Pesticide leaching under climate change: the role of climate input uncertainty

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Climate Change & Pesticide Leaching

Higher temperatures $\rightarrow$ reduced pesticide leaching

More precipitation $\rightarrow$ increased pesticide leaching
Sources of Uncertainty

ES = GHG emission scenario
GCM = global climate model
RCM = regional climate model
T = temperature
P = precipitation

Introduction

Parameters

Structure

Water flow
Degradation
Sorption

Leaching

Soil properties
Hydraulic properties
Pesticide properties
Crop development

ES

Initial conditions

GCM

down-scaling

T

P

Input data

Introduction
Aims

- To assess ... 

  ... the impact of different climate scenarios ... 
  ... the relative importance of different sources of uncertainty ... 
  ... on long-term predictions of pesticide leaching under climate change
Aims

• To assess ...

... the impact of different climate scenarios ...
... the relative importance of different sources of uncertainty ...

... on long-term predictions of pesticide leaching under climate change

MACRO was run for 30 years at one site with different parameterizations and input of different climate scenarios
The MACRO-model

- Used for registration purposes in the EU
- 1D, deterministic, process-oriented
- Dual-permeability model
- Variably saturated flow, root water uptake, drain systems, pesticide degradation & sorption

Modelled Site

- Field site in SW-Sweden (Lanna)
- Tile-drained heavy clay soil
- No-till practice since 1988

Soil properties

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
<th>Org.C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>46.5</td>
<td>46.2</td>
<td>7.3</td>
<td>2</td>
</tr>
<tr>
<td>30-60</td>
<td>56.1</td>
<td>40.6</td>
<td>3.3</td>
<td>0.8</td>
</tr>
<tr>
<td>60-100</td>
<td>60.6</td>
<td>37.4</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>100-175</td>
<td>66.6</td>
<td>30.5</td>
<td>2.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Model Calibration

- Monte-Carlo approach (GLUE)
- Non-reactive tracer bromide
- Bentazone: mobile, non-persistent herbicide
- 56 acceptable parameterizations of MACRO

Climate Input Data

- Future climate: 2070-2099
- Delta change approach for temperature, precipitation, solar radiation

MACRO was run for 30 years at one site with different parameterizations and input of different climate scenarios.

<table>
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<th>MACRO-parameterizations</th>
<th>Climate Scenarios</th>
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<tbody>
<tr>
<td></td>
<td>CS1</td>
</tr>
<tr>
<td>Par 1</td>
<td>Par1-CS1</td>
</tr>
<tr>
<td>Par 2</td>
<td>Par2-CS1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Par 56</td>
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The Modelling Approach

MACRO was run for 30 years at one site with different parameterizations and input of different climate scenarios.

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<td></td>
</tr>
<tr>
<td>Par 56</td>
<td>Par56-CS1</td>
<td>Par56-CS2</td>
</tr>
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Cumulative distribution function of pesticide losses

Each curve = one CS

Each point on the curve = one parameterization
Pesticide Application Scenarios

- Scaling calibrated Koc-values to obtain different hypothetical pesticides
- Crop: winter wheat
- Annual application of 0.45kg/ha pesticide
- Application within the application window on day with < 2mm rainfall
- Output: total loss of pesticide to drains as percentage of applied dose

<table>
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<tr>
<th>Koc-Scaling Factor</th>
<th>Sorption</th>
<th>Spring Application</th>
<th>Autumn Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Ws)</td>
<td>Weak</td>
<td>WsSpr</td>
<td>WsAut</td>
</tr>
<tr>
<td>10 (Ms)</td>
<td>Moderate</td>
<td>MsSpr</td>
<td>MsAut</td>
</tr>
<tr>
<td>50 (Ss)</td>
<td>Strong</td>
<td>SsSpr</td>
<td>SsAut</td>
</tr>
</tbody>
</table>
Results – Absolute Loss

- Weakly > moderately > strongly
- Autumn > spring
- Large effect of parameter uncertainty
- Fraction of parameter uncertainty (FPU): 85-98%
- No consistent direction of change
Absolute Loss & Change in Loss

WsSpr

Cumulative distribution function

Total pesticide losses [% of applied dose]

FPU: 92% (absolute loss)
Absolute Loss & Change in Loss

**Results**

- **FPU:** 92% (absolute loss)
- **FPU:** 54.9% (change in loss)

**Charts**

- **WsSpr**
  - Reference climate
  - Climate scenarios
  - Ensemble prediction

**Axes**

- **Cumulative distribution function**
  - Total pesticide losses [\% of applied dose]
  - Changes in total pesticide losses

**Graphs**

- **Left graph:** Cumulative distribution of total pesticide losses for different climate scenarios compared to reference climate.
- **Right graph:** Cumulative distribution showing changes in total pesticide losses across climate scenarios.
Absolute Loss & Change in Loss

FPU: 92% (absolute loss)

FPU: 54.9% (change in loss)
Probabilistic Ensemble Predictions

Results
Conclusions

- **Parameter uncertainty** dominates predictions of absolute losses.

- **Climate input uncertainty** is very important for predictions of changes.
  → apply an ensemble of climate scenarios.

- Deterministic approach with 1 parameterization seems sufficient for predictions of **average changes** in leaching loss (all mobile and all spring-applied pesticides).
  - Probabilistic assessments of changes require an ensemble of climate scenarios + different parameterizations.
Thank you for your attention!

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Steffens et al. (2013). Modelling pesticide leaching under climate change: parameter versus climate input uncertainty. HESS-Discussions