What is the environmental impact of plant protection in European pomefruit orchards?

RA3.3 – Environmental risk and benefit assessment

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Contents

Objective
To assess the environmental impact of plant protection in four orchard regions on landscape level

Risk assessment was conducted with SYNOPS
  Risk assessment on field level
  Risk assessment on landscape level

GIS Database in the orchard regions

Application of SYNOPS in the orchard regions
  Results of different scenarios in the three orchard regions
SYNOPS

Exposure

- Soil
- Surface water
- Non target plants

Toxicity

- Earthworm
- Daphnia, algae, fish, lemina
- Bee

Risk (ETR) = \[
\frac{\text{calculated Exposure}}{\text{Toxicity}}
\]

Model application within ENDURE

SYNOPS (SustainOS)

- Region specific worst cases scenarios
- Application calendars from:
  - Orchard system definitions (BS, AS, IS)

SYNOPS-GIS

- Field specific GIS-data
  - Application calendars form:
  - Field based surveys
  - Orchard system definitions (BS, AS, IS)
Risk assessment of application strategies

chronic aquatic risk

ingredient 1
- application 1
- application 2
- application 3

ingredient 2
- application 1
- application 2
Risk assessment of application strategies

chronic aquatic risk

ingredient 1
- application 1
- application 2
- application 3

\[ \text{NOEC}_{daphnia} = 0.52 \text{ mg l}^{-1} \]

ingredient 2
- application 1
- application 2

\[ \text{NOEC}_{daphnia} = 0.00002 \text{ mg l}^{-1} \]
Aquatic risk

\[
ETR_{\text{aquatic}} = \max(ETR_{\text{algae}}, ETR_{\text{daphnia}}, ETR_{\text{fish}}, ETR_{\text{lemna}})
\]
GIS-based risk assessment with SYNOPS

SYNOPS calculates the risk potential of all orchards within the considered region.

➔ regional approach
  - input data for all fields in the considered region have to be available on field level
  - the calculated field based risk potentials are then analysed or aggregated in the spatial dimension

➔ geographical databases + GIS procedures
GIS-based risk assessment with SYNOPS

The average slope is calculated for each field using a digital elevation model.

Long-term precipitation and temperature (1971-2000) is derived from digital climate maps or from regional climate stations.

Fruit crops are distributed randomly according to agricultural statistics.

The application strategies are distributed randomly according to a field based survey.

The main soil types are derived from a digital soil maps.

Minimal distance from the field to the edge of the surface water is derived from a land cover database.

Geographical Database, high resolution data set on land use and land cover.
available spatial databases

<table>
<thead>
<tr>
<th>country region</th>
<th>land cover data and surface water</th>
<th>slope</th>
<th>climate</th>
<th>soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>ATKIS</td>
<td>digital elevation model (25m)</td>
<td>regional climate data (5 stations)</td>
<td>digital soil map</td>
</tr>
<tr>
<td>Lake Constance</td>
<td>area=10248 ha orchards=4232</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Swisstopo</td>
<td>digital elevation model (2m)</td>
<td>regional climate data (1 station)</td>
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<tr>
<td>Lake Constance</td>
<td>area=6370 ha orchards=6230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>digitalized from areal photos</td>
<td>Hair database (10*10 km average values)</td>
<td>regional climate data (1 station) (10*10 km)</td>
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<tr>
<td>Rhone Valley</td>
<td>area=1871 ha orchards=3157</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Italy</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; level of Corine Land cover classification</td>
<td>digital elevation model (10m)</td>
<td>regional climate data (interpolated)</td>
<td>digital soil map</td>
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<tr>
<td>Emilia-Romagna</td>
<td>area= 10135 ha orchards (artificial)=5561</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(part Ferrara)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>No GIS data</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kromme Rijn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>No GIS data</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lleida</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>country / region</td>
<td>Survey</td>
<td>years</td>
<td>number of application schedules per year</td>
<td>defined systems (RA. 2.5)</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------</td>
<td>---------</td>
<td>-------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Germany</td>
<td>NEPTUN field based</td>
<td>01, 04, 07,</td>
<td>&gt;50</td>
<td>BS, AS1, AS2, IS</td>
</tr>
<tr>
<td>Lake Constance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>field based (not available for publication)</td>
<td>01, 02, 03, 04, 05</td>
<td>&gt;250</td>
<td>BS, AS1, AS2, IS</td>
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<td>Lake Constance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>“zone 13” field based</td>
<td>06, 07, 08</td>
<td>&gt;70</td>
<td>BS, AS1, AS2, IS</td>
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<tr>
<td>Rhone Valley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>recommendations from advisor</td>
<td>09</td>
<td>&gt;15</td>
<td>-</td>
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<tr>
<td>Emilia-Romagna</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Orchard regions
### Rating of chronic aquatic risk

