Collaborative Research Centre/Transregio 38 (SFB/TRR 38)

The artificial catchment Chicken Creek: A priori predictions in small catchment hydrology

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H. Flühler (ETH Zurich)
Artificial catchments

- well defined boundary (e.g. identification of flow paths) and initial conditions
- knowledge about degree of heterogeneity
- approximation to hydrological systems in their initial phase
Lignite mining landscape in Lusatia, East Germany
Transregional Collaborative Research Centre (SFB/TRR 38)

“Structures and processes of the initial ecosystem development phase in an artificial water catchment“

Partners:
1. BTU Cottbus
2. TU München
3. ETH Zürich

Financed since 07/2007
12-year perspective
Structures and Processes for Ecosystem Characterization

**Organisms (Producers, Consumers, Destruents)**

<table>
<thead>
<tr>
<th><strong>Initial substrate/Soil</strong></th>
<th><strong>Water</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface of mineral soil matter</strong></td>
<td><strong>Surface structures, erosion structure</strong></td>
</tr>
<tr>
<td><strong>Organic soil matter</strong></td>
<td><strong>Erosion, settlement, sorting</strong></td>
</tr>
<tr>
<td><strong>Soil aggregates, pores</strong></td>
<td><strong>Water channels</strong></td>
</tr>
<tr>
<td><strong>Weathering, sorption, interactions with solution</strong></td>
<td><strong>Development of soil morphology, transport</strong></td>
</tr>
<tr>
<td><strong>Accumulation, stabilization, hydrophobicity</strong></td>
<td><strong>Preferential flow paths, pore space</strong></td>
</tr>
<tr>
<td><strong>Aggregation forming, infiltration, water flow, transport</strong></td>
<td><strong>Infiltration, water flow, transport</strong></td>
</tr>
<tr>
<td><strong>Colony formation patterns</strong></td>
<td><strong>Groundwater</strong></td>
</tr>
<tr>
<td><strong>Habitats, food webs</strong></td>
<td><strong>Lateral water movement, transport</strong></td>
</tr>
<tr>
<td><strong>Biological crusts</strong></td>
<td><strong>C-transformation, litter destruction</strong></td>
</tr>
<tr>
<td><strong>Rhizosphere</strong></td>
<td><strong>C/N-transformation, succession, growth, production, destruction</strong></td>
</tr>
<tr>
<td><strong>Input of organic substances, exsudation</strong></td>
<td><strong>Erosion, settlement, sorting</strong></td>
</tr>
</tbody>
</table>

**Abiotic structures and processes**

**Biotic structures and processes**
The artificial watershed ‘Chicken Creek’
‘Chicken Creek’ : Construction phase

conveyor bridge spoil dump
‘Chicken Creek’ : Construction phase

basis layer dumped by spreader
‘Chicken Creek’ : Construction phase

clay layer dumped by spreader
‘Chicken Creek’ : Construction phase

sandy layer dumped by spreader
‘Chicken Creek’ : Construction phase

flattened surface
‘Chicken Creek’ : General construction plan

- Top layer (> 2 m thickness): Quaternary substrate (loamy-sandy till from Pleistocene moraines)
- Clay layer (1-2 m thickness): Tertiary clay
- Basis layer above conveyor bridge spoil dump
‘Chicken Creek’

- about 6 ha (450 m x 130 m)
- Difference in altitude 13 m (1-6% gradient)
- 2-3 m sandy layer on top of a clay base layer
- Central discharge point from a small lake (equipped with gauging weir)
Surface of the catchment
Basement of the catchment
## Technical equipment

<table>
<thead>
<tr>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 x 20 m grid</td>
</tr>
<tr>
<td>2 weather stations</td>
</tr>
<tr>
<td>dry/wet deposition sampler</td>
</tr>
<tr>
<td>bulk precipitation samplers</td>
</tr>
<tr>
<td>observation wells</td>
</tr>
<tr>
<td>flumes</td>
</tr>
<tr>
<td>outflow gauge</td>
</tr>
<tr>
<td>water level lake</td>
</tr>
<tr>
<td>PR2-profile probes</td>
</tr>
<tr>
<td>tensiometers</td>
</tr>
<tr>
<td>L-band radiometer (ELBARA)</td>
</tr>
<tr>
<td>soil pits (ceramic suction plates, TDR)</td>
</tr>
<tr>
<td>automatic water samplers</td>
</tr>
</tbody>
</table>

