# Modelling soil erosion in a sub-humid tropical environment at the regional scale considering land use and climate changes

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# Structure of presentation

- Introduction
- Model setup, calibration and validation
- Scenarios analysis (climate/land use changes)
- Conclusions and outlook

# IMPETUS project

## An integrated approach to the efficient management of scarce water resources in West Africa

Phase 1 (2000-2003): field studies

Phase 2 (2003-2006): modelling

Phase 3 (2006-2009): management tools


www.impetus.uni-koeln.de

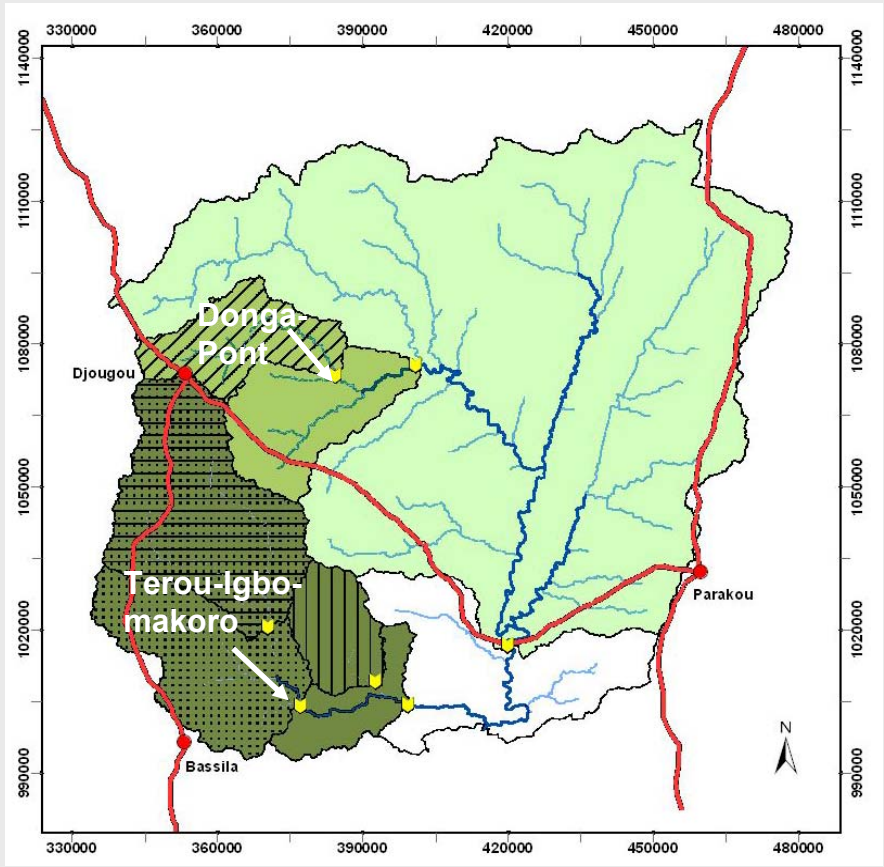
## Objectives of this study

- quantification of water erosion in the Upper Ouémé
- recent (1998-2005), future (2000-2025)
- considering climate and land use change

## Related IMPETUS poster:

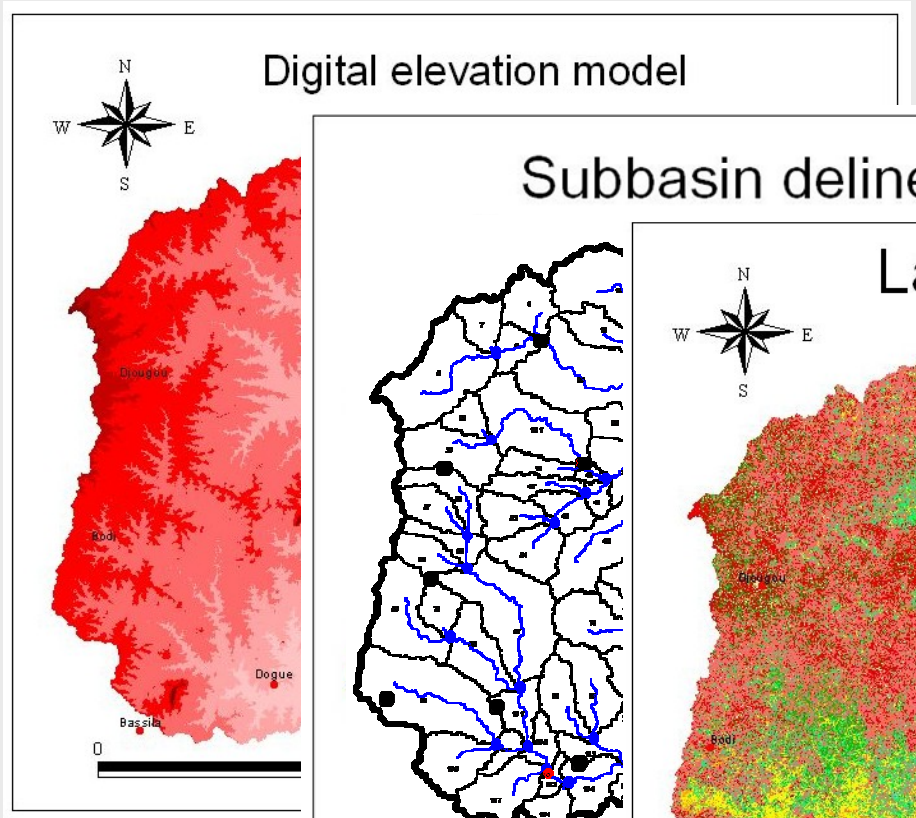
Busche, H. & B. Diekkrüger: Modelling hydrological processes in a semi-arid, mountainous environment at the regional scale