<table>
<thead>
<tr>
<th>Four risk categories for SYNOPS results</th>
<th>Chronic risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low risk</td>
<td>ETR&lt;0.1</td>
</tr>
<tr>
<td>low risk</td>
<td>0.1&lt; ETR&lt;1</td>
</tr>
<tr>
<td>medium risk</td>
<td>1&lt; ETR&lt;10</td>
</tr>
<tr>
<td>high risk</td>
<td>ETR &gt;10</td>
</tr>
</tbody>
</table>
chronic aquatic risk assessed with SYNOPS

Lake Constance
- Germany

Lake Constance
- Switzerland

Rhone Valley
- France
Spatial aggregation of the risk potential

Evaluation based on fixed spatial units (communities, water sheds, counties)

Frequency distribution of risk indices

- 90th percentile
- Fraction orchard area with medium and high risk
- Mean + std
- xth percentile

Evaluation for the whole orchard region on statistical value representing the regional risk
aquatic risk on landscape level: impact of product specific drift mitigation requirements

• Region: Lake Constance, Germany

• Pesticide applications from field based surveys (NEPTUN) in the year 2001, 2004, 2007

• random distribution of the application calendars (n= 42-112)

Scenario 1: No (0%) producer follows the product specific drift mitigation requirements

Scenario 2: All (100%) producers follow the product specific drift mitigation requirements
aquatic risk potential: Lake Constance
product specific drift mitigation requirements

No (0%) producer follows the product specific drift mitigation measures

All (100%) producer follow the product specific drift mitigation measures

NEPTUN 2001
all applications

NEPTUN 2004
all applications

NEPTUN 2007
all applications

<0.05
0.05-0.10
0.10-0.50
0.50-1.00
1.00-5.00
5.00-10.0
>10.0
### Aquatic Risk Potential: Lake Constance

**Product Specific Drift Mitigation Requirements**

<table>
<thead>
<tr>
<th>Year</th>
<th>Risk Reduction</th>
<th>no DR</th>
<th>DR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 vs. 2007</td>
<td>no DR</td>
<td>-75.2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DR</td>
<td>-64.0%</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>no DR</td>
<td>-92.6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DR</td>
<td>-89.0%</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>no DR</td>
<td>-89.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DR</td>
<td>-89.3%</td>
<td></td>
</tr>
</tbody>
</table>

#### Aquatic Risk (90th Percentile)

- **Without DR**
  - 2000: 8.416
  - 2002: 3.809
  - 2004: 2.085
  - 2006: 0.621
  - 2008: 0.420

- **With DR**
  - 2000: 8.416
  - 2002: 3.809
  - 2004: 2.085
  - 2006: 0.621
  - 2008: 0.420

**Level of Negligible Risk**

- 0.223

**Legend**

- Blue line: Aquatic without DR
- Orange line: Aquatic with DR
aquatic risk potential: Lake Constance
product specific drift mitigation requirements

