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Assessment of Pesticide Leaching to Groundwater in Germany:
Comparison of Indicator and Metamodel Approaches

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Background and target

- ***Application of two models developed for the assessment of the pesticide leaching risk on a large scale (i.e. EU / Germany)***
- ***Evaluation of the differences (input data, results, conclusions)***

METAMODEL: to monitor the progress of the EU Thematic Strategy on the Sustainable Use of Pesticides (http://www.pearl.pesticidemodels.eu/)

- Application in the project HAIR (**Ha**rmonized environmental **I**ndicators for pesticide **R**isk) supported by the European Commission under the 6th EU framework program

INDICATORMODEL: Nationwide Analysis and evaluation of pesticide leaching risk and groundwater endangerment in Germany

- Application in a project funded by the Federal German Office for Consumer Protection and Food Safety (BVL)

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit

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Introduction

- METAMODEL and INDICATORMODEL
- Comparison of input parameters obtained from national German vs. European data bases
- Comparison of model results METAMODEL / INDICATORMODEL:
  - *Impact of used data bases*
  - *Comparison of concentrations in the leachate (METAMODEL) / leaching risk (INDICATORMODEL)*
  - *Comparison of predicted concentrations / leaching risks with findings in groundwater monitoring wells*

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METAMODEL

Metamodel of EuroPEARL (Tiktak et al., 2006, JEQ, 35:1213-1226):

= regression model

$$\ln C_L = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2$$

ln C_L: pesticide concentration in the leachate at 1m depth.

a_0, a_1, a_2: regression coefficients from PEARL model estimated from data sets of simulated lnCL by the mechanistic transient flow and transport model PEARL that was parameterized for 1062 soil-climate combinations and 56 pesticides

Independent variables: $X_1 = \frac{\mu(T)\Theta L}{q}$; $X_2 = \frac{\mu(T)\rho f_{om} K_{om} L}{q}$

Input parameters:

μT: degradation rate determined from DT50 and temperature (DT50 = time lag to degradate 50% of initial pesticide concentration)

Φ: Water content

L: leaching depth

q: percolation water rate

P: soil density

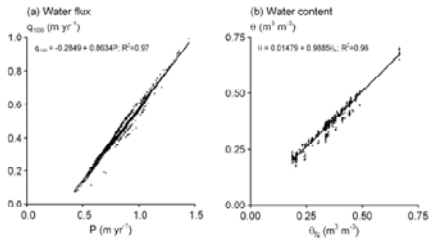
f_{om}: Humic content

K_{om}: distribution coefficient of pesticide between water and humic substances (Sorption)

MEATAMODEL (Tiktak et al., 2006, JEQ, 35:1213-1226)

q: vertical flux at 1 m (= percolation water rate) estimated from rainfall, P

θ: volumetric water content = estimated from water content at field capacity



u(T): degradation rate = estimated from DegT50 and temperature

$$\mu(T) = \frac{\ln 2}{DegT50} \exp\left[-\frac{E_a}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right]$$

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INDICATORMODEL (Müller, Arbeitshefte Boden 2004/2)

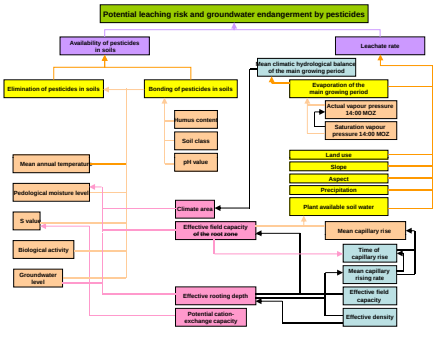
Assessment of the potential

- bonding
- elimination
- availability
- leaching risk

of pesticides at a large scale

Important input data:

- Leachate rate
- Soil parameters (organic matter, clay content, pH-values)
- Meteorological parameters (mean annual temperature, climate area)



Leachate rate modeled with GROWA (Kunkel & Wendland, 2002, J. Hydrol. 259: 152-162):

$$Q_{tot}(\ell) = P_y - h_{relief}\left[a_\ell \cdot P_{wi} + b_\ell \cdot P_{su} + c_\ell \cdot \log(W_{pl}) + d_\ell \cdot ET_{pot} + e_\ell \cdot D_p + f_\ell\right]$$

