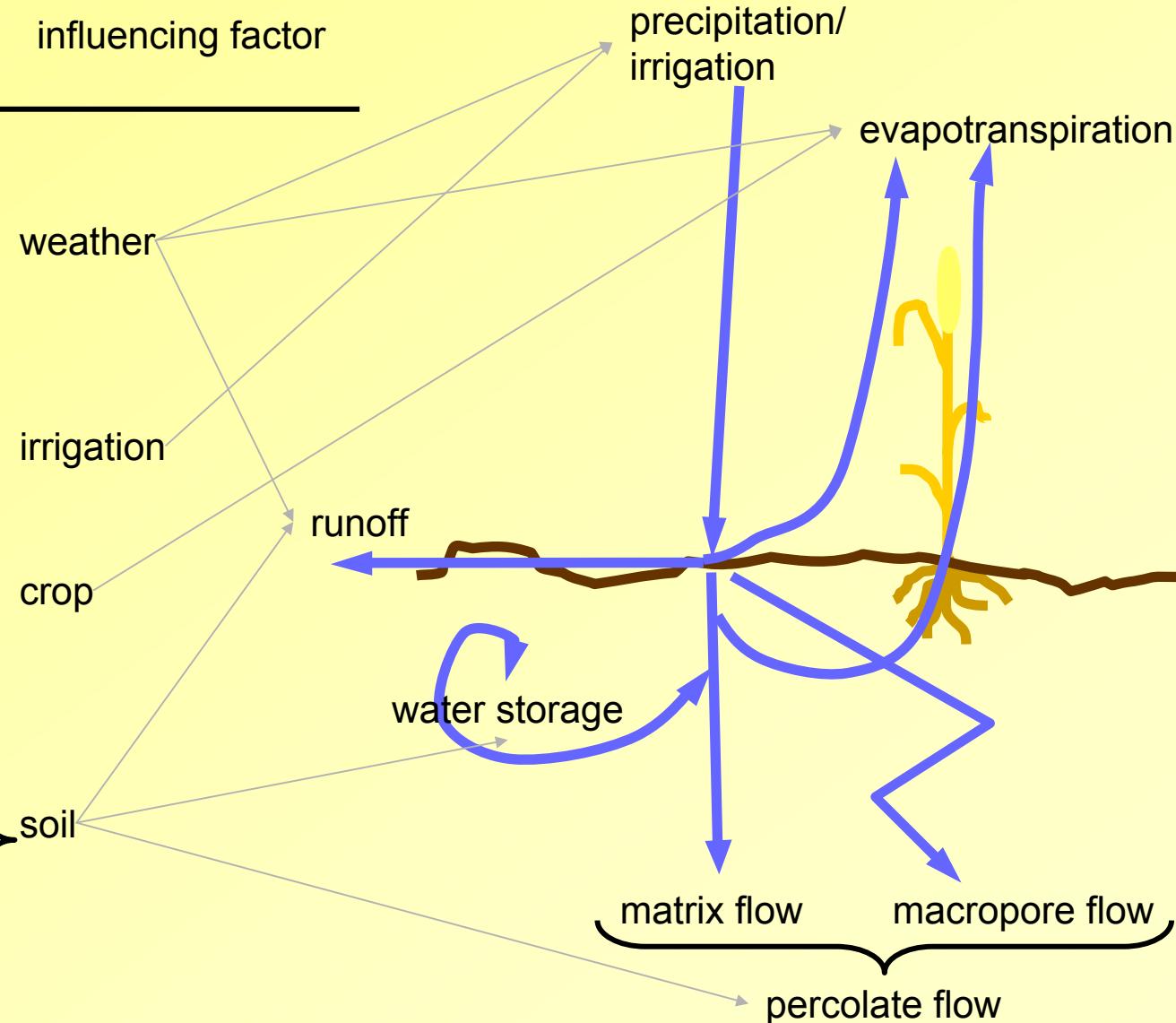
20 years of weather per site simulated
=> percentiles

irrigation schedule (per site)

crop 1 (min. percolate flow)
crop 2 (max. percolate flow)

site: soil/weather combination

Pelmo: matrix flow
Macro: matrix and macropore flow



Logic Tree: Site Parameter

FOCUS-sites



site name \ unit	characteristics of the sites			
	mean annual precipitation mm/a	mean annual temperature °C	topsoil texture	mean oc- content (1m depth)
Sevilla	< 600	> 12.5	silt loam	0.72
Chateaudun	< 600-800	5-12.5	silty clay loam	0.76
Hamburg	600-800	5-12.5	sandy loam	0.78
Kremsmünster	800-1000	5-12.5	loam/silt loam	0.90
Okehampton	1000-1200	5-12.5	loam	0.90
Piacenza	800-1200	> 12.5	loam	0.55

