Coupling SWAT with In-stream Models for an Integrated Assessment of Sediment Transport

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Outline

1. Background and scope of the project
2. Model coupling
3. Modeling water fluxes on three scales
4. Modeling sediment fluxes on three scales
5. Discussion
## Integrated ecohydrological river basin assessment

<table>
<thead>
<tr>
<th>Reality</th>
<th>Abstraction</th>
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<tbody>
<tr>
<td>![Map](Kirchweddelbek (SH), Foto: U. Holm)</td>
<td><img src="HEC-RAS" alt="HEC-RAS" /> <img src="ADH" alt="ADH" /> <img src="SWAT" alt="SWAT" /></td>
</tr>
<tr>
<td>Catchment processes</td>
<td>Habitat</td>
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<td>In-stream processes (1D, 2D)</td>
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**Kirchweddelbek (SH), Foto: U. Holm**
The in-stream models

**HEC-RAS**

Widely used hydraulic model for simulating open channel flow and sediment processes in river networks

ArcGIS interface available

(USACE 2010)

**ADH**

Adaptive Hydraulics model for simulating 2D-shallow water problems with sediment transport on a triangular finite element mesh

Dynamic adaption of mesh resolution during simulation

ArcGIS interface had to be programmed

(Berger et al. 2010)
Why additional in-stream models?

Supplies spatially distributed results from the catchment.

No differentiation of stream properties beyond subbasin.

Supplies spatially distributed results at cross sections.

Too coarse to model in-stream morphodynamics for habitat assessments.

Supplies spatially distributed results on points.

Very high resolution in the stream possible.
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Kielstau catchment, UNESCO demosite for Ecohydrology

- 50km²
- 8.2°C
- 870mm/a
- Low hydraulic gradients, near-surface groundwater
- Agricultural land use
- Urban influence
Process depiction on three scales

- ADH: Velocity, Depth, Sediment
- HEC-RAS: Velocity, Depth, Sediment
- SWAT: Flow, Sediment
ArcGIS 9.2 PYTHON script:

- SWAT tributary flows (output.rch) are transferred to the according HEC-RAS cross sections.
- SWAT tributary sediment loads (output.sub) are transferred to the according HEC-RAS cross sections.
- SWAT water temperature is transferred to HEC-RAS time series.
Model coupling

- HEC-RAS
- ADH

ADH mesh

HEC-RAS channel

HEC-RAS cross section (xs)

10m scale
HEC-RAS flow values and loads of each grain fraction are transferred from the cross section to the ADH inflow mesh nodes for each daily time step.
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Catchment hydrology

$r^2 = 0.82$

$NS = 0.78$

PCP

Observed

Modelled (calibration)

PCP

Observed

Modelled (verification)

Flow [m³/s]

Sinks

Drains

$Sinks$
1D stream hydraulics

Dep. of Hydrology and Water Resources Management – Fohrer et al.
1D stream hydraulics

Water depth

![HEC-RAS depth comparison](image)

Flow velocity

![HEC-RAS velocity comparison](image)

24 flow scenarios: $Q_{\text{min}} = 0.06 \text{m}^3/\text{s}$, $Q_{\text{max}} = 1.26 \text{m}^3/\text{s}$
2D stream hydraulics

- depth cross sections
- depth and velocity cross sections

[Diagram showing a stream with depth and velocity cross sections indicated by green and red lines, respectively.]
2D stream hydraulics

Water depth

Flow velocity

1 flow scenario: \( Q = 0.73 \text{m}^3/\text{s} \)
2D stream hydraulics

- Green: depth cross sections
- Red: depth and velocity cross sections

1 2 3
2D hydraulics – cross sections

Water depth [m]

Flow velocity [m/s]

Distance from left bank [m]

1

2

3

modelled

measured
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Daily sediment loads in lowland catchments

Field 15%
Drains 15%
River 70%

R²=0.63  NSE=0.57
R²=0.65  NSE=0.58
1D stream sediment - temporal

\[ r^2 = 0.31, \text{ monthly } r^2 = 0.68 \]
1D stream sediment - spatial

Channel change in 4 years (2006 to 2009)

- 6.6 cm
0 cm
+ 3.0 cm
2D stream sediment

Bed displacement 01.-30. April 2008

Bed displacement [m]
-0.13 - -0.08
-0.08 - -0.05
-0.05 - -0.04
-0.04 - -0.02
-0.02 - -0.01
0.00 - 0.01
0.01 - 0.02
0.02 - 0.04
0.04 - 0.06

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Discussion

• The combined SWAT – HEC-RAS model is a feasible way to model different sediment pathways over yearly periods in a reasonable resolution.

• The shown temporal and spatial 1D sediment results are plausible and can be used to identify erosion and deposition sections.

• The combined HEC-RAS – ADH model can simulate detailed substrate conditions, but with a high computational demand.

• The shown spatial 2D sediment results need further calibration, as current displacement rates are too high.

• The capability of the model system to depict hydraulic- and substrate conditions on different scales based on catchment and in-stream properties is valuable for habitat assessments.
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Thank you for your attention