Lake Constance (Germany)

fraction of farmers not following the labeled drift mitigation requirements
level of negligible risk
aqueous risk on landscape level: application calendars form defined orchard systems

- Regions: Lake Constance-GER, Lake Constance-CH, Rhone valley
- Pesticide applications from orchard system definitions BS, AS-1, AS-2
- Random distribution of the application calendars of each system (n=4-10)
- Random distribution of the defined drift mitigation measures

Scenario 1: Baseline System (BS) is applied on all orchards (100%)
Scenario 2: Advanced System 1 (AS-1) is applied on all orchards (100%)
Scenario 3: Advanced System 2 (AS-2) is applied on all orchards (100%)
**aquatic risk on landscape level:**
definition of drift mitigation measures for orchard systems

<table>
<thead>
<tr>
<th></th>
<th>0% drift reduction</th>
<th>50% drift reduction</th>
<th>75% drift reduction</th>
<th>90% drift reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Constance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>18%</td>
<td>25%</td>
<td>43%</td>
<td>15%</td>
</tr>
<tr>
<td>AS1</td>
<td>0%</td>
<td>9%</td>
<td>32%</td>
<td>59%</td>
</tr>
<tr>
<td>AS2</td>
<td>0%</td>
<td>0%</td>
<td>11%</td>
<td>89%</td>
</tr>
<tr>
<td><strong>Lake Constance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>AS1</td>
<td>0%</td>
<td>25%</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>AS2</td>
<td>0%</td>
<td>0%</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td><strong>Rhone Valley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>54%</td>
<td>42%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>AS1</td>
<td>0%</td>
<td>9%</td>
<td>46%</td>
<td>45%</td>
</tr>
<tr>
<td>AS2</td>
<td>0%</td>
<td>0%</td>
<td>18%</td>
<td>82%</td>
</tr>
</tbody>
</table>
aquatic risk potential: Lake Constance (GER)
application calendars form orchard system definitions

Reduction compared to BS

<table>
<thead>
<tr>
<th></th>
<th>aquatic risk, 90th percentile</th>
<th>fraction of area with ETR&gt;1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1</td>
<td>-88.7%</td>
<td>-87.8%</td>
</tr>
<tr>
<td>AS2</td>
<td>-95.0%</td>
<td>-89.5%</td>
</tr>
</tbody>
</table>

fraction of orchard area with ETR_{chronic}>1

22.7% 2.8% 2.4%

Reduction compared to BS aquatic risk, 90th percentile fraction of area with ETR>1

AS1 88.7% 87.8%
AS2 95.0% 89.5%
aquatic risk potential: Lake Constance (CH)
application calendars form orchard system definitions

Reduction compared to BS
<table>
<thead>
<tr>
<th></th>
<th>aquatic risk, 90th percentile</th>
<th>fraction of area with ETR&gt;1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1</td>
<td>-99.3%</td>
<td>-100%</td>
</tr>
<tr>
<td>AS2</td>
<td>-99.4%</td>
<td>-100%</td>
</tr>
</tbody>
</table>

fraction of area with ETR>1

chronic aquatic risk, 90th percentile

Reduction compared to BS
aquatic risk potential: Rhone Valley (FR)
application calendars form orchard system definitions

Reduction compared to BS

<table>
<thead>
<tr>
<th></th>
<th>aquatic risk, 90th percentile</th>
<th>fraction of area with ETR &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS1</td>
<td>-87.5%</td>
<td>-21.1%</td>
</tr>
<tr>
<td>AS2</td>
<td>-99.9%</td>
<td>-100.0%</td>
</tr>
</tbody>
</table>
aquatic risk on landscape level:
successive introduction of the defined orchard systems

• Regions: Lake Constance-GER, Lake Constance-GER, Rhone valley

• The 100% scenarios are not realistic.

• A mixture of available scenarios depending on the availability and acceptance of the orchard systems is more realistic.