Processes influencing Pesticide Leaching: Pesticide Mass Balance

Parameter in logic tree
(derived from FOCUS)

influencing factor

user input (interception tables)

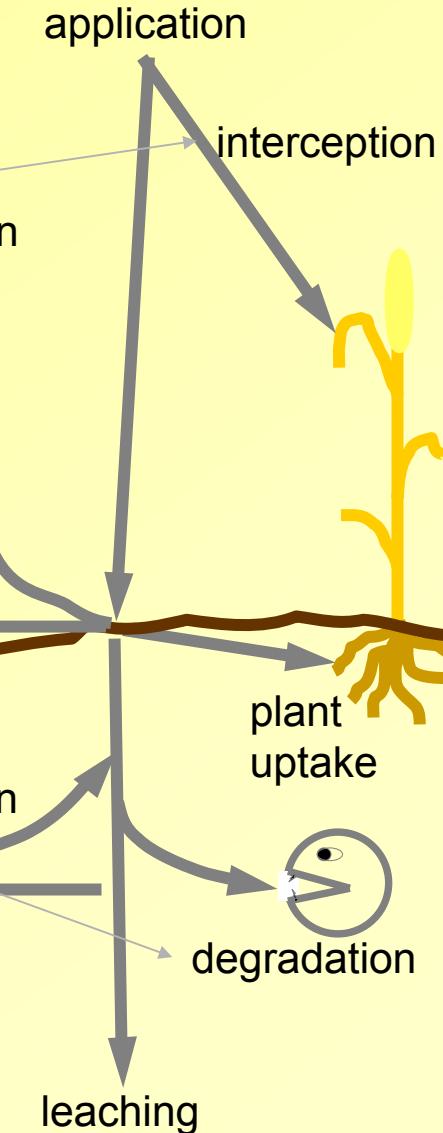
crop growth

Henry-constant cutoff
($K_h < 0.001 \text{ J/mole}$)