# The Upper Ouémé catchment




- 14500 km$^2$, sub-humid (P~1100 mm/yr), wet season Mai-Oct.
- Slightly undulated pediplain on crystalline basement
- mainly wet savannah, soils: Acrisols/Lixisols
- agricultural expansion, sheet and rill erosion

# Model setup – AVSWAT 2005




SRTM 90m




2 climate stations
14 pluviometers




Landsat, 28.5m




French soil map + own field investigations

Thresholds (6000 ha, 10%): 121 subbasins, 926 HRUs

# Model calibration

Manual calibration; automatic calibration confirmed results

## Hydrology

→ Curve number ↓ , Surlag↓, ESCO ↓

→ Groundwater parameters (↑ Alpha_bf , $GWQ_{min}$, $GW_{REVAP}$, $Rchrg_{DP}$ ↓ $Revap_{Mn,}$ $GW_{Delay}$)

→ Soil parameters: Sol_AWC ↑, SOL_Z ↑, min SOL_K ↑

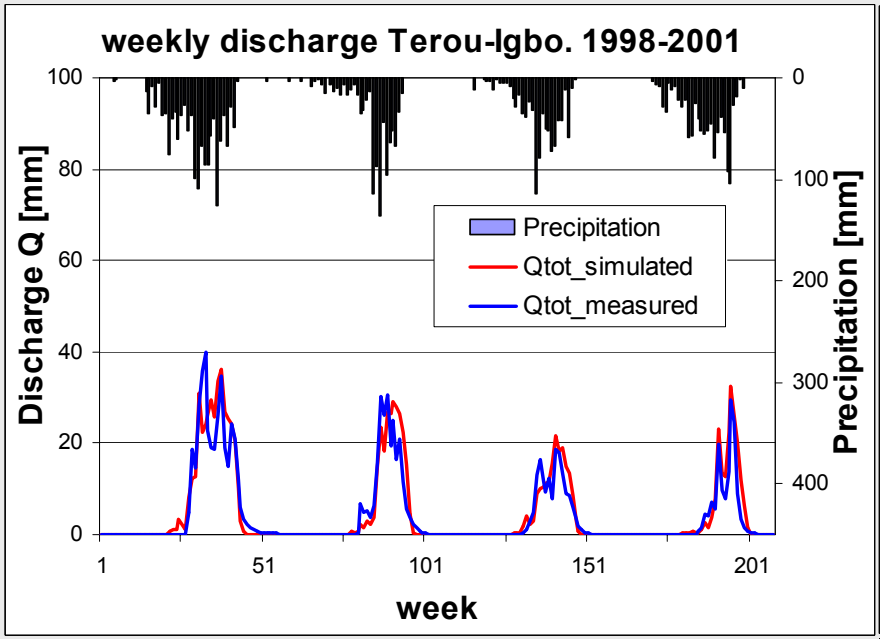
## Sediment

→ USLE_C factors ↑

