Modelling the impact of land use change on the water balance in the Xiangxi Catchment (Three Gorges Region, China) using SWAT

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Outline

1. Introduction
2. YANGTZE Project
3. Study area
4. SWAT model application
5. Outlook
1. Introduction
Three Gorges Dam
Land use change

• Uphill shift of agricultural areas
• Resettlement
• Construction of infrastructure
Impact on water balance and quality

- Alteration of runoff and evaporation processes
- Risk of increasing diffuse inputs to rivers because of increase in erosion and landslides
- Higher potential of eutrophication due to limited exchange of water in Three Gorges Reservoir
2. **YANGTZE-Project**
Project collaboration

YANGTZE-Project:
land use change, erosion, mass movement, diffuse inputs

Coordination: Research Centre Jülich

Remote Sensing
Potsdam
Assessment of mass movements using remote sensing techniques

Land use change
Giessen
Classification of land use and assessment of vulnerability

Erosion
Tübingen
Assessment and analysis of soil erosion

Landslides
Erlangen
Assessment and analysis of landslides

Diffuse sediment and P inputs
Kiel
Analysis of sediment and phosphorus inputs to rivers using SWAT

Aim:
Analysis of land use change and vulnerability, risk assessment of mass movements, soil erosion and diffuse inputs to rivers
Objectives

• Assessment of the impact of land use change on water quantity and quality in the Xiangxi Catchment
  • How has the changing land use in the last 20 years influenced the water balance and diffuse inputs?
  • How will possible future land use patterns affect these factors?

• Development of sustainable land use options for the Three Gorges Region
Methods

• SWAT2009
• Water balance, sediment, phosphorus
• Past and present land use (1987-2007)
• Land use scenarios
• Study area: Xiangxi Catchment
  • Example for a catchment impacted by a large dam project
  • Methods and results to be transferable to similar regions
3. Study area
Location of study area
Xiangxi River

- Length of river: 94 km
- Catchment area: 3099 km²
- Mean annual discharge (Gauge Xingshan): 65.5 m³/s
- Mean annual temperature/precipitation: 16.9 °C/1000 mm
- Xiangxi Bay: Influence of Three Gorges Reservoir impoundment

Legend
- Xiangxi Catchment
- Backwater area
- River
- Gauge Xingshan
  - new
  - old
4. SWAT model application
Spatial input data I: DEM

- SRTM 3, Version 4 (CGIAR-CSI): resolution 90 m, resampled to 45 m
- Large differences in elevation (>3000 m)
- Steep slopes
  - Mean 24° (46%)
  - Maximum 76° (414%)
Spatial input data II: soil map

- Digitized from analogue soil maps of the counties Shennongjia, Xingshan and Zigui (1:160000 and 1:180000) (Schönbrodt & Scholten 2009)

- Dominating soils: Limestone soil and Yellow brown soil

- Attributes taken from Chinese Soil Database (www.soil.csdb.cn)
Spatial input data III: land use maps

Major changes especially close to Xiangxi Bay, rivers and roads!

- Land use maps for 1987 and 2007 classified from Landsat-TM images (Seeber et al. 2010)

<table>
<thead>
<tr>
<th>Land use class</th>
<th>Change (km²)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland</td>
<td>+99.0</td>
<td>+3.68</td>
</tr>
<tr>
<td>Arable land</td>
<td>-119.0</td>
<td>-28.07</td>
</tr>
<tr>
<td>Orchard</td>
<td>+15.6</td>
<td>+27.86</td>
</tr>
<tr>
<td>Grassland</td>
<td>-7.0</td>
<td>-36.84</td>
</tr>
<tr>
<td>Built-up area</td>
<td>+0.3</td>
<td>+4.30</td>
</tr>
<tr>
<td>Bare rock</td>
<td>+3.3</td>
<td>+33.00</td>
</tr>
<tr>
<td>Reservoir</td>
<td>+9.4</td>
<td>---</td>
</tr>
</tbody>
</table>

Classification of further scenes planned
Model setup I: watershed delineation

- Threshold: 4500 ha → 37 subbasins
- 1 subbasin outlet added manually at Gauge Xingshan → 38 subbasins
- 1 point source added to each subbasin
- Reservoirs in subbasins 18 and 22
Model setup II: HRU definition

- **Soil** (Schönbrodt & Scholten 2009)
  - Threshold: 0%

- **Land use** (Seeber et al. 2010)
  - Threshold: 10%
  - 5 slope classes: 26, 39, 50, 65, 9999

- **Slope** (SRTM)
  - Threshold: 10%

1597 Hydrologic Response Units
Model setup III: Climate data

• 3 climate stations: Xingshan, Zigui, Shennongjia
  • Precipitation
  • Temperature
  • Wind speed
  • Humidity
  • Solar radiation (calculated from sunshine duration)

• Weather generator: climate station Xingshan (1958-2007)
Model setup IV: Simulation

- Discharge data (Gauge Xingshan): 1970-2005
- Warm-up: 1980-1987
- Calibration: 1988-1996
- Validation: 1997-2005

- Model evaluation statistics:
  - NSE
  - $R^2$
  - PBIAS
  - RMSE
Uncalibrated simulation: discharge

NSE: -0.25

$R^2$: 0.62

PBIAS: 42.93

RMSE: 23.38
Analysis of weak points

Runoff too low in winter and spring

Peaks caused by single, large rainfalls are overestimated

Peaks caused by a number of consecutive, smaller rainfall events are underestimated
Specific characteristics of the catchment

• Steep slopes
• Terraces
• Reservoirs
• Hydropower stations
5. Outlook
Outlook

- Improvement of soil database
- Adjustment of agricultural management
- Rainfall regionalization
- Reservoir operation guidelines
- Point sources
- Sensitivity analysis, calibration, validation, uncertainty analysis
- Sediment and phosphorus
  → sediment dredging, phosphorus company
Thanks for your interest and attention!

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Hydropower stations
Sediment dredging
Sediment transport