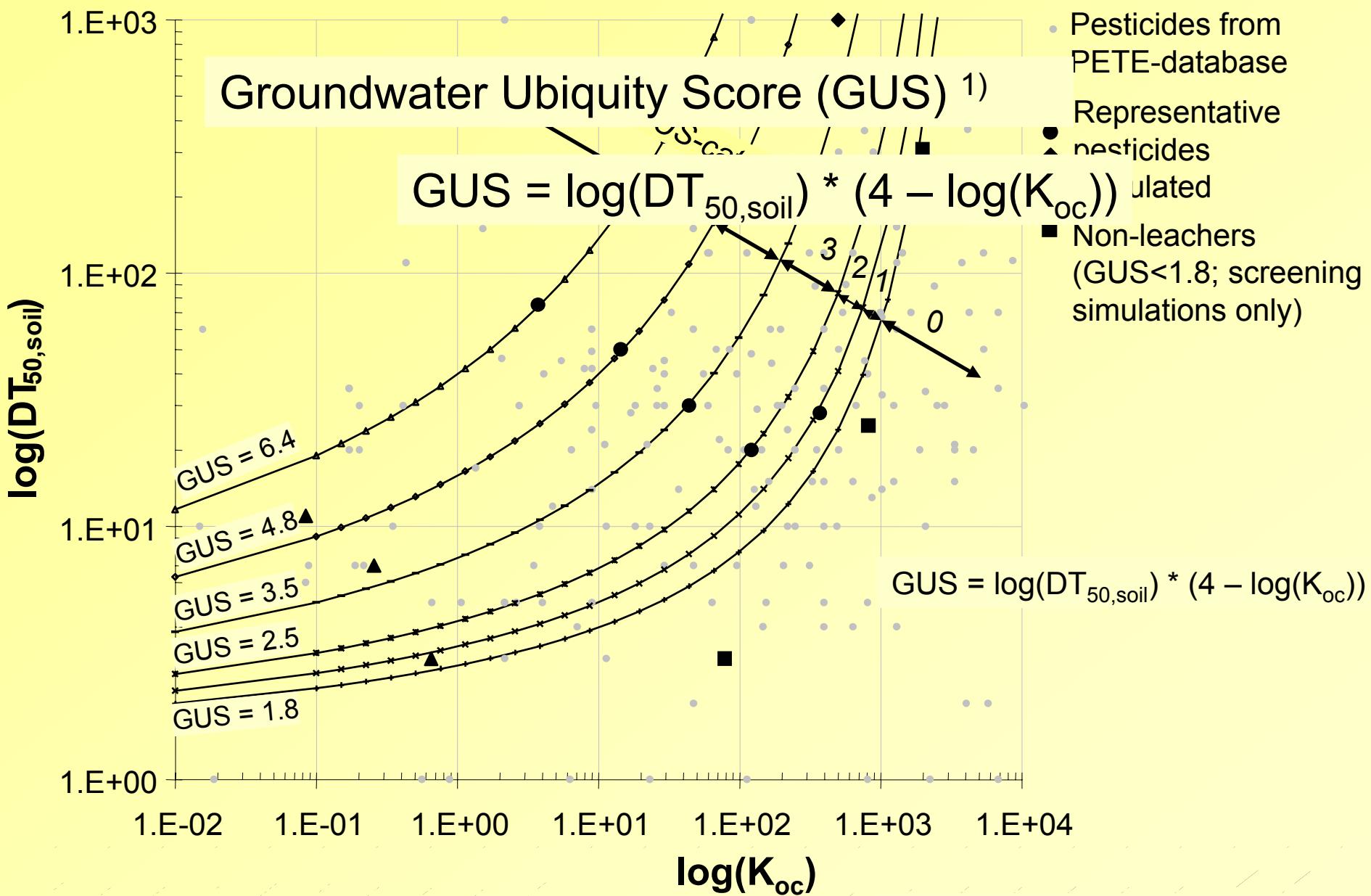
volatility of pesticide

Groundwater Ubiquity Score

{
pesticide K_{oc}
pesticide $DT_{50,soil}$



GUS-Space and Representative Pesticides



Processes influencing Pesticide Leaching: Pesticide Mass Balance

Parameter in logic tree
(derived from FOCUS)

influencing factor

user input (interception tables)

crop growth

Henry-constant cutoff
($K_h < 0.001 \text{ J/mole}$)