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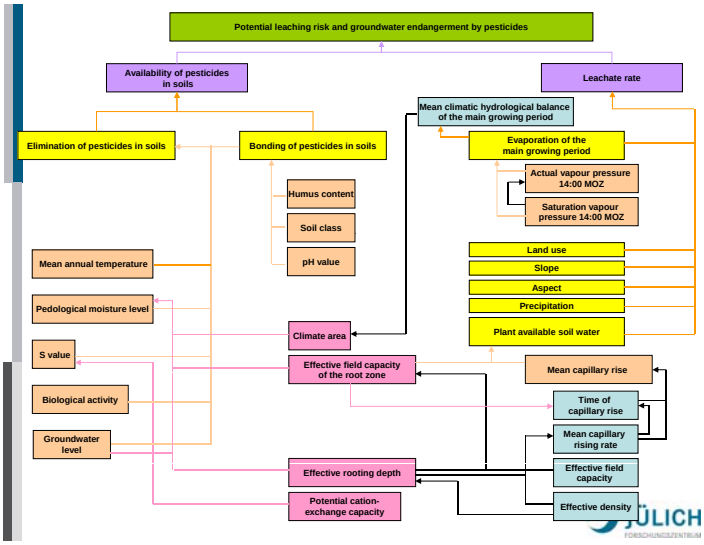


Indicator approach

Leachate rate modeled with GROWA (Kunkel & Wendland, 2002, J. Hydrol. 259: 152-162):

- Total runoff: $Q_{tot}(\ell) = \mathrm{P}_y - h_{relief}\left[a_\ell \cdot \mathrm{P}_{wi} + b_\ell \cdot P_{su} + c_\ell \cdot \log(W_{pl}) + d_\ell \cdot ET_{pot} + e_\ell \cdot D_p + f_\ell\right]$
- Surface runoff according to US Soil Conservation Service (1972): $Q_O = Q_{ges} \cdot 2 \cdot 10^{-6} \cdot (N_{Jahr} - 500)^{1,65}$

Bonding of pesticides in soils (FOB):

- Depending on soil parameters humus content, clay content and pH-value different factors are given and summed up to derive the bonding strength of a given pesticide

Elimination of pesticides in soils (FOE):

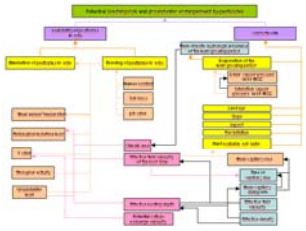
- Depending on the soil moisture, groundwater influence and climate parameters (temperature) factors are given and summed up to derive the elimination of a given pesticide in soil

Availability of pesticides in soils (FOV):

$$FOV = \frac{FOB + FOE}{2}$$

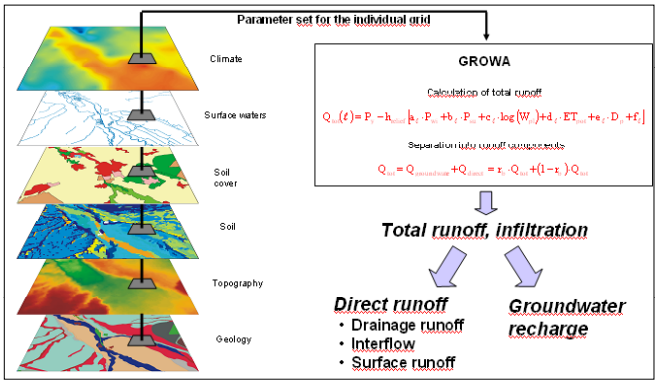
Potential leaching risk and groundwater endangerment by pesticides:

- Depending on leachate rate and availability of pesticides in soils a factor is given which represents the potential leaching risk



Water balance model GROWA (Kunkel & Wendland, 2002, J. Hydrol. 259: 152-162)

Infiltration rate



INDICATORMODEL

Potential leaching risk and groundwater endangerment by pesticides:

- Factors depending on leachate rate and availability of pesticides in soils (FOV)

Leachate rate [mm/a]	FOV 5	4	3	2	1	0
0 – 100	0	1.0	2.0	3.0	4.0	5.0
100 – 200	0	1.5	2.5	3.4	4.0	5.0
200 – 400	0	2.0	3.0	4.0	4.5	5.0
> 400	0.5	2.0	3.5	4.5	5.0	5.0

