Assessment of the environmental fate of the herbicides Metazachlor & Flufenacet with the SWAT model

A. Dietrich, U. Ulrich and N. Fohrer
Project background

Development of management options to reduce herbicide loads in a rural watershed

funded by the State Agency for Agriculture, Environment and Rural Areas (LLUR) from 2010 - 2012
Model application

Reduction of herbicide entry in water bodies

Calibration phase
- Water balance
- Herbicide fate

Output

Management

Impact of pcp pattern

mm/d | Basis | dry | moist
---|---|---|---
Ø | 3.5 | 0.1 | 8.9
Range | (0-33) | (0-2) | (0-71)
Study Area – Rural lowland catchment Kielstau

**Low hydraulic gradients, near-surface groundwater**
- 2 % Slope on average

**High potential for water retention**
- Riparian wetlands and interaction between groundwater & surface water
- Depression areas
- 1 Lake

**Anthropogenic influences**
- Fertilizer and pesticides application
- 5 sewage treatment plants
- River regulations
- Drainages

Area: 50 km²
Mean T: 8.2 °C
PCP: 870 mm/a

27-79 m ASL
56 % arable land
30 % grassland / fallow
9 % forest
50 % Stagnic Luvisols
38 % drained area

(FOHRER ET AL. 2007)
Setup of SWAT 2009

Initial Setup

Climate (1993 – 2009)
Precipitation, Wind, Humidity, Temperature DWD (2010)

Topography (DEM 5x5 m)
LVERMA (2005)

Land use (mapping in 2008)
GOLON (2009)

Soils (1:200.000)
BGR (1999)

Calculating ALPHA_BF
(Baseflow Program; ARNOLD ET AL. 1995)

Subbasins: 17
HRU: 938
Thresholds: (0% land use, 20% soil, 20% slope)
Drain input:
- Artificial drained areas calculated after Fohrer et al. (2007)
- Via soil properties (Ksat, AWC)

Depression input:
- After the approach by Kiesel et al. (2010)
- Input as Wetlands
Other

Winter cereals

RAPE WWHT WBAR
POTA WWHT WBAR
RAPE WWHT WWHT
Maize Maize BARL

Land use (mapping in 2008, GOLON 2009)

Department of Hydrology and Water Resources Management - Fohrer et al.
• Measurements at the outlet by ULRICH 2010, LLUR 2010
  MET: 2008 (09/01-11/30/2008)
  FLU: 2009 (09/24-12/05/2009)

• Farmer interviews:
  - application date, products
  - application amount
    - MET: 52 % of rape fields
    - FLU: 43 % of winter cereal fields


<table>
<thead>
<tr>
<th>Warm-up</th>
<th>Validation period</th>
<th>Calibration period</th>
</tr>
</thead>
</table>

Discharge
Metazachlor
Flufenacet
### Selected herbicide properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Metazachlor</th>
<th>Flufenacet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water solubility [mg/l]</td>
<td>450</td>
<td>56</td>
</tr>
<tr>
<td>Sorptivity [$K_{oc}$ ml/g]</td>
<td>220</td>
<td>354</td>
</tr>
<tr>
<td>Persistence [$DT_{50soil}$ d]</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>Persistence [$DT_{50Water}$ d]</td>
<td>216</td>
<td>54</td>
</tr>
<tr>
<td>Crops</td>
<td>Oil seed rape (RAPE)</td>
<td>Winter grain (WHHT, WBAR)</td>
</tr>
<tr>
<td>Simulation year</td>
<td>2008 (24 d)</td>
<td>2009 (36 d)</td>
</tr>
<tr>
<td>Application amount</td>
<td>0.7 kg/ha</td>
<td>0.36 kg/ha</td>
</tr>
</tbody>
</table>

- Mobile, low sorptivity in soil
- Moderately mobile and medium sorptivity
Discharge simulation

Validation period

 Calibration period
Sensitivity of pesticide properties

Soil absorption coefficient

Half live foliage

Half live soil

Wash off fraction
Sensitivity of pesticide properties

Application efficiency
Percolation efficiency
Metazachlor loads

NSE: 0.68, $r^2=0.62$
Flufenacet loads

NSE: 0.13, $r^2=0.51$
Analysis of potential entry pathways

Flufenacet entry pathways

Metazachlor entry pathways

- Surface runoff
- Tile drainage flow
- Lateral flow
- Groundwater flow
Erosion assessment
**BMP Analysis**

- Calibration phase
- Water balance
- Herbicide fate

**Output**

**Reduction of herbicide entry in water bodies**

**Scenarios**

- Management
- Impact of pcp pattern

<table>
<thead>
<tr>
<th>mm/d</th>
<th>Basis</th>
<th>dry</th>
<th>moist</th>
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<tbody>
<tr>
<td>Ø</td>
<td>3.5</td>
<td>0.1</td>
<td>8.9</td>
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<tr>
<td>Range</td>
<td>(0-33)</td>
<td>(0-2)</td>
<td>(0-71)</td>
</tr>
</tbody>
</table>
Management restrictions

• 1. min. distance to stream at application:
  – 5 m, 10 m, 20 m if slope > 1.75 %

• 2. drained areas
  – a. only half of the appl. amount on drained areas
  – b. no application on drained areas
<table>
<thead>
<tr>
<th></th>
<th>Basis run</th>
<th>Distance to stream</th>
<th>Appl. On Tile Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 m</td>
<td>10 m</td>
<td>20 m</td>
</tr>
<tr>
<td>True pcp</td>
<td>15.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>moist</td>
<td>31.68</td>
<td>19.73</td>
<td>17.01</td>
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<tr>
<td>dry</td>
<td>0.42</td>
<td>0.42</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1/2 Drain</td>
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<td></td>
<td></td>
<td></td>
<td>12.86</td>
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<td></td>
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<td>26.29</td>
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<td></td>
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<td>0.42</td>
</tr>
</tbody>
</table>
Conclusion: pesticide project

- Satisfying representation of herbicide fate and BMPs
- Weather conditions during/after application are essential for effectiveness of BMP
- Under moist conditions application on drained areas should be restricted and max. distance to stream kept
- Under dry conditions no visible effect of BMP for MET
Conclusion: SWAT model

- Distribution of application time is crucial
- AP_EF and PERCOP are very sensitive
- Herbicide properties have low sensitivities
- No degradation in groundwater so far
- No consideration of transformation product
Assessment of the Environmental Fate of the Herbicides Flufenacet and Metazachlor with the SWAT Model
Nicola Fohrer, Antje Dietrich, Olga Kolychalow and Uta Ulrich
Journal of Environmental Quality 2013
0: 0: - doi:10.2134/jeq2011.0382

Kielstau (Springer, 2007)
Scenarios: reduction of herbicides on drained areas