volatility of pesticide

Groundwater Ubiquity Score

pesticide K_{oc}

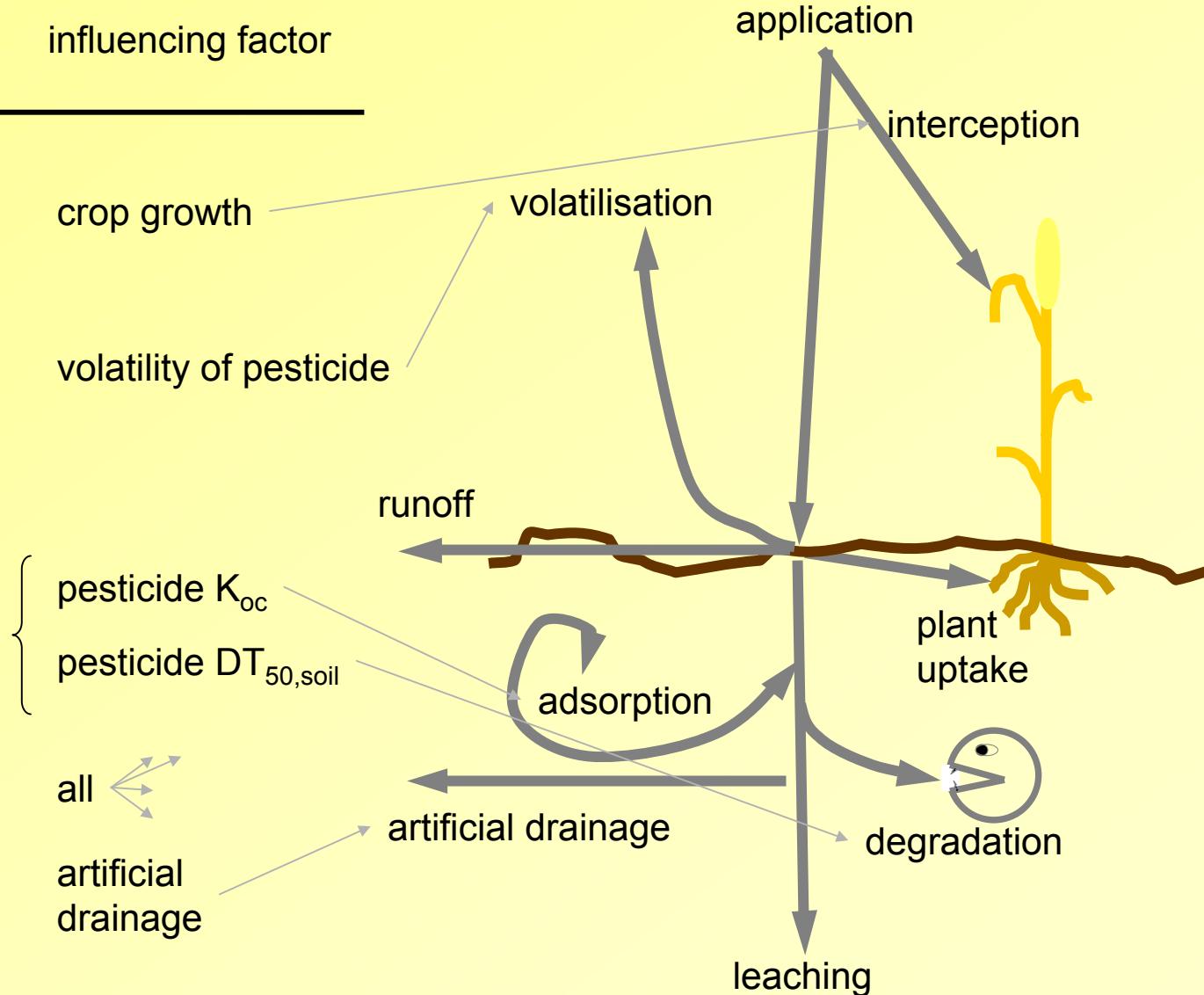
pesticide $DT_{50,soil}$