Increasing leaching ↓ / Increasing availability →

- The higher the leachate rate and the higher the availability the higher is the pesticide leaching risk
- Leaching risk is given in classes

→ ***possibilities to compare results from METAMODELL and INDICATORMODEL "limited"***

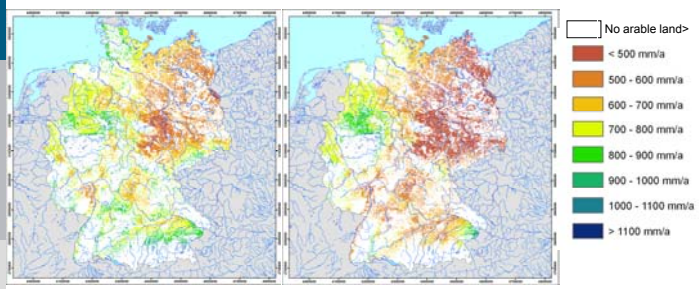
Comparison of input parameters obtained from national German vs. European data bases

- Spatial extent: Germany, all input data gridded to 1x1 km²
- Arable land (Corine)

Data bases	Input data Metapearl	Input data Indicator approach
Extent database	EU-27	Germany
Mean annual temperature	Worldclim	German Meteorological Survey
Precipitation	Worldclim	German Meteorological Survey
Leachate rate	Metapearl model	GROWA model
Organic matter content (0-1m)	OCTOP	German soil map 1:1 Mio (BÜK)
θ; water content at field capacity (0-1m)	SPADE	German soil map 1:1 Mio (BÜK)

Comparison of Input Data: Annual Precipitation

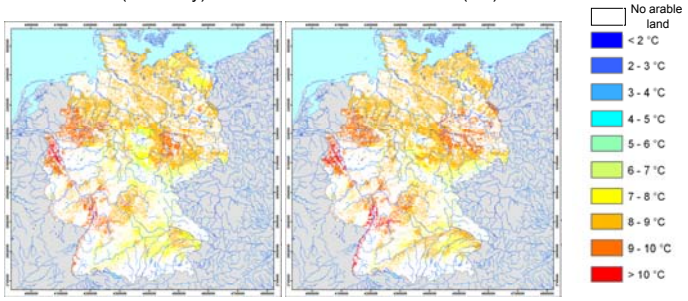
DWD (Germany) Worldclim (EU)



- Quite comparable although DWD-Data base shows a better regional representation of precipitation patterns in Germany

Comparison of Input Data: Temperature

DWD (Germany) Worldclim (EU)



- Quite comparable although DWD-Data base shows a better regional representation of temperatue patterns in Germany

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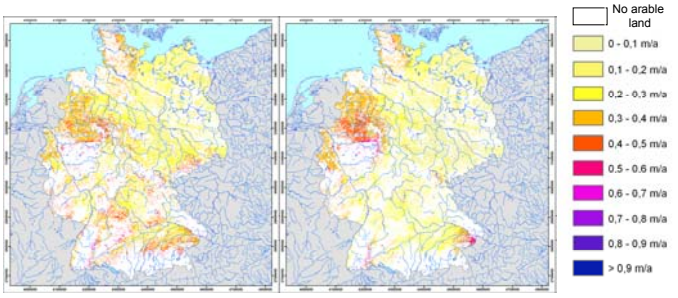
Comparison of results on leachate rate

GROWA (Germany) Metapearl (Germany)



- Same tendency although GROWA model results show a higher spatial distribution
- GROWA: validated against measured runoff

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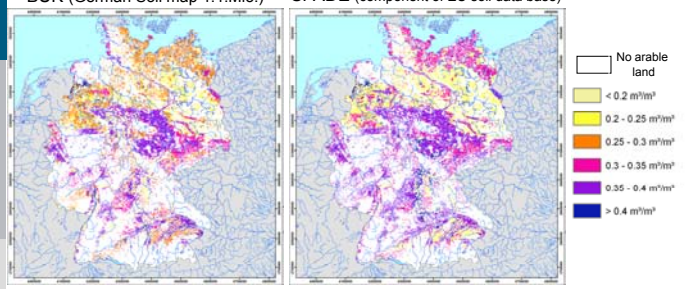
Comparison of Input Data: Water content at field capacity (0-1m)

BÜK (German Soil map 1:1.Mio.) SPADE (component of EU soil data base)



