Soil degradation by water erosion at the regional scale – current and future problems in Benin (West-Africa)

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Structure

• Introduction
• Methods and field investigations
• Selected modelling results
  – Scenarios
• Conclusions
Objectives of this study

Part of IMPETUS project: An integrated approach to the efficient management of scarce water resources in West Africa

- Quantify recent and future soil erosion by water in the Upper Ouémé catchment
- Conclusions about soil degradation and options for soil conservation

Donga-Pont (586 km²)
- 39% cropland
- 1294 mm/yr

Terou-Igbomakoro (2324 km²)
- 11% cropland
- 1157 mm/yr
Soil degradation - Upper Ouémé

- 38% of farmers report soil degradation on their fields
- Topsoil erosion by water
- Nutrient depletion - $C_{\text{org}}$
  Forest: fallows: exhausted fields
  2.6% : 1.1% : 0.9%

Sheets and rill erosion
Surface crusts and gravel
During heavy rainfall

One day after ….
Modelling hydrology and sediment

- process understanding at regional scale; scenario analysis
- regional scale hydrological model: SWAT (Soil Water Assessment Tool)

**Parametrisation**

"Adjust parameters so that model results can reproduce field data"

**Calibration**

"Check for different time/space"

**Validation**

**Calibration/validation data**

- Discharge (components)
- Suspended sediment concentrations
- Pedotransfer functions

Soil data (38 representative profiles)

DEM 90m, land use map 28.5m
Soil map, climate data
121 subbasins, 926 HRUs
+ related databases
Data: Suspended sediment measurements

- Water sampling
- Filtration, gravimetric weight

Turbidity probe

Graphs: Donga-Pont 2005
- Sediment load [t/h]
- Discharge [m³/s]

Graph: Donga Pont
- Turbidity [NTU] vs. Suspended sediment concentration [g/l]

Equation: \( y = 500.99x + 77.125 \)
- \( R^2 = 0.59 \)
Model calibration/validation: Hydrology

**Weekly discharge Donga-Pont 1998-2001**

- ME: 0.85
- R²: 0.87
- IoA: 0.96

**Weekly discharge Donga-Pont 2002-2005**

- ME: 0.83
- R²: 0.85
- IoA: 0.96

**Weekly discharge Oueme-Beterou 1998-2005**

- ME: 0.82
- R²: 0.84
- IoA: 0.96

**Weekly discharge Terou-Igbo 1998-2001**

- ME: 0.81
- R²: 0.81
- IoA: 0.95
Model calibration/validation: Sediment

**Interpretation of results**

**ME 0.68  R^2 0.69  IoA 0.90**

**ME 0.71  R^2 0.87  IoA 0.94**

**daily SY Ouémé-Beterou 2005**

Sediment load:
- Cropland (97%)
- Brush and grass savannah (2.4%)
- Others <1%
Modelling – future scenarios

Parametrisation of scenarios

CLUE-S model: land use maps (2001-2025), scenarios L1-L3

Regional climate model REMO
IPCC SRES scenarios A1B and B1

ECHAM4
300km, 200yrs

REMO
55km, 90yrs

REMO By station

Settlement
Forest and dense savannah
Cropland
Shrub and grass savannah
### Modelling – future scenarios

#### Scenarios analysis

- **Land use scenarios** (original period)
- **Climate scenarios** (2001-2050)
- **Combined scenarios** (2001-2025)

#### Interpretation of results

<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>Water Yield (Lu2025)</th>
<th>Surface Runoff (Lu2025)</th>
<th>Sediment Yield (Lu2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land use scenarios</strong> Lu2025</td>
<td>+3 to +7%</td>
<td>+11 to +23%</td>
<td>+42 to +95%</td>
</tr>
<tr>
<td><strong>Climate scenarios</strong> 2001-25/2026-50</td>
<td>-3 to -8%</td>
<td>-3 to -15%</td>
<td>-5 to -27%</td>
</tr>
<tr>
<td><strong>Combined scenarios</strong> 2001-25</td>
<td>-3 to -11%</td>
<td>-4 to +6%</td>
<td>-2 to +31%</td>
</tr>
</tbody>
</table>

**SWAT**

- **Climate scenarios** (2001-2050)
- **Land use scenarios** (original period)
- **Combined scenarios** (2001-2025)
Scenarios: Temporal results

Lu scenarios:
Regularly distributed

Clim scenarios:
↑WY/SY in May,
↓WY/SY in June to Sept
Conclusions

- SWAT successfully applied, improved understanding, regional hotspots
- Opposite effects of climate and land use change, LU change dom (SY -2 to +31% in 2001-30), aggravating soil degradation
- After 2030 CC more relevant with ↑differences among scenarios
- Further aggravation of existing hotspots of soil erosion
- New hotspots in S and NE of the catchment
• Hotspot analysis can support land use planning, SDSS

• Impact assessments crucial for climate change adaptation, need to look at climate + land use change

• Link erosion to productivity loss, management scenarios

• Soil and water conservation is a no-regret option

**Main challenges in impact assessments:**

• Data collection
• Robust model calibration/validation requires expertise
• Transdisciplinary work
• Limitations of climate models
Towards a sustainable land use

- Little active soil management
- Solution lies in the farming system
- Adoption is location- and livelihood specific

Wide range of soil conservation measures

- Cultural technology and soil tillage
- Plant management
- Use of organic/mineral fertilizer
- Improve framework conditions

![Pie chart showing soil conservation methods: Rotation 35%, Improved fallow 14%, Burning each year 8%, Erosion measures 13%, Others (Fertilizer, drainage) 25%]
PEDRO
SDSS for the estimation of discharge, soil erosion rates and crop yields

Definition of scenarios by the user
- Land use?
  - Actual (Reference)
  - Future scenario
    - Economic growth
    - Stagnation
    - Business as usual
- Climate?
  - Observed Climate (1998-2008)
  - Simulated
    - Past (1981-2000)
    - Scenarios (IPCC A2, B1)
    - 2001-50
- Crop?
  - Rainfed Irrigation
  - Varieties
  - Fertilizer

Scenario variants
- Hydrological model
  - SWAT
- Agroecosystems
  - EPIC

Annual rainfall
Annual runoff
Annual soil erosion
Annual discharge
Sediment load
Yield of rice (Mg/ha)
Thank you!

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http://www.impetus.uni-koeln.de/en