→ SLSUBBSN (av. slope length) ↑

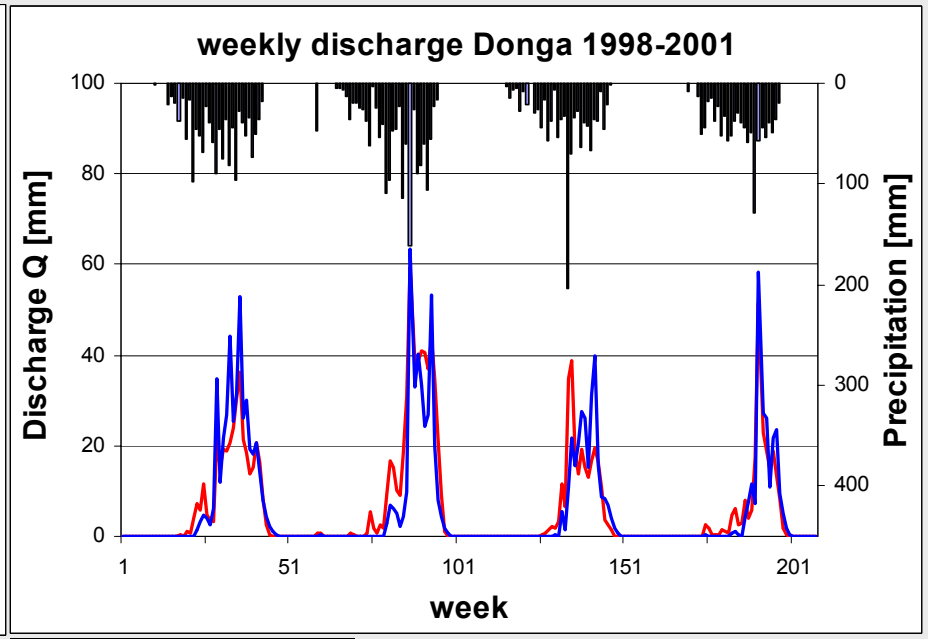
# Model calibration – hydrology

## Terou-Igbomakoro (2334km²)




| ME | $R^2$ | IoA |
|---|---|---|
| 0.87 | 0.87 | 0.72 |

## Donga-Pont (586km²)

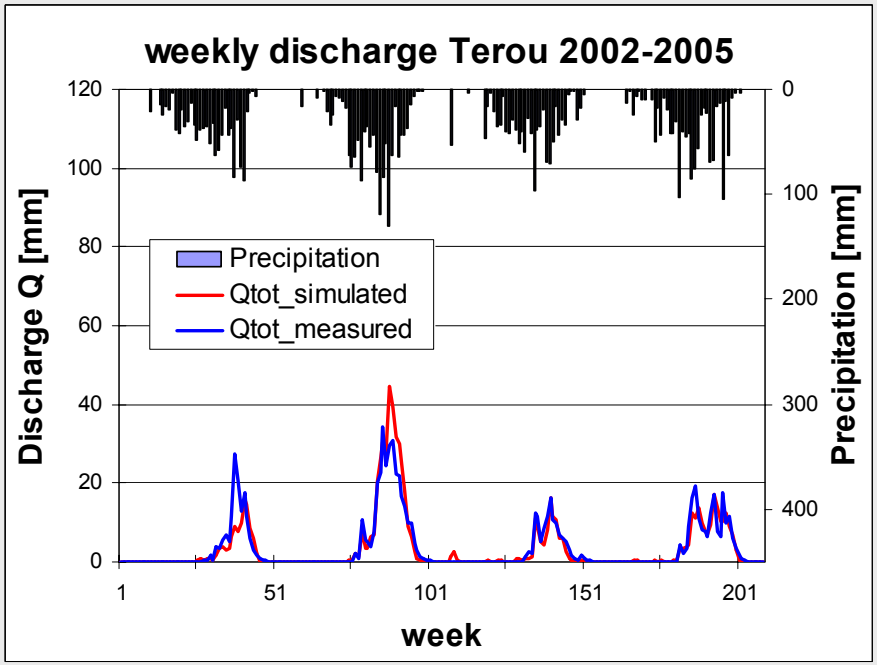



| ME | $R^2$ | IoA |
|---|---|---|
| 0.78 | 0.81 | 0.75 |

| | Simulated | | | Measured | | | $Q_{tot}$_sim/ $Q_{tot}$_meas | $Q_{surf}$_sim/ $Q_{surf}$_meas | $Q_{base}$_sim/ $Q_{base}$_meas |
|---|---|---|---|---|---|---|---|---|---|
| | $Q_{tot}$ [mm] | $Q_{surf}$ [mm] | $Q_{base}$ [mm] | $Q_{tot}$ [mm] | $Q_{surf}$ [mm] | $Q_{base}$ [mm] | [%] | [%] | [%] |
| **Donga-Pont** | 318 | 185 | 133 | 311 | 176 | 135 | 102 | 105 | 99 |
| **Terou-Igbomakoro** | 242 | 106 | 136 | 229 | 103 | 126 | 106 | 103 | 108 |

