Modelling the fate of pesticides in vegetated filter strips using VFSMOD-W

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Overview

- Including risk mitigation into risk assessment
- VFSMOD-W model to simulate pesticide transfer through vegetated filter strips
- Generation of European scenarios for vegetated filter strips
- Soil conditions within the strip
- Outlook
Incorporation of mitigation into risk assessment

- Established practice, e.g. no-spray zones to reduce aquatic exposure via spray drift
- Requirement for methods to mitigate surface runoff strongly signposted
  - FOCUS Landscape and Mitigation
  - PPR Opinion on FOCUS LM
- Clear principles for implementation
  - Mitigation measure must be effective and practicable
  - Requires an accepted approach to incorporate into the estimate of exposure
VFSMOD-W: model to describe reduction in pesticide transfer across a vegetated filter strip

Predicted vs. measured reductions in pesticide transfer across vegetated filter strips (Sabbagh et al., 2009):
- development (n=47; left-hand figure)
- evaluation (n=120; right-hand figure) datasets
Use of VFSMOD-W in regulatory modelling

Explore the integration of the vegetated filter strip model VFSMOD-W into exposure assessment

- Mechanistic basis
- Validation
- Documentation and version control
- Fit with existing tools (FOCUS-PRZM)
Software development

FOCUS PRZM → VFSMOD-W → FOCUS TOXSWA

SWAN

Edge-of-field runoff → Interception in VFS → Fate in surface water
Requirements for regulatory modelling

- Standardisation
- Conservatism
- Transparency

Use agreed parameter sets (scenarios) based on robust analysis of conditions within the target area.
EU VFS scenario development project

Objective:

Analyse European datasets to develop representative scenarios for VFSMOD-W for use in simulating the efficiency of vegetated filter strips
Step 1 – Sensitivity analysis

- Existing analysis based on field experiments reported in the literature
- Two soil types and six pesticides with a range of different properties
- Two approaches to sensitivity analysis
  - Screening method - Morris
  - Variance based – extended Fourier analysis

Muñoz-Carpena et al. (2010). JEQ 39:630-641
## Step 2 – parameter separation (examples)

<table>
<thead>
<tr>
<th>Sensitive parameters</th>
<th>Insensitive parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Vegetation</td>
</tr>
<tr>
<td>- saturated hydraulic</td>
<td>- spacing of stems</td>
</tr>
<tr>
<td>conductivity (<strong>K</strong>&lt;sub&gt;sat&lt;/sub&gt;)</td>
<td></td>
</tr>
<tr>
<td>- saturated water content</td>
<td>- height</td>
</tr>
<tr>
<td>(<strong>θ</strong>&lt;sub&gt;sat&lt;/sub&gt;)</td>
<td></td>
</tr>
<tr>
<td>Sediment</td>
<td>- hydraulic resistance</td>
</tr>
<tr>
<td>- average diameter of</td>
<td></td>
</tr>
<tr>
<td>particles</td>
<td></td>
</tr>
<tr>
<td>- organic carbon content</td>
<td></td>
</tr>
<tr>
<td>- clay content</td>
<td></td>
</tr>
</tbody>
</table>
Step 3 – insensitive parameters

- For example: average distance between stems of grass...

- Assess likely range in values

- Propose default values relevant to the Step 3 scenarios

  - Appropriate level of conservatism

  - Documentation to justify selection from published sources
Step 4 – sensitive parameters

- Assess variation across the European Union
- GIS analysis within the framework of FOCUS Step 3 scenarios
- Generate distributions for each parameter
  - Support selection of conservative values
  - Allow testing of alternative assumptions
  - Facilitate higher-tier modelling, e.g. probabilistic approaches
Variance-based sensitivity

Muñoz-Carpena et al., 2010
Probability distributions for Ksat

<table>
<thead>
<tr>
<th>scenario</th>
<th>n</th>
<th>sigma</th>
<th>mu</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>356</td>
<td>0.756</td>
<td>2.58</td>
</tr>
<tr>
<td>R2</td>
<td>75</td>
<td>0.694</td>
<td>4.35</td>
</tr>
<tr>
<td>R3</td>
<td>175</td>
<td>0.945</td>
<td>3.45</td>
</tr>
<tr>
<td>R4</td>
<td>223</td>
<td>0.859</td>
<td>3.62</td>
</tr>
</tbody>
</table>

lognormal distribution
Ksat as variable and area as density
Deriving conservative values for Ksat and θsat