season of application

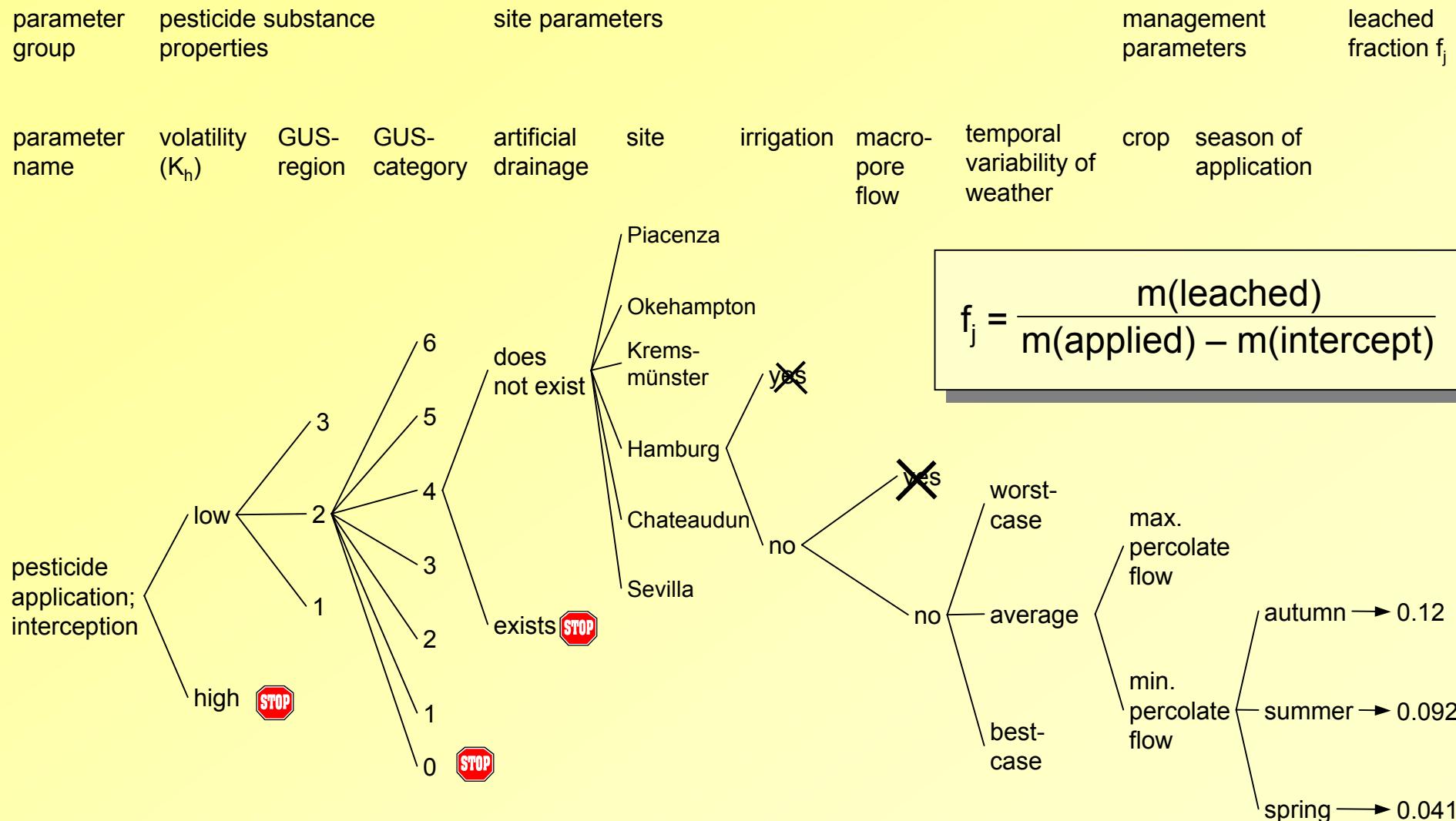
all

artificial drainage
(exists => insignificant leaching)