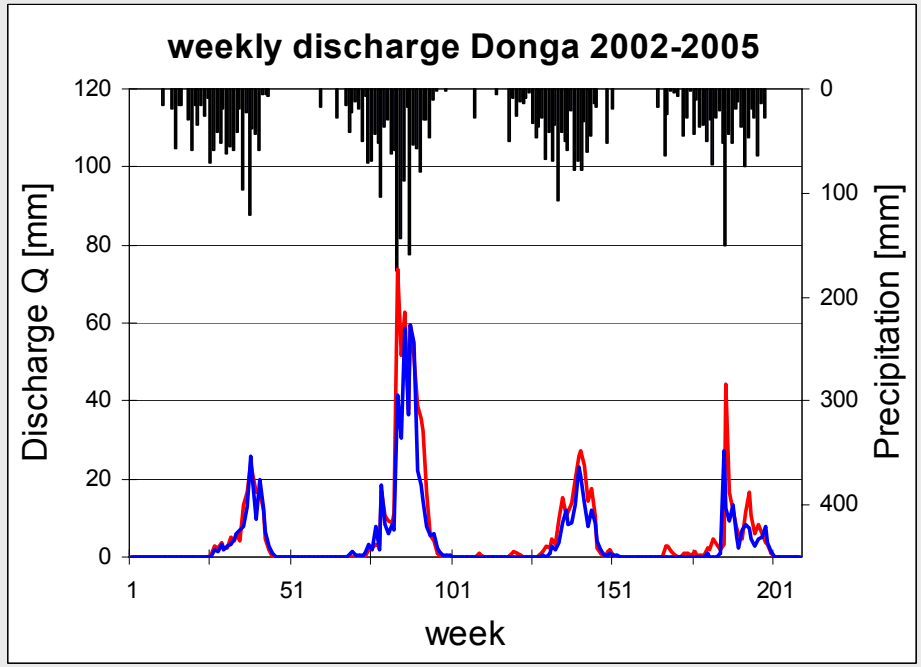
# Model validation – hydrology

## Terou-Igbomakoro (2334km²)




| ME | $R^2$ | IoA |
|---|---|---|
| 0.85 | 0.85 | 0.72 |

## Donga-Pont (586km²)

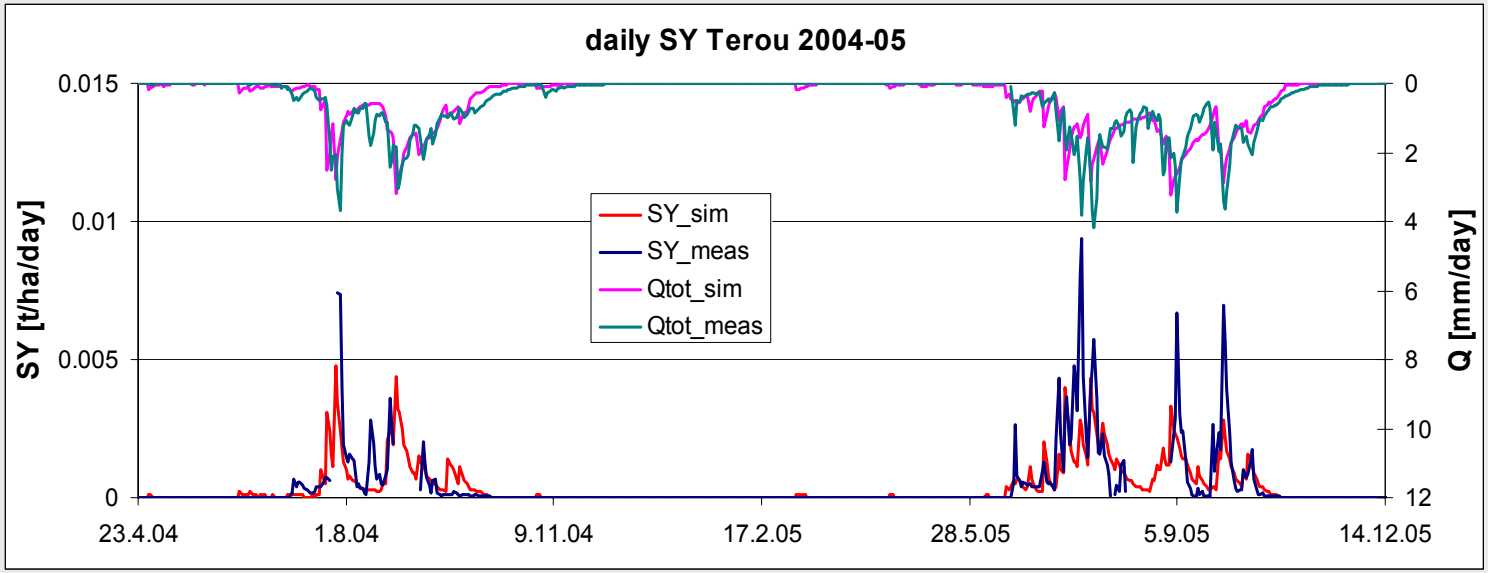



| ME | $R^2$ | IoA |
|---|---|---|
| 0.88 | 0.85 | 0.69 |

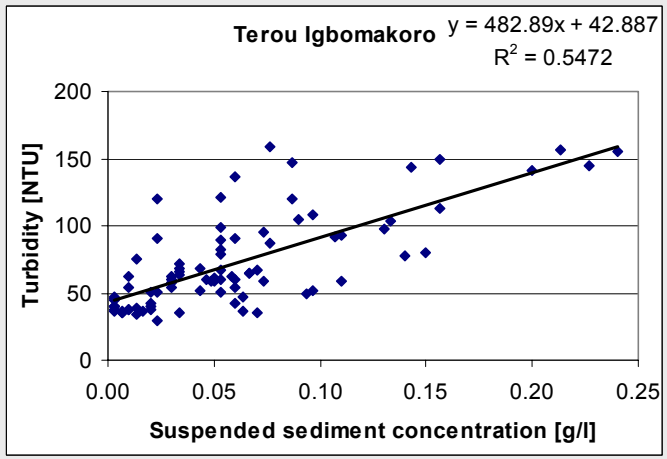
Besides temporal validation, spatial validation at several outlets