- N for each R scenario small (75-356)
- Two parameters are strongly correlated
- Undertake runs with VFSMOD-W for all soil units and use results to derive conservative values
Deriving conservative values for Ksat and θsat

- Separate simulations for:
  - The four FOCUS R scenarios (n = 75 – 356)
  - Storm events with 30 mm rain over 1 hour or 8 hours
  - Pesticides with Koc of 100 L/kg or 10,000 L/kg

- Each run reads Ksat, θsat and θfc for one soil unit
  - θfc used as fixed (and correlated) input for initial water content

- All other parameters held at constant values relevant to the FOCUS R scenario
Distribution in VFS efficiency for FOCUS R1

Large event (30 mm); VFS at field capacity prior to event

[Graph showing the distribution in VFS efficiency for FOCUS R1 with different event durations and Koc values.

- 8 hour event, Koc=10,000
- 8 hour event, Koc = 100
- 1 hour event, Koc = 10,000
- 1 hour event, Koc = 100

Legend:
- Blue line: 8 hour event, Koc=10,000
- Green line: 8 hour event, Koc = 100
- Red line: 1 hour event, Koc = 10,000
- Orange line: 1 hour event, Koc = 100]
Overview of simulation results

- **Relative vulnerability ranking of soil units:**
  - Independent of event size (prelim. runs 20 vs. 30 mm)
  - Virtually identical for the two pesticides when event length held constant
  - Some differences with differing event duration, but differences are very small at either end of the distribution
90th percentile worst-case for R1 pilot runs

Ksat drives the vulnerability of the scenario

<table>
<thead>
<tr>
<th>worst-case %tile</th>
<th>Ksat</th>
<th>θsat</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 mm in 1 hr</td>
<td>30 mm in 8 hr</td>
<td>(m/s)</td>
</tr>
<tr>
<td>89.0</td>
<td>89.0</td>
<td>1.19 x 10^{-6}</td>
</tr>
<tr>
<td>89.3</td>
<td>89.7</td>
<td>1.13 x 10^{-6}</td>
</tr>
<tr>
<td>89.7</td>
<td>89.3</td>
<td>1.12 x 10^{-6}</td>
</tr>
<tr>
<td>89.9</td>
<td>89.9</td>
<td>1.15 x 10^{-6}</td>
</tr>
<tr>
<td>90.2</td>
<td>90.2</td>
<td>9.56 x 10^{-7}</td>
</tr>
<tr>
<td>90.4</td>
<td>90.7</td>
<td>9.05 x 10^{-7}</td>
</tr>
<tr>
<td>90.7</td>
<td>90.4</td>
<td>1.32 x 10^{-6}</td>
</tr>
<tr>
<td>91.0</td>
<td>91.0</td>
<td>1.10 x 10^{-6}</td>
</tr>
</tbody>
</table>
Changes to $K_{sat}$ and $\theta_{sat}$ under permanent grass

- Largest dataset is from SEISMIC for soil series in England and Wales
- SEISMIC reports $K_{sat}$ and $\theta_{sat}$ for each soil series and distinguishes between permanent grassland and arable land
- Use information to refine estimates of arable $K_{sat}$ and $\theta_{sat}$ from batch analyses?
  - Account for influence of grass vegetation on soil properties
Theta sat

$y = 1.1058x$

$R^2 = 0.2344$

Residuals (Pred - Obs)

Theta sat (cm/day) Permanent grassland

Theta sat (cm/day) Arable land
European vegetated filter strip scenarios

- Representative VFSMOD-W scenarios for use in conjunction with each FOCUS R scenario
- Available for use in Step 4 calculations
- Underlying data accessible

Beta-version of SWAN incorporating VFSMOD-W available now; full implementation mid-2012

Discussions with EFSA / Member States on uptake into risk assessment
With thanks to the co-authors and project steering group