Integrating water resources management in eco-hydrological modelling

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Overview

• The model SWIM
• Reservoir management
• Study Area
• Scenarios & Results
• Discussion / Conclusion
The Model SWIM (Soil and Water Integrated Model): Processes included

Climate: Global radiation, temperature, precipitation

Hydrological cycle
- Upper ground water
- Lower ground water
- Soil profile
- Soil profile

Vegetation/ Crop growth
- LAI
- Biomass
- Roots

Nitrogen cycle
- \( \text{N-NO}_3 \)
- \( \text{N}_{\text{ac}} \)
- \( \text{N}_{\text{st}} \)
- \( \text{N}_{\text{res}} \)

Phosphorus cycle
- \( \text{P}_{\text{lab}} \)
- \( \text{P}_{\text{m-ac}} \)
- \( \text{P}_{\text{m-st}} \)
- \( \text{P}_{\text{org}} \)
- \( \text{P}_{\text{res}} \)

Land use pattern & land management

Source: Huang et al., PIK Potsdam

SWIM was developed in PIK, Potsdam based on SWAT-93 and MATSALU for climate and land use change impact studies (Krysanova et al., 1998)
The Model SWIM (Soil and Water Integrated Model): Spatial disaggregation

- process based eco-hydrological model, simulates runoff generation, nutrient and carbon cycling, plant growth and crop yield, river discharge and erosion as interrelated processes with a daily time step on the river basin scale

Source: Huang et al., PIK Potsdam
Reservoirs: Overview

Loucks and van Beek, 2005
The model provides three different reservoir management options:

i) Variable daily minimum discharge to meet (e.g. environmental) targets downstream under consideration of maximum and minimum water levels in the reservoir

ii) Daily release based on firm energy yield by a hydropower plant: the release to produce the required energy is calculated depending on the water level (consideration of maximum and minimum water levels in the reservoir)

iii) Daily release depending on water level: rising/falling release with increased/falling water level, depending on the objective of reservoir management
The Upper Niger Basin

- Area: ~350,000 km²
- Peak discharge: 2,000 – 10,000 m³/s
- Monsoon-type of rainfall
- Annual rainfall: ~830 mm (200 – 2,000 mm)

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<tbody>
<tr>
<td>obs</td>
<td>sim</td>
<td>obs</td>
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<td>obs</td>
<td>sim</td>
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<tr>
<td>Mean [m³/s]</td>
<td>300</td>
<td>302</td>
<td>252</td>
<td>292</td>
<td>347</td>
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<tr>
<td>RMSE [m³/s]</td>
<td>101</td>
<td>70</td>
<td>149</td>
<td>247</td>
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<td>BIAS [m³/s]</td>
<td>2.0</td>
<td>8.1</td>
<td>-9.8</td>
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<td>-23</td>
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<td>PBIAS [%]</td>
<td>1%</td>
<td>3%</td>
<td>-3%</td>
<td>-26%</td>
<td>-7%</td>
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<tr>
<td>NSE</td>
<td>0.94</td>
<td>0.95</td>
<td>0.89</td>
<td>0.69</td>
<td>0.89</td>
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Performance results for the SWIM model, gauge Guelelinkoro (inflow to Selingue dam)
# Reservoir model – Data requirements

<table>
<thead>
<tr>
<th></th>
<th>Selingue</th>
<th></th>
<th>Fomi</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>dead storage</td>
<td>active storage</td>
<td>dead storage</td>
</tr>
<tr>
<td>volume [million m³]</td>
<td>238.0</td>
<td>1,928.7</td>
<td>2,460.0</td>
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<tr>
<td>max. water level [m a.m.s.l.]</td>
<td>342.2</td>
<td>349.2</td>
<td>380.0</td>
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<tr>
<td>min. water level [m a.m.s.l.]</td>
<td>338.5</td>
<td>342.2</td>
<td>351.0</td>
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<tr>
<td>max. water surface [km²]</td>
<td>50</td>
<td>500</td>
<td>450</td>
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<tr>
<td>Hydropower Plant (HPP)</td>
<td></td>
<td></td>
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<tr>
<td>max. fall height of HPP [m]</td>
<td>17.2</td>
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<td>27.4</td>
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<td>base of HPP [m a.m.s.l.]</td>
<td>332.0</td>
<td></td>
<td>363.1</td>
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<tr>
<td>capacity of HPP [m³/s]</td>
<td>360.0</td>
<td></td>
<td>421.0</td>
</tr>
</tbody>
</table>

- measurements of inflow to & outflow from reservoir
  or
- planning values for release (rule curve) or for hydropower production
Test for Reservoir model (Selingue dam)

Date
1/1/92 2/1/92 3/1/92 4/1/92 5/1/92 6/1/92 7/1/92 8/1/92 9/1/92 10/1/92 11/1/92 12/1/92

Flow [m^3/s]
0 250 500 750 1000 1250

inflow simulated
outflow observed
outflow sim. option 1
outflow sim. option 2
Scenarios: New reservoir & Climate change

Reservoirs:

i) Natural discharge without dams

ii) Discharge with existing Selingue dam

iii) Discharge with planned Fomi dam

Climate change (100 Realisations each scenario):

i) +/- 0K

ii) + 1 K

iii) + 2 K
Results: Natural flow at gauge Koulikoro (Upstream of IND)
Results: Natural flow at gauge Koulikoro (Upstream of IND)
Results: Natural flow at gauge Koulikoro (Upstream of IND)
Reservoir model: Results Selingue dam

### Inflow [m$^3$/s]

- **+2 K**
- **+1 K**
- **+0 K**

### Outflow [m$^3$/s]

- **+2 K**
- **+1 K**
- **+0 K**

**Day of Year**

- 1
- 31
- 61
- 91
- 121
- 151
- 181
- 211
- 241
- 271
- 301
- 331
- 361

**Reservoir Model**

- Selingue dam

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Reservoir model: Results planned Fomi dam

![Graph showing inflow and outflow over the year with different scenarios and error bands.](image)

H. Koch et al.: Water resources management & eco-hydrological modelling
Reservoir model: Hydropower production

Mean electricity production Selingue dam (1982-2003): 19.5 MW (after Zwarts et al.)

- **Mean values + 0K**
  - reservoir Selingue (mean: 20.0 MW)
  - reservoir Fomi (mean: 45.1 MW)

- **Mean values + 1K**
  - reservoir Selingue (mean: 16.6 MW)
  - reservoir Fomi (mean: 39.7 MW)

- **Mean values + 2K**
  - reservoir Selingue (mean: 11.3 MW)
  - reservoir Fomi (mean: 31.2 MW)

Mean electricity production Selingue dam (1982-2003): 19.5 MW (after Zwarts et al.)
Reservoir model: Results gauge Koulikoro (Upstream of IND)

Reservoir Selingue

Reservoirs Selingue & Fomi

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Reservoir model: Results gauge Koulikoro (Upstream of IND)

Reservoir Selingue

+/- 0 K (natural)

+ 1 K

+ 2 K

Reservoirs Selingue & Fomi

+/- 0 K (natural)

+ 1 K

+ 2 K

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DISCUSSION / CONCLUSION

The new model

- *Reservoir model* can be used to simulate *effects of reservoir management* on downstream discharges and hydropower production within the eco-hydrological model SWIM; but “real” reaction on floods/droughts might not be simulated (flood storage, dead storage)

Purpose

- Simulation of possible *upstream-downstream conflicts* (here *hydropower* production - *agricultural* production)
- Simulation of impacts of *climate change* and variability
- *Adaptation* options can be simulated (changed reservoir management)
Thanks