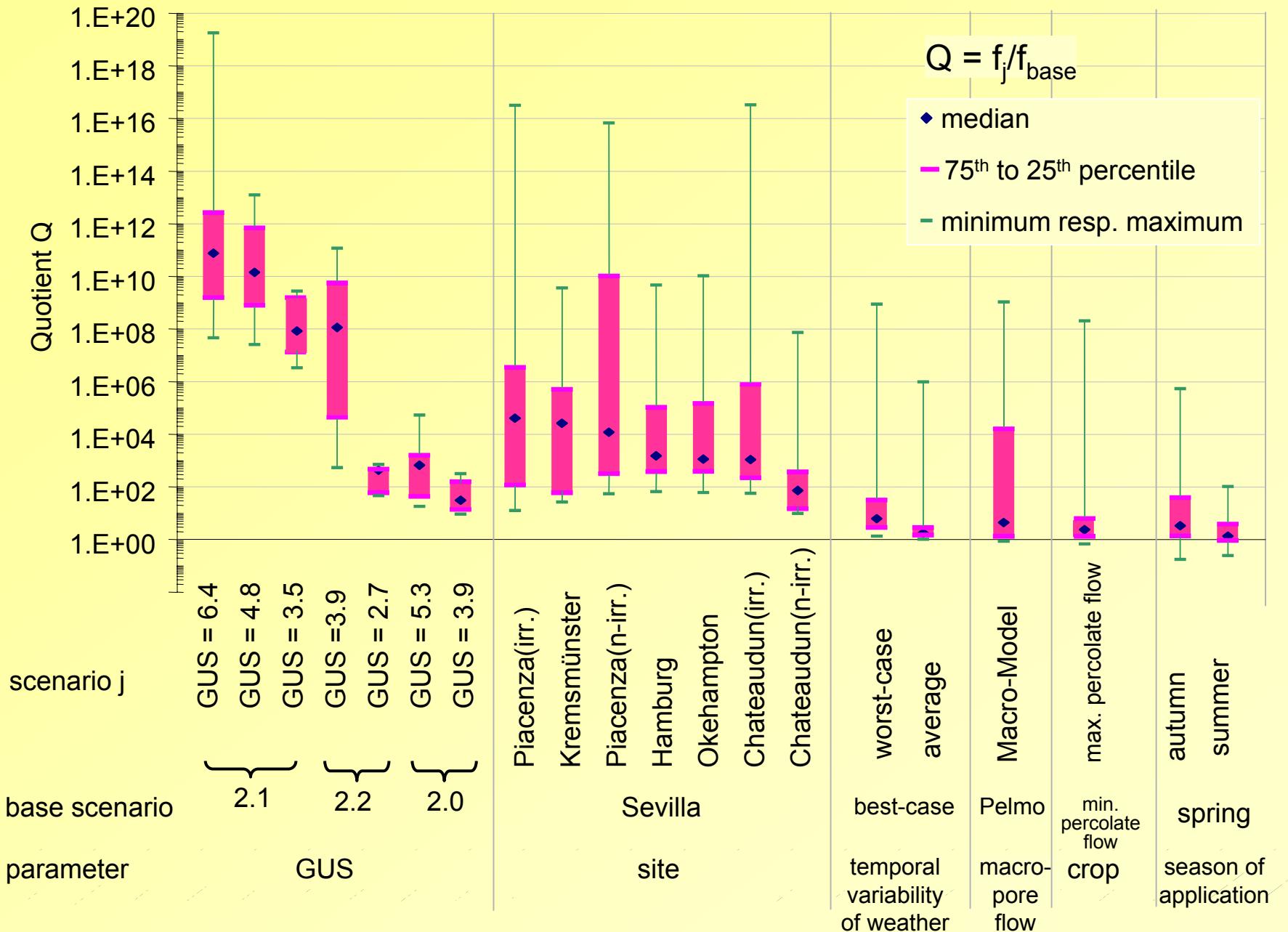
artificial drainage



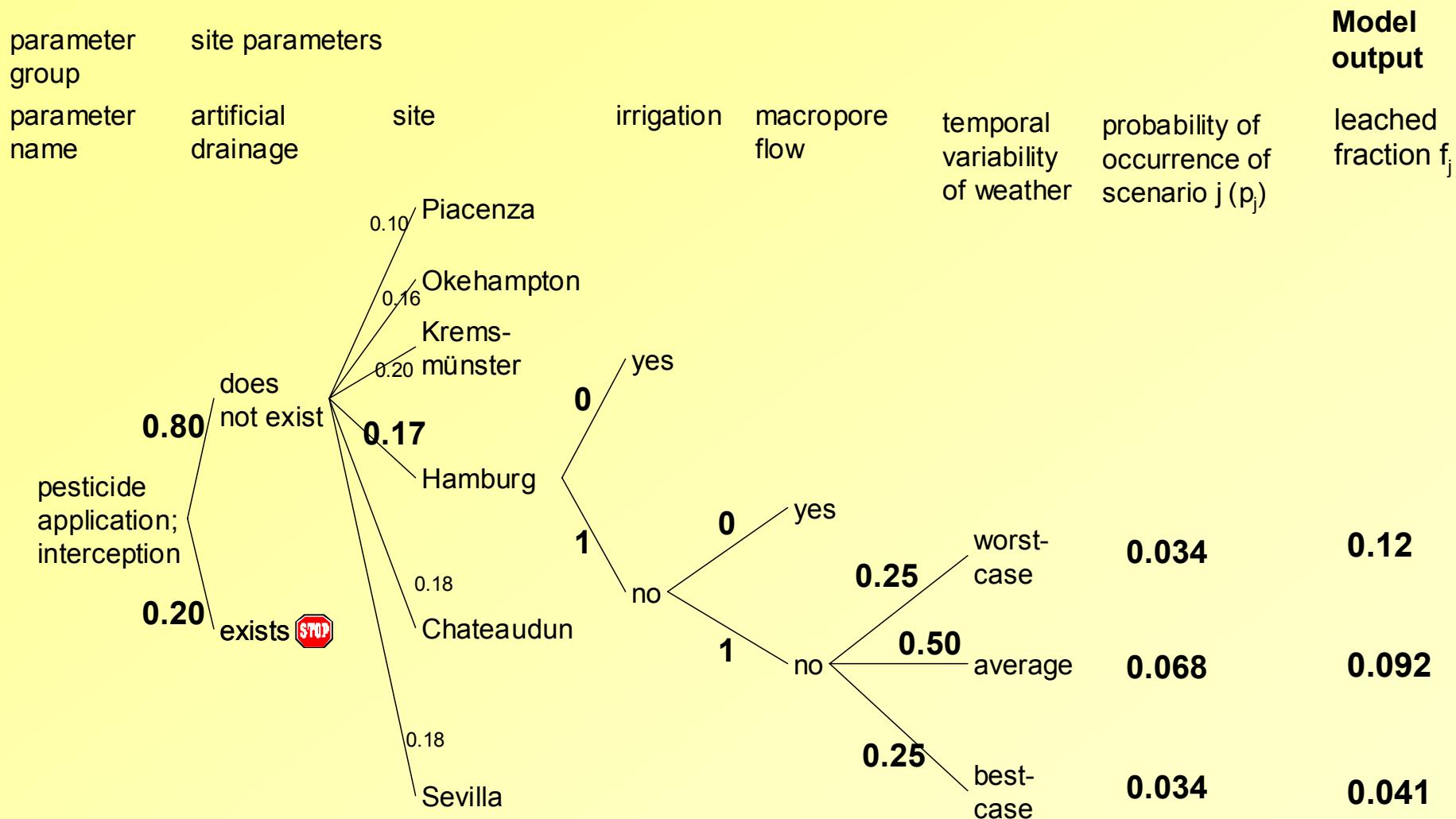
Logic Tree of Scenarios of Pesticide Leaching