- Some considerable differences, above all in the Northern part of Germany

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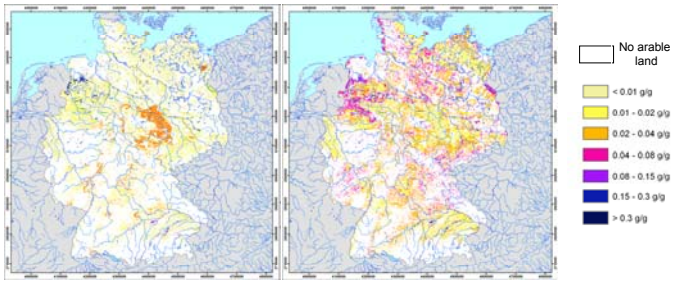
Comparison of Input Data: organic matter content (0-1m)

Derived from BÜK (i.e. 72 idealized soil profiles in Germany) Derived from OCTOP: (Map of Organic Carbon Content In Topsoils In Europe)



- **Significant differences all over Germany, which could not be explained yet!!!**

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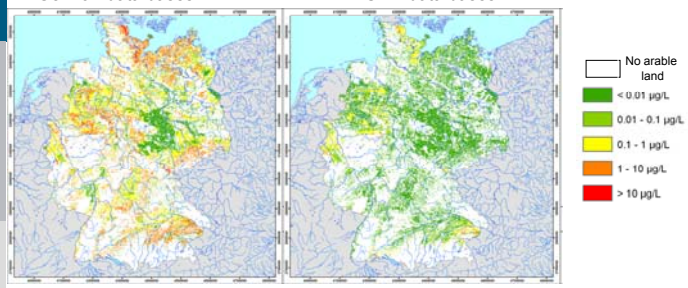
Comparison of concentrations predicted with MEATAMODEL using the two different data bases

Substance D: Kom=35 l/kg; DT50 = 20 d

German data bases EU-27 data bases



- Significant differences all over Germany, due to different input data layer "organic matter content"

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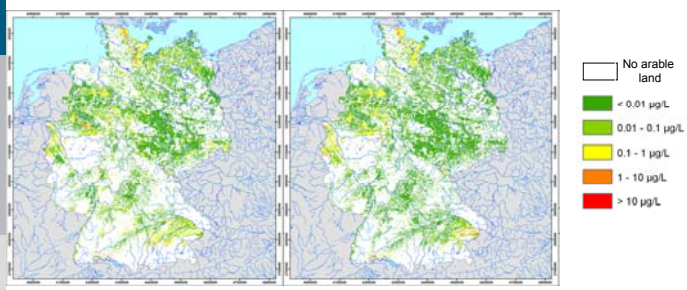
Comparison of concentrations predicted with MEATAMODEL using the OCTOP data base

German data bases + OCTOP EU-27 data bases + OCTOP



- Quite comparable results now, i.e. METAPEARL model is sensitive to organic matter content of soils
- Concentrations > 0.1 ug/l only in some regions

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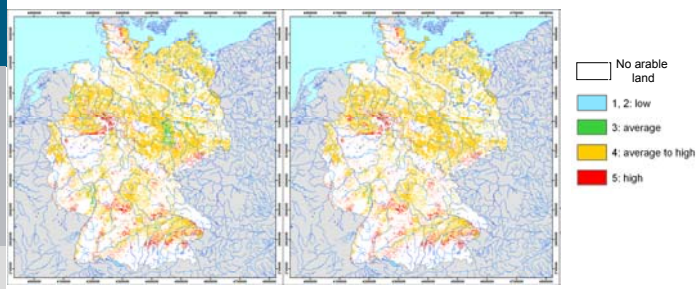
Comparison of pesticide leaching risk predicted with INDICATORMODEL using the two different data bases

German data bases | German data bases, OCTOP



- Quite comparable results in spite of different input data layer "organic matter content", i.e. INDICATORMODEL model is **NOT very sensitive** to organic matter content of soils
- high leaching risk in general