• random distribution of the defined systems according to the following scenarios:

  **Scenario 1**  in 0-2 years:  70% BS, 20% AS-1 and 10% AS-2
  **Scenario 2**  in 2-5 years:  50% BS, 30% AS-1 and 20% AS-2
  **Scenario 3**  in 5-10 years:  20% BS, 50% AS-1 and 30% AS-2
aquatic risk potential: Lake Constance (GER)
successive introduction of the defined orchard systems

**frequency distribution of risk indices**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Aquatic Risk, 90th Percentile</th>
<th>Fraction of Area with ETR &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>22.7%</td>
<td>22.7%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>16.4%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>12.6%</td>
<td>12.6%</td>
</tr>
</tbody>
</table>

**Reduction compared to BS**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Aquatic Risk, 90th Percentile</th>
<th>Fraction of Area with ETR &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>-36.98%</td>
<td>-27.78%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-48.69%</td>
<td>-44.43%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>-79.69%</td>
<td>-70.81%</td>
</tr>
</tbody>
</table>

**fraction of orchard area with ETR > 1**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>100% BS</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>100% AS1</th>
<th>100% AS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>0.00%</td>
<td>2.66%</td>
<td>1.68%</td>
<td>1.36%</td>
<td>0.54%</td>
<td>0.30%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>0.54%</td>
<td>2.66%</td>
<td>1.68%</td>
<td>1.36%</td>
<td>0.54%</td>
<td>0.30%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.54%</td>
<td>2.66%</td>
<td>1.68%</td>
<td>1.36%</td>
<td>0.54%</td>
<td>0.30%</td>
</tr>
</tbody>
</table>
aquatic risk potential: Lake Constance (CH)
successive introduction of the defined orchard systems

Scenario 1
BS (70%)
AS1 (20%)
AS2 (10%)

Scenario 2
BS (50%)
AS1 (30%)
AS2 (20%)

Scenario 3
BS (20%)
AS1 (50%)
AS2 (30%)

frequency distribution of risk indices
chronic aquatic risk (ETR)
Switzerland, orchard systems with drift reduction

Reduction compared to BS
aquatic risk, 90th percentile fraction of area with ETR>1

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Reduction aquatic risk</th>
<th>Reduction fraction of area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>-59.38%</td>
<td>-28.66%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-78.27%</td>
<td>-49.07%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>-98.37%</td>
<td>-82.09%</td>
</tr>
</tbody>
</table>
aquatic risk potential: Rhone Valley (FR)
successive introduction of the defined orchard systems

Scenario 1
BS (70%)
AS1 (20%)
AS2 (10%)

Scenario 2
BS (50%)
AS1 (30%)
AS2 (20%)

Scenario 3
BS (20%)
AS1 (50%)
AS2 (30%)

frequency distribution of risk indices

Reduction compared to BS
aquatic risk, 90th percentile
fraction of area with ETR>1

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Reduction aquatic risk, 90th percentile</th>
<th>Reduction fraction of area with ETR&gt;1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>-49.99%</td>
<td>-15.38%</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-52.92%</td>
<td>-26.43%</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>-86.38%</td>
<td>-39.61%</td>
</tr>
</tbody>
</table>
Summary

• A detailed spatial risk analysis can be conducted with SYNOPS-GIS

• The best case of data availability are geo-referenced environmental databases on field level in combination with field based information on pesticide use

• By using successively conducted surveys for pesticide use it is possible to show temporal changes in the regional risk

• The regional impact of drift mitigation measures can be evaluated by comparing different scenarios

• Drift mitigation measures have an substantial impact on the aquatic risk

• Both Advanced Systems AS1 and AS2 show a clear improvement of the environmental risk compared to the Baseline System with a reduction of $>87\%$ for AS1 and $>95\%$ for AS2.

• Within a timeframe of 5-10 years (scenario 3) a reduction of the environmental risk by 70-89\% is realistic. The orchard area with medium and high risk is reduced by 40-80\%.
Thank you for your attention