Contributions of Parameters to the Variability of the Leached Fraction



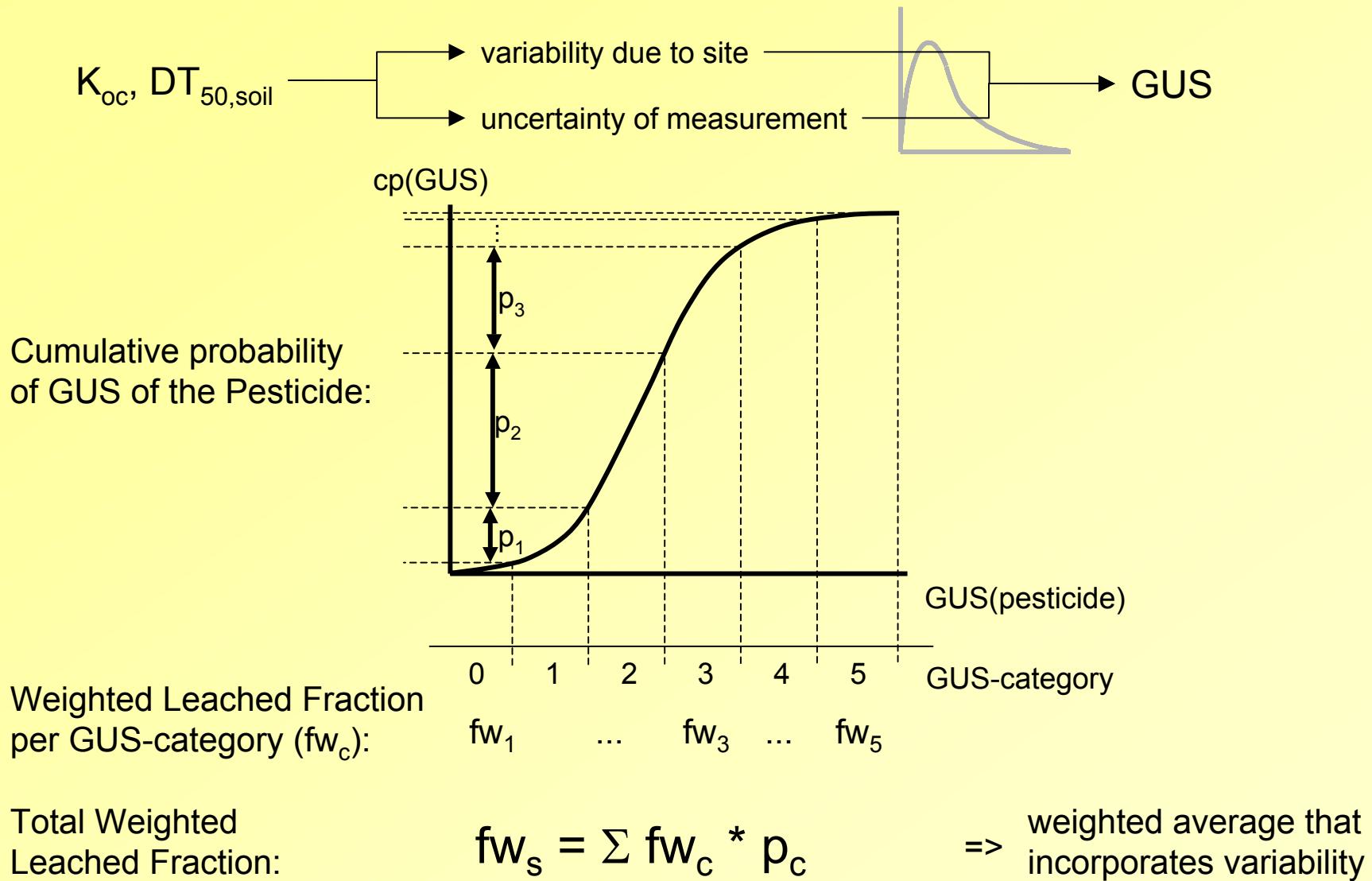
Aggregation of Leaching Scenarios: Site Factors



Weighted Leached Fraction:

$$fw = \sum f_j * p_j$$

Aggregation of Leached Fractions: Substance Properties of Pesticides



Case Study: Atrazine in Maize

Assumptions:

- season of application = spring
- no interception (preemergence application);
- all sites included (geographical scope = EU-agriculture)
- irrigation yes
- crop 1

Results:

GUS-category	GUS-range	logic tree output leached fraction per GUS-category (fw_c), %	Atrazine GUS probability of GUS-value of Atrazine (p_c), %
0	GUS < 1.8	0	3.2
1	1.8 ≤ GUS < 2.1	1.0.E-07	4.8
2	2.1 ≤ GUS < 2.5	3.65E-04	12
3	2.5 ≤ GUS < 3.5	0.4	47
4	3.5 ≤ GUS < 4.8	6.7	28
5	4.8 ≤ GUS < 6.4	15	5.0
6	6.4 ≤ GUS	15	0.041

total weighted
leached fraction

$$fw_s = \sum fw_c * cp_c$$

$$fw_s = 1.6 \%$$

substance properties of Atrazine: Fenner (2001); <http://lrcmail.ethz.ch/hungerb/publications/pu2001.html#dissertations>

Case Study: Atrazine in Maize – Human Toxicity Potential in EDIP

Tentative normalisation and weighting of HTP(groundwater)

Nitrate and pesticide emissions to groundwater considered

Normalisation and weighting factor similar to that of HTP(surface water)

Full pesticide life cycle for Atrazine in maize:

Functional Unit: 1 ha Maize treated with recommended dose (1 kg/ha)

Atrazine production: ecoinvent 1994 (only energy demand)

Application by tractor: ecoinvent 2000 (emissions);
ecoinvent 1994 (infrastructure); BUWAL300 (Diesel)

=> Fraction of HTP(groundwater) due to Atrazine leaching in HTP(total life cycle):

0.5 %

Valuation Question ?