# Model calibration – sediment

## e.g. Terou-Igbomakoro (2334km²)

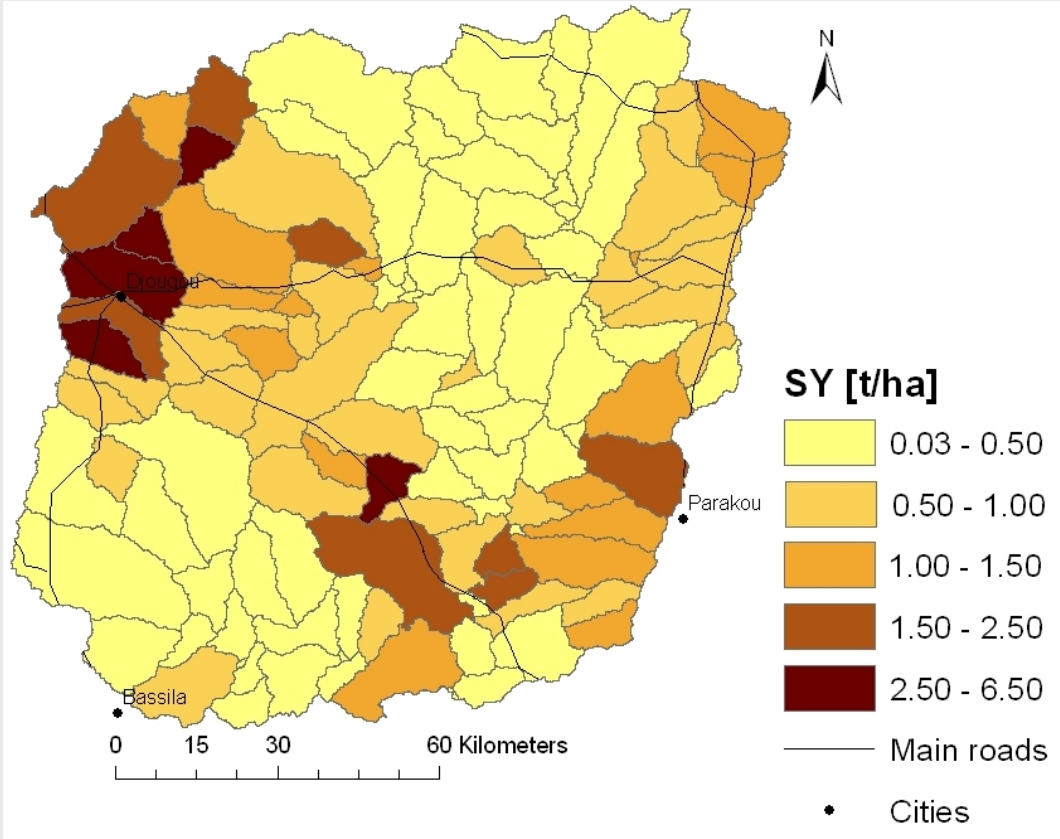


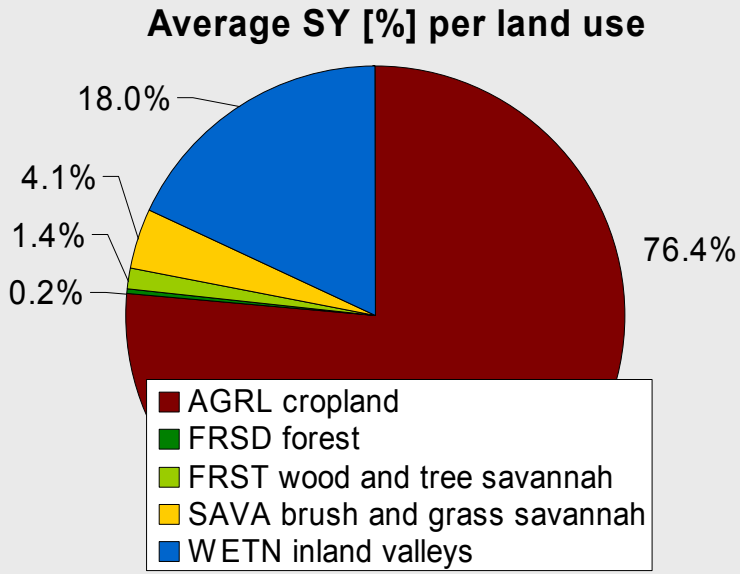

| | year | # days with measured SY | $Q_{tot}$_sim/ $Q_{tot}$_meas [%] | SY_sim/ SY_meas [%] |
|---|---|---|---|---|
| **Donga-Pont** | 2004 | 45 | 131 | 94 |
| | 2005 | 118 | 133 | 99 |