### Input
- hydrology
- soil moisture
- soil solution, water solution

Collaborative Research Center/Transregio 38
SFB-Transregio 38 – Subproject C2

Structures and processes of the initial ecosystem development phase in an artificial water catchment – A priori predictions in small catchment hydrology
Prediction in Ungauged Basins (PUB)

- Predicting state variables within and fluxes between compartments as well as across catchment boundaries
- Considerable uncertainties, e.g. caused by heterogeneity of catchment features
- Needed for data sparse regions
- Leads to the question of how to improve the predictive quality by acquiring additional information
  - on process understanding and catchment features
  - and/or by reducing the parametric requirements
Objectives

• Test of prediction quality of different conceptualized models covering water budget
• Supplying same small data set
• Runoff data were not given
• Simulations mimic the case of ungauged catchments
• Workshops with all modeling groups concerned: analysis of predictions and discussion of model enhancement
  – Model predictions (formulation and coupling of processes)
  – Parameterization of the catchment
  – Necessary additional input data
- DEM of soil and clay layer surface,
- soil texture (mean value and standard deviation) at all observation squares,
- gully network and aerial photo (summer ´07)
- hourly, daily and monthly record of weather data (29.09.05 to 09.09.08)
  - precipitation
  - temperature (air & soil at 10 cm depth)
  - wind speed and direction
  - humidity
  - global radiation
- yearly vegetation coverage in the observation squares (one per year),
- initial hydraulic head at 15 locations (19.09.05)
Hydrological models

- Catflow (TU Munich/University of Potsdam, Germany)
- CMF (University of Giessen, Germany)
- CoupModel (KTH Stockholm, Sweden)
- HILLFLOW (University of Potsdam, Germany)
- Hill-Vi (University of Freiburg, Germany)
- HYDRUS-2D (Eawag Dübendorf, Switzerland)
- NetThales (TU Vienna, Austria)
- SIMULAT (University of Oldenburg, Germany)
- SWAT (University of Giessen, Germany)
- Topmodel (University of Bristol, United Kingdom)
- WaSiM-ETH (University of Bonn, Germany)
### Water budget for the hydrological year 2006/2007

<table>
<thead>
<tr>
<th></th>
<th>P (mm/y)</th>
<th>PET (mm/y)</th>
<th>AET (mm/y)</th>
<th>Discharge (mm/y)</th>
<th>Storage (mm/y)</th>
<th>Balance (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catflow</td>
<td>565</td>
<td>NA</td>
<td>170</td>
<td>262</td>
<td>80</td>
<td>53</td>
</tr>
<tr>
<td>CMF(^{(2)})</td>
<td>452</td>
<td>139</td>
<td>104</td>
<td>238</td>
<td>13</td>
<td>97</td>
</tr>
<tr>
<td>CoupModel</td>
<td>666</td>
<td>NA</td>
<td>563</td>
<td>27</td>
<td>76</td>
<td>0</td>
</tr>
<tr>
<td>Hill-Vi</td>
<td>565</td>
<td>718</td>
<td>156</td>
<td>346</td>
<td>58</td>
<td>5</td>
</tr>
<tr>
<td>HYDRUS-2D</td>
<td>635</td>
<td>602</td>
<td>520 – 579</td>
<td>19 – 67</td>
<td>27 – 33</td>
<td>1 – 17</td>
</tr>
<tr>
<td>NetThales</td>
<td>565</td>
<td>421</td>
<td>284</td>
<td>259</td>
<td>23</td>
<td>-1</td>
</tr>
<tr>
<td>SIMULAT</td>
<td>565</td>
<td>713</td>
<td>318</td>
<td>339</td>
<td>-9</td>
<td>-83</td>
</tr>
<tr>
<td>SWAT</td>
<td>565</td>
<td>815</td>
<td>409</td>
<td>145</td>
<td>18</td>
<td>-7</td>
</tr>
<tr>
<td>Topmodel</td>
<td>565</td>
<td>573</td>
<td>384</td>
<td>171</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>WaSiM-ETH</td>
<td>565</td>
<td>689</td>
<td>371</td>
<td>162</td>
<td>0</td>
<td>32</td>
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<tr>
<td>Chicken Creek</td>
<td>565</td>
<td>782</td>
<td>165</td>
<td>105</td>
<td>69</td>
<td>226</td>
</tr>
</tbody>
</table>
• PET in all models by Penman-Monteith except SWAT (Hargreaves) and Hill-Vi (Turc)
  – Penman-Monteith: 600-720 mm/y, CMF 140 mm/y, NetThales 420 mm/y
  – SWAT: 720 mm/y, well established plant cover (max. LAI: 2.68)
  – Hill-Vi: 820 mm/y, grass-referenced method