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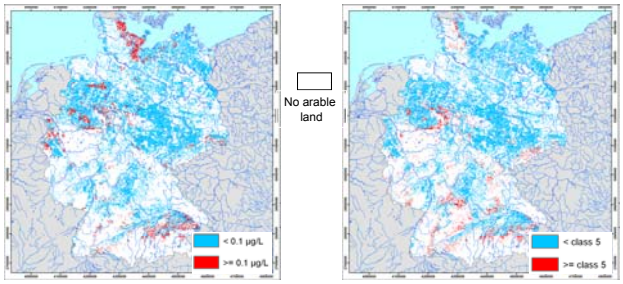
Comparison of model results using the same data base (German + Organic Carbon Content In Topsoils from OCTOP)

Metapearl | Indicator



- Regional representation is quite comparable, e.g. regions in which EU groundwater threshold value (0,1 ug/l) may be exceeded according to METAPERAL coincides with regions which display a high pesticide leaching risk according to INDICATORMODEL

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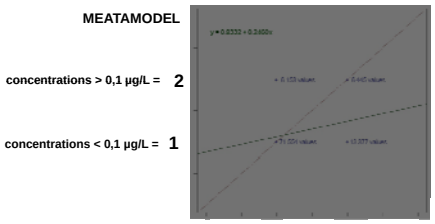
Comparison METAMODEL vs. INDICATORMODEL



Correlation of grids:

71.554 values in classes 1-4 according to INDICATORMODEL and with concentrations < 0,1 µg/l according to METAMODEL
6.445 values in class 5 according to INDICATORMODEL and with concentrations > 0,1 µg/l according to METAMODEL

Spatial agreement ca. 80%, i.e. model results show the same tendency

6.153 value in in classes 1-4 according to INDICATORMODEL and with concentrations > 0,1 µg/l according to METAMODEL
13.377 values in class 5 according to INDICATORMODEL and with concentrations < 0,1 µg/l according to METAMODEL

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Comparison with findings

METAMODEL | INDICATORMODEL

- All pixels: 95% of all values < 0,1 ug/l
- Pixels with findings: 85% of values < 0,1 ug/l
- → Predicted concentrations at monitoring sites slightly underestimated

- All pixels: 75% of all values < 0,1 ug/l
- Pixels with findings: 60% of values < 0,1 ug/l
- → Predicted leaching risk at monitoring sites slightly underestimated

Further work:

Extension to more substances

Investigate reasons for deviations between predicted concentrations and measured concentrations at locations with findings:

- **Effect of application time on predicted leaching concentrations?**
- **Effect of temporal averaging of predicted concentrations?**
- **Effect of other processes (e.g. preferential flow)?**

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Summary and Conclusions

- Uncertainty of input data (soil organic matter!)
- INDICATORMODEL: less sensitive to "soil organic matter content of soil" than METAMODEL
- Results of METAMODEL show a high leaching risk for selected areas
- Results of INDICATORMODEL show a high leaching risk in general
- Locations where METAMODEL predicts concentrations > 0.1 mg l^{-1} corresponded best with class of highest sensitivity to leaching according to INDICATORMODEL
- Predicted concentrations (METAMODEL) and classes of highest sensitivity to leaching (INDICATORMODEL) at locations with pesticide findings in groundwater were slightly underestimated
- In spite of the quite comparable results there is enough potential for further model improvement, e.g. investigation of the effects of the application time on leaching concentrations or the consideration of preferential flow…

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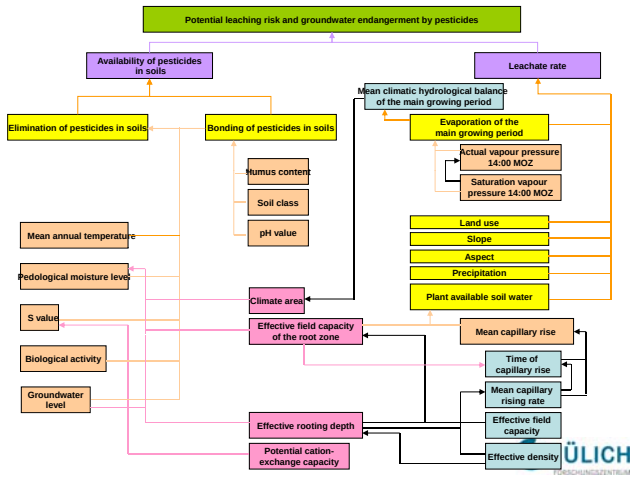
Indicator approach (Müller et al., 2004)



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Comparison with findings

Substance X: DegT50= 14 d, Kom= 30 l/kg