| **Terou-Igbo.** | 2004 | 160 | 84 | 90 |
| | 2005 | 176 | 91 | 76 |




# Model results (1998-2005) - sediment





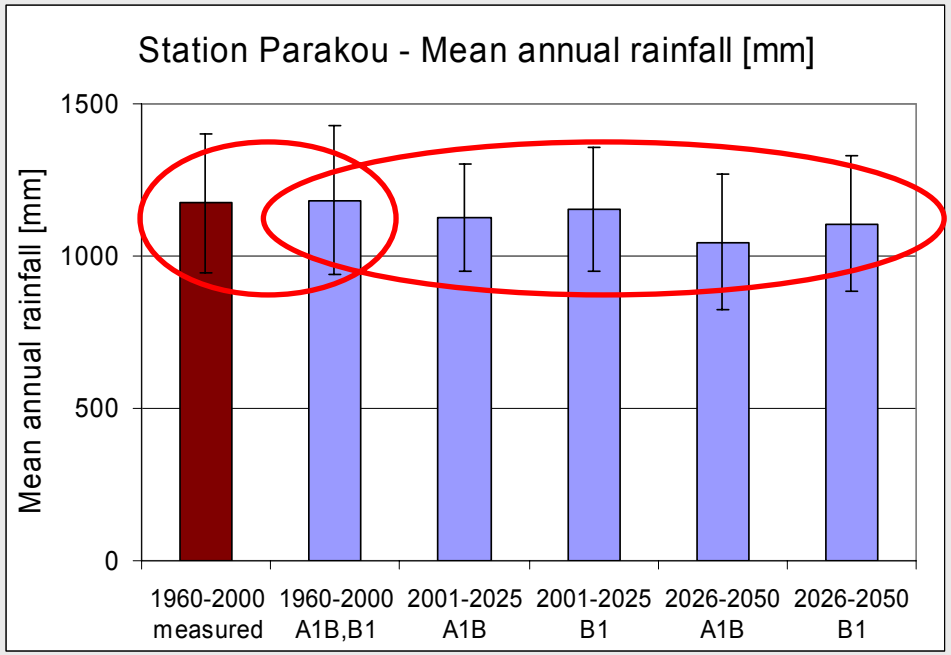

## Hotspots of soil erosion

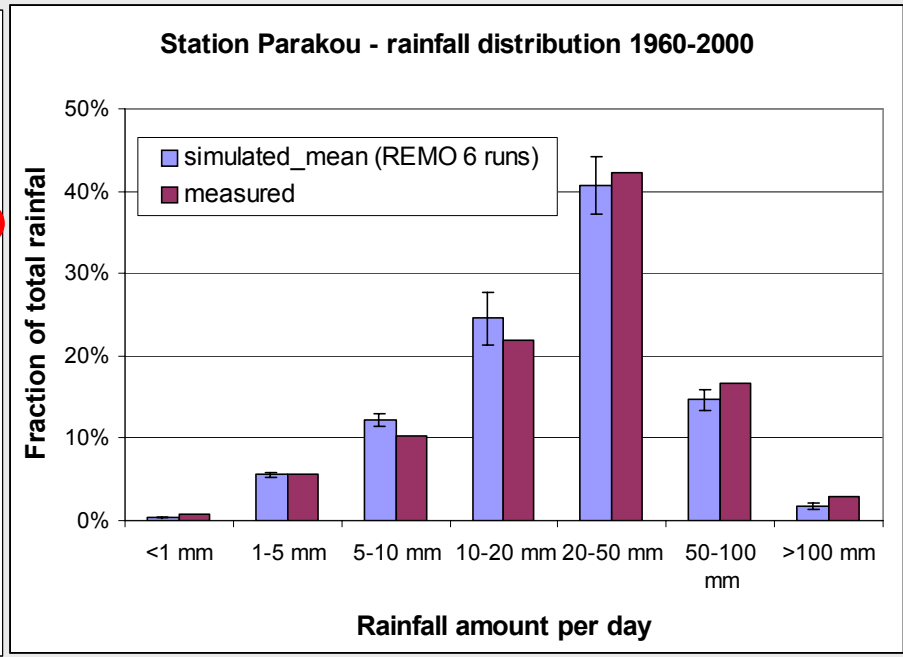
North-West: high fraction of fields (28-48%) & high rainfall sums/intensities
North-East: high rainfall sums
East: high fraction of fields (20-48%)

