Integrated Agricultural and Hydrological Modelling within an Intensive Livestock Region Taking Supra-regional Manure Transports into Account

Diffuse Inputs into the Groundwater Monitoring – Modelling - Management

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Structure of the Presentation

- Introduction and objectives
- Description of the agricultural economic and hydrological model network
- Model results on impacts of nutrient reductions measures taking supra-regional manure transports into account
- Conclusions and outlook
Objectives and scope of the RAUMIS, GROWA / WEKU model-network

Area differentiated status quo and impact analyses of policies aiming at reducing diffuse pollution of ground- and surface waters

- Comprehensive consideration of meso- to macroscale catchments
  - Catchments 1,000 - 100,000 km²
  - Consistent link-up of well established, operational agricultural economics and hydro(geo)logical models
  - Quantification of nutrient inputs (N and P) via all relevant diffuse input pathways

- Uniform and transferable assessment approach
  - Uniform methods arranged in tiers according to data availability
  - Uniform data base (e.g. EU wide data = minimum standard on macro scale, … )
  - Indication of data gaps and recommendations (e.g. monitoring programs)

- Support of policy decision-making
  - Impacts of nutrient reduction measures on nutrient load in rivers and on the agricultural sector (area differentiated)
  - Consideration of the downstream/upstream problematic
  - Consensual agricultural and environmental policies beyond state borders (e.g. achievement of HELCOM / PARCOM agreements)
  - Support the establishment of management plans as required by WFD

Integrated agroeconomic / hydro(geo)logic model system (RAUMIS and GROWA/WEKU)

Scenario analysis

Diffuse nitrogen surpluses

Degradation and retention

soil (DENUZ)

Degradation and retention

groundwater (WEKU)

Residence times

Water balance model (GROWA)

Separation into outtake pathways

N – leaching from soil

N – load of direct runoff

N – load of groundwater recharge

impact periods of nutrients in subsurface

“hot-spots” for diffuse pollution

N – load of groundwater runoff

disaggregation

N – leaching from soil

Residence times

Fluss

f

hn

kv

r

r

f

∇⋅−=

\sum_{j,i}^{\text{Fluss}} j,iv_{j,in,mt} l_{hn}^{f} v^{f} - r^{f} \cdot \Delta t^{f}

\text{Degradation and retention}

\frac{\alpha_{max}}{\alpha} - \frac{\alpha_{max}}{\alpha} N_{max} + \frac{\Delta t}{\alpha}

\text{Residence times}

(\text{DENUZ})
General model structure: RAUMIS

<table>
<thead>
<tr>
<th>German Agricultural Sector</th>
<th>Regional Description: Input-Output-Matrices</th>
<th>Optimization, Calibration &amp; Ex-Post-Analyses</th>
<th>Prognoses &amp; Impact</th>
<th>Policy Counselling</th>
</tr>
</thead>
</table>

Fields of application

- **Common Agricultural Policy**
  - decoupling of premiums
  - sugar market reform
  - milk market reform
- **Environmental Policy**
  - reduction of diffuse water pollution by agriculture
  - reduction of greenhouse gas emissions
  - impacts of cross compliance
- **Other**
  - impacts of global/climate change on agriculture
  - impacts of energy production from biomass on agriculture
Solution / endogenous variables / Indicators

- Agricultural land use
- Intensity of arable land and grassland use
- Marginal use / profits of agricultural area
- Agricultural income
- Livestock-/Manure-Unit density
- Nutrient balances
- Agricultural greenhouse gases
- Plant protection expenditures
- …

Nitrogen Bilancing

Nitrogen Supply to Agriculture

- Symbiotic Nitrogen Fixation (Nitrogen Harvest-Index)
- AsynbioticNitrogen Fixation (lump sum 1.4 kg/ha)
- Mineral Fertilizer (Difference between nutritional requirement of plants and manure)
- Atmospheric Deposition (lump sum 30 kg/ha)

Plant Production (Soil)
- Data from regional agricultural production statistics and surveys

Crop Yield

Manure

Animal Production (Stable)
- Data from regional animal production statistics and surveys
- Coefficients on nutrient contents in manure according to information from the BMELV

Ammonia-Emission: 40% of nitrogen from manure non-accessible for plants

Surplus (Losses), Denitrification

Surplus Plant Production

Surplus Animal Production
Regional Nitrogen Balances

Nitrogen-surplus
Base year 1999

in kg per ha AA

- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more

0 100 200 300 50 km

RAUMIS-Calculations 03/2005
P. Kreins, H. Gömann

Nitrogen Balance (reference scenario)
without supra-regional manure transports

Nitrogen-surplus
Scenario: Reference

in kg ha LF

- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more

0 50 100 150 200 km

RAUMIS-Calculations 03/2005
P. Kreins, H. Gömann
Nitrogen Balance (max. 140 kg N per ha)