Use of Leached Fractions in LCA

A) Emission mass flows in LCI

- ☺ impacts of pesticide leaching ↔ other impacts in a life cycle
- ☹ characterisation factors for emissions to groundwater unavailable
 - normalisation of HTP(groundwater) possible for EDIP
- ☹ valuation of LCIA not always in line with goals of study
 - impacts on local scales often dominated by „energy impacts“ in LCA ¹⁾

B) Separate impact indicators with groundwater as safeguard subject

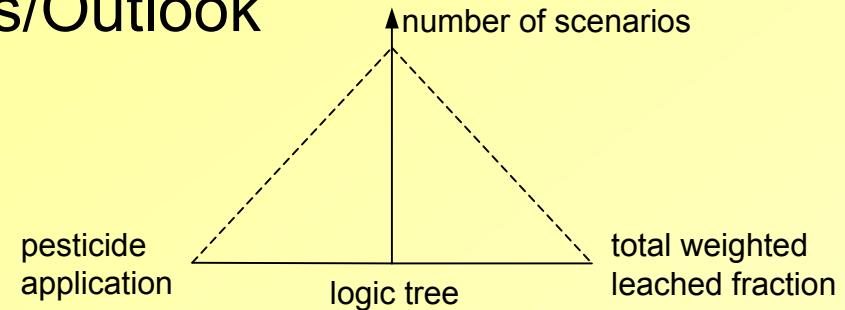
for studies where local, uncertain impacts are valued highly
(precautionary approach), separate indicator would be appropriate

¹⁾ Beck A, Scheringer M, Hungerbühler K (2000): Int J LCA 5

Conclusions/Outlook

Leached fractions ...

Incorporation of variability of local-scale impacts,
in a „sophisticated“ average.



... use in LCA

Relevance of groundwater exposure to pesticides will often be low in LCA

Separate indicator may be appropriate, depending on goal of study

Logic tree and modelling of leached fractions

Model uncertainties (FOCUS-framework): Scenarios of median leaching vulnerability

Assessing pesticide flux in 1 m depth

Improvements of logic tree

Higher resolution of GUS-categories

Include more management factors

Scenario/Aggregation approach to incorporate variability in LCA

Use for other emission pathways of pesticides.

Broader use for site-dependent LCA.

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Group S&U, ETH Zürich

Risk Assessment ↔ Life Cycle Assessment

FOCUS-framework

Life Cycle Assessment

leaching vulnerability

realistic worst-case

„80th percentile“ of
soil vulnerability

80th percentile of
leaching vulnerability due
to weather

not modifiable

median case *plus variability*

„80th percentile“ soil *in different sites*

median weather *plus 20th and 80th percentile*

target parameter

pesticide concentration in 1 m depth

mass flow in 1 m depth

leached fraction of dose

Site and Management Factors - Interdependencies

site name \ unit	scenarios with combinations of dependent parameter values calculated for each site					characteristics of the sites			
	irrigation applied	macropore flow scenario calculated	crop case ⁴	crop corresponding to crop case	season of application	mean annual precipitation	mean annual temperature	topsoil texture	mea organ carb conte
	-	-	-	-	-	mm/a	°C	-	%
Sevilla	n/r ³	n	only one ¹	winter wheat	autumn, spring	< 600	> 12.5	silt loam	0.7%
Chateaudun	n	y	only one ¹	winter wheat	autumn, spring	< 600	5-12.5	silty clay loam	0.7%
Chateaudun	y	y	1	maize	autumn, spring, summer	600-800	5-12.5	silty clay loam	0.7%
Chateaudun	y	y	2	sugar beets	autumn, spring, summer	600-800	5-12.5	silty clay loam	0.7%
Hamburg	n/a ²	n	2	winter wheat	autumn, spring	600-800	5-12.5	sandy loam	0.7%
Hamburg	n/a ²	n	1	maize	autumn, spring, summer	600-800	5-12.5	sandy loam	0.7%
Kremsmünster	n/a ²	n	1	maize	autumn, spring, summer	800-1000	5-12.5	loam/silt loam	0.9%
Kremsmünster	n/a ²	n	2	winter rape	autumn, spring	800-1000	5-12.5	loam/silt loam	0.9%
Okehampton	n/a ²	n	1	maize	autumn, spring, summer	1000-1200	5-12.5	loam	0.9%
Okehampton	n/a ²	n	2	winter wheat	autumn, spring	1000-1200	5-12.5	loam	0.9%
Piacenza	n	n	1	winter wheat	autumn, spring	800-1000	> 12.5	loam	0.5%
Piacenza	n	n	2	winter rape	autumn, spring	800-1000	> 12.5	loam	0.5%
Piacenza	y	n	only one ¹	sugar beets	autumn, spring, summer	1000-1200	> 12.5	loam	0.5%

¹ only one crop case calculated

² n/a – not applicable

³ n/r – irrigation is not a relevant factor for the leached fraction at the Sevilla-site

⁴ crop case 1 – minimum percolate flow; crop case 2 – maximum percolate flow

Statistics of the Leached Fractions calculated