Fields: 4.54 t/ha soil loss → 0.3 mm/a topsoil loss

# Climate change scenarios

- regional climate model REMO (H.Paeth), IPCC SRES scenarios A1B & B1, including land degradation acc. to FAO
- for each scenario 3 ensemble runs (2001-2050), baseline (1960-2000)
- model output statistics (MOS) for all climate parameters + attribution of rainfall to stations
- check of consistency of precipitation and ETpot for baseline scenario (1960-2000)



# Climate scenarios - results

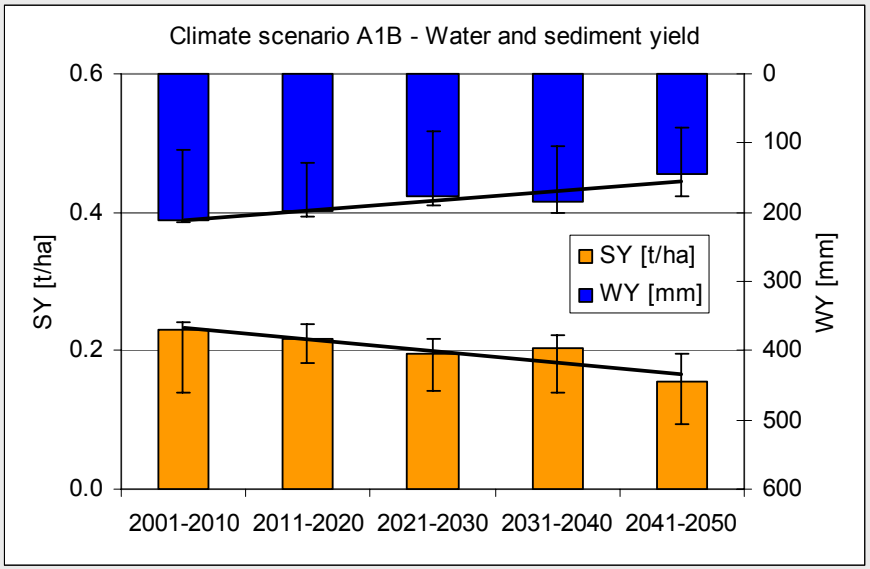
## Upper Ouémé

| | A1B, 3 runs | | | B1, 3 runs | | |
|---|---|---|---|---|---|---|
| | ΔPCP | ΔWY | ΔSY | ΔPCP | ΔWY | ΔSY |
| 2001-2025 | -4% | -12% | -10% | -3% | -6% | -1% |
| 2026-2050 | -8% | -23% | -21% | -5% | -12% | -6% |