Nitrogen-surplus
Szenario: max. 140 kg N-Bilanzüberschuss pro ha LF

in kg/ha LF
- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more

Nitrogen Balance (max 120 kg N per ha)

Nitrogen-surplus
Szenario: max. 120 kg N-Bilanzüberschuss pro ha LF

in kg/ha LF
- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more
Nitrogen Balance (max. 100 kg N per ha)

Nitrogen surplus
Scenario: max. 100 kg N-Bilanzüberschuss pro ha LF

in kg/ha LF
- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more

0 50 100 150 200 250 km

RAUMIS-Calculations 03/2005
P. Kreins, H. Gömann

Nitrogen Balance (max. 80 kg N per ha)

Nitrogen surplus
Scenario: max. 80 kg N-Bilanzüberschuss pro ha LF

in kg/ha LF
- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 and more

0 50 100 150 200 250 km

RAUMIS-Calculations 03/2005
P. Kreins, H. Gömann
Nitrogen Balance (max. 60 kg N per ha)

Szenario: max. 60 kg N-Bilanzüberschuss pro ha LF

in kg/ha LF
- less than 50
- 50 up to 75
- 75 up to 100
- 100 up to 150
- 150 up to

RAUMIS-Calculations 03/2005
P. Kreins, H. Gömann

Share of N-surplus leaching into surface water

Regional nitrogen discharges in surface water as shares of nitrogen surplus

less than 15
15 to 30
30 to 45
45 to 60
more than 20

RAUMIS/GROWA/WEKU-Calculations
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**Nitrogen entry into surface water**

Reference scenario | UniNbalNoTrans | UniNbalWithTrans | DiffNbalWithTrans
--- | --- | --- | ---
max. 100 kgN/ha | max. 80 kgN/ha | max. 80 kgN/ha

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**Aggregate impacts**

<table>
<thead>
<tr>
<th>Reference scenario</th>
<th>UniNbalNoTrans</th>
<th>UniNbalWithTrans</th>
<th>DiffNbalWithTrans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen surplus (ton)</td>
<td>241,155</td>
<td>201,760</td>
<td>210,951</td>
</tr>
<tr>
<td>Nitrogen discharges in surface water (kg per ha)</td>
<td>93</td>
<td>78</td>
<td>81</td>
</tr>
<tr>
<td>Agricultural labour force (1,000 LFU)</td>
<td>73.6</td>
<td>65.7</td>
<td>68.4</td>
</tr>
<tr>
<td>Livestock density (LU per ha)</td>
<td>1.4</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Supra-regional manure transport (million m³)</td>
<td>10.3</td>
<td>14.3</td>
<td></td>
</tr>
<tr>
<td>Average transport costs (Euro per m³)</td>
<td>-10.5</td>
<td>-9.8</td>
<td></td>
</tr>
<tr>
<td>Total transport costs (million Euro)</td>
<td>-109</td>
<td>-141</td>
<td></td>
</tr>
<tr>
<td>Net agricultural value added (million Euro)</td>
<td>2,606</td>
<td>2,393</td>
<td>2,465</td>
</tr>
<tr>
<td>Cost of N discharge reduction in surface water (Euro per kg N)</td>
<td>13.5</td>
<td>9.6</td>
<td>9.0</td>
</tr>
</tbody>
</table>
Conclusion and Outlook

• Comprehensive consideration of agricultural and hydro(geo)logical conditions in large catchments
  - Limited correlation between risk indicator “nitrogen surpluses from agriculture” and actual depositions of nitrogen into water bodies
  - Consideration of main diffuse input pathways and natural degradation in soil and groundwater
  - Consideration of agricultural adjustments (e.g. with supra-regional impacts)

• Further development of the model network RAUMIS, GROWA, WEKU and ...
  - Stronger regionalization to describe the units under the county level (i.e., with the help of community statistics, ICAS, GIS – Daten (remote sensing, soil)
  - Integration of further models in the model-network (e.g. MONERIS)
  - Implementation of further environmental processes
  - Validation of the model network based on measured values
  - Application of the methodology to other German or European river catchments is possible

• Impact assessment of various agricultural and environmental policies social and economic consequences for agriculture (according to Art. 9 WFD)

Thanks!
Any questions?