• AET a function of PET and soil water status
  – $K_{sat}$: 54 to 118 mm/h; CMF 420 mm/h (mainly Rawls & Brakensiek, Sc
  – van Genuchten parameter $n$: 1.13 to 2.28
  – Models with high AET used small $n$, vis-à-vis
  – HYDRUS-2D changed L-factor from 0.5 to -0.78 resulting lower AET
  – Only NetThales does not use the unsaturated flow for AET calculation
Discharge of the actual system

 hourly values of

- precipitation
- lake's waterlevel
- runoff out of the lake
Discharge including lake

Hourly values of:
- precipitation
- lake’s water level
- lake’s storage change
- and runoff out of the lake
Discharge for the hydrological year 2006/2007
Comparison: measured and observed runoff

- Predicted baseflow overestimates measurements
- Small events are underestimated -> the catchments react very fast on every event
- Large storm events are overestimated
### Runoff components

<table>
<thead>
<tr>
<th>Model</th>
<th>Runoff (mm/y)</th>
<th>Interflow (mm/y)</th>
<th>Baseflow (mm/y)</th>
<th>Total discharge (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catflow</td>
<td>101</td>
<td>161</td>
<td></td>
<td>262</td>
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<td>238</td>
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<tr>
<td>CoupModel</td>
<td>20</td>
<td>7</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Hill-Vi</td>
<td>&gt;1</td>
<td>346</td>
<td></td>
<td>346</td>
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<tr>
<td>HYDRUS</td>
<td></td>
<td></td>
<td></td>
<td>19 - 67</td>
</tr>
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<td>171</td>
</tr>
<tr>
<td>WaSiM-ETH</td>
<td>2</td>
<td>138</td>
<td>22</td>
<td>162</td>
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</tr>
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</table>
Runoff components

Baseflow, 30th May 2008

June 2007
Soil & infiltration

• Unsaturated zone: Richards equation used by all models except NetThales (no unsat. flow) and Topmodel (exponential transmissivity function); parameterization: van Genuchten/Brooks-Corey

• Saturated flow: Richards (Darcy) equation and a large amount of other attempts

• Infiltration: Richards (Darcy) equation; Green-Ampt attempt, SCS -> mainly all based on $K_{sat}$ and anisotropy -> no/nearly no infiltration assess simulated -> most is subsurface flow
Data missing (workshop Dec. 2008)

- soil water status for the initial condition
- more soil data, especially $K_{sat}$, porosity
- more information about vegetation, although vegetation is just developing: SIMULAT
- better DEMs: TOPMODEL
Further Procedure (2009)

- Supply of same data sets for all modeling groups
- Workshop I: Evaluation of predictions, discussion of model differences, variations between the results (predictions), identification of additional data requirement
- Supply of additional (existing) data (preferably on request of the modeling groups) for a 2nd prediction (end of March), results in April
- 1st calibration set (catchment of flume II, time series after Feb. 2008, end of May), results June/July
- 2nd calibration set (complete discharge and time series, August), results October
- 2nd workshop for presentation of enhanced predictions and comparison with calibrated data. Comparison of model enhancements due to additional data and in relation to the effort for these additional information in October/November
Sparse data sets lead to a large variation for prediction of hydrological of different hydrological models
  - Water balance
  - Discharge (and components)
  - Groundwater levels and fluctuations

Most crucial parameter were soil parameter, especially for infiltration and discharge components

Plant parameter had a minor importance, due to the early state of the artificial catchment
  - PET mainly depended on the method (Penman-Monteith)
  - AET in the soil water content and therefore on van Genuchten parameter
Thank you!

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