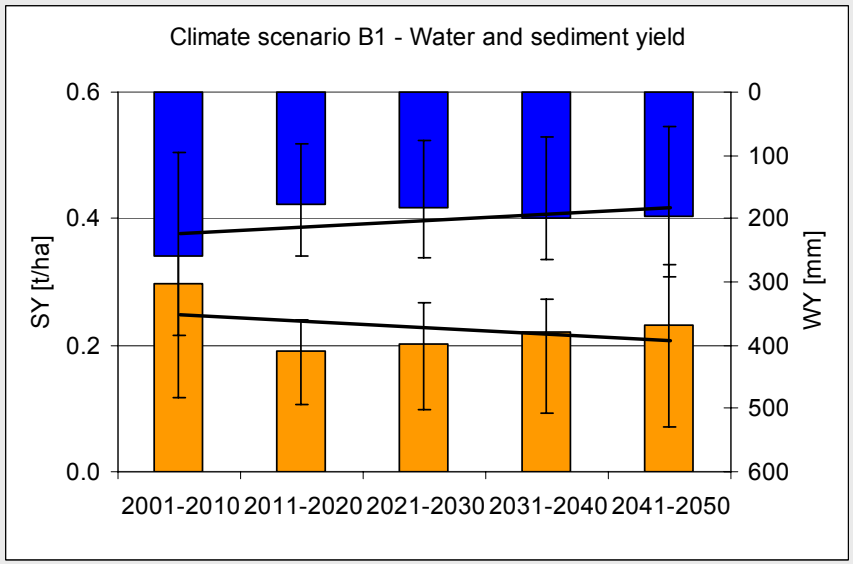
Donga-Pont ↓↓

Terou-Igbo ↑

## Scenario A1B: 2001-2050

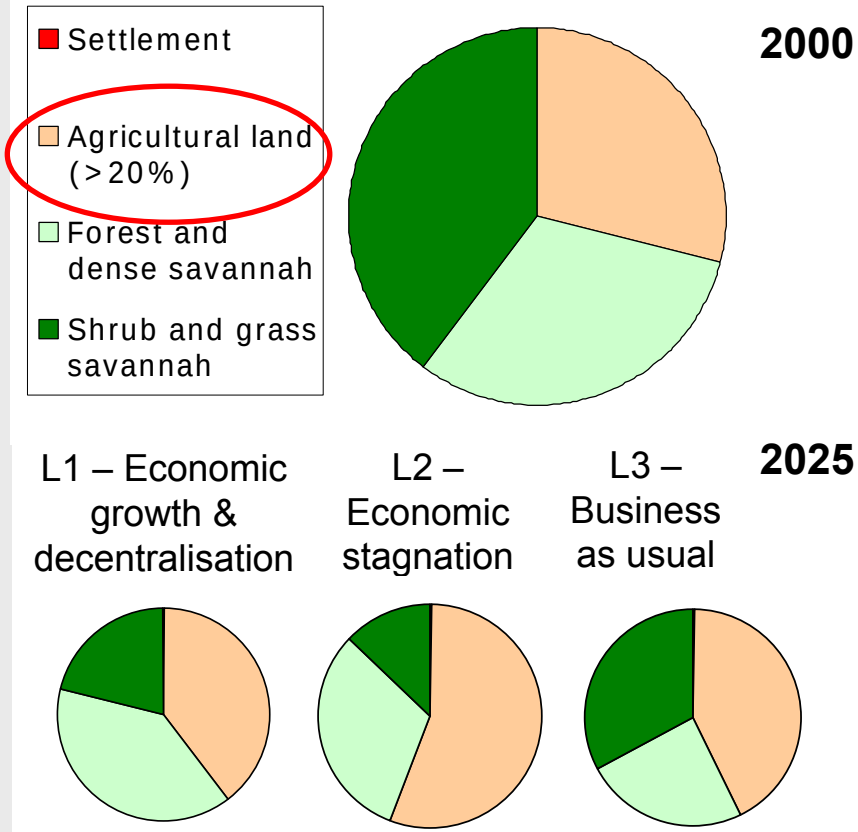


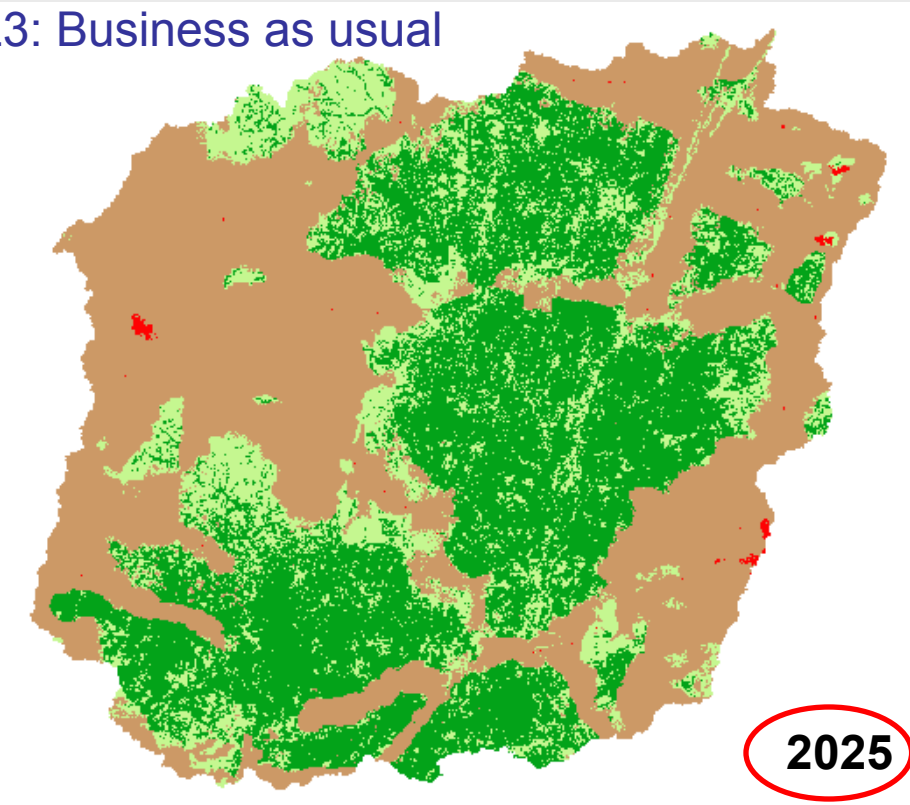

## Scenario B1: 2001-2050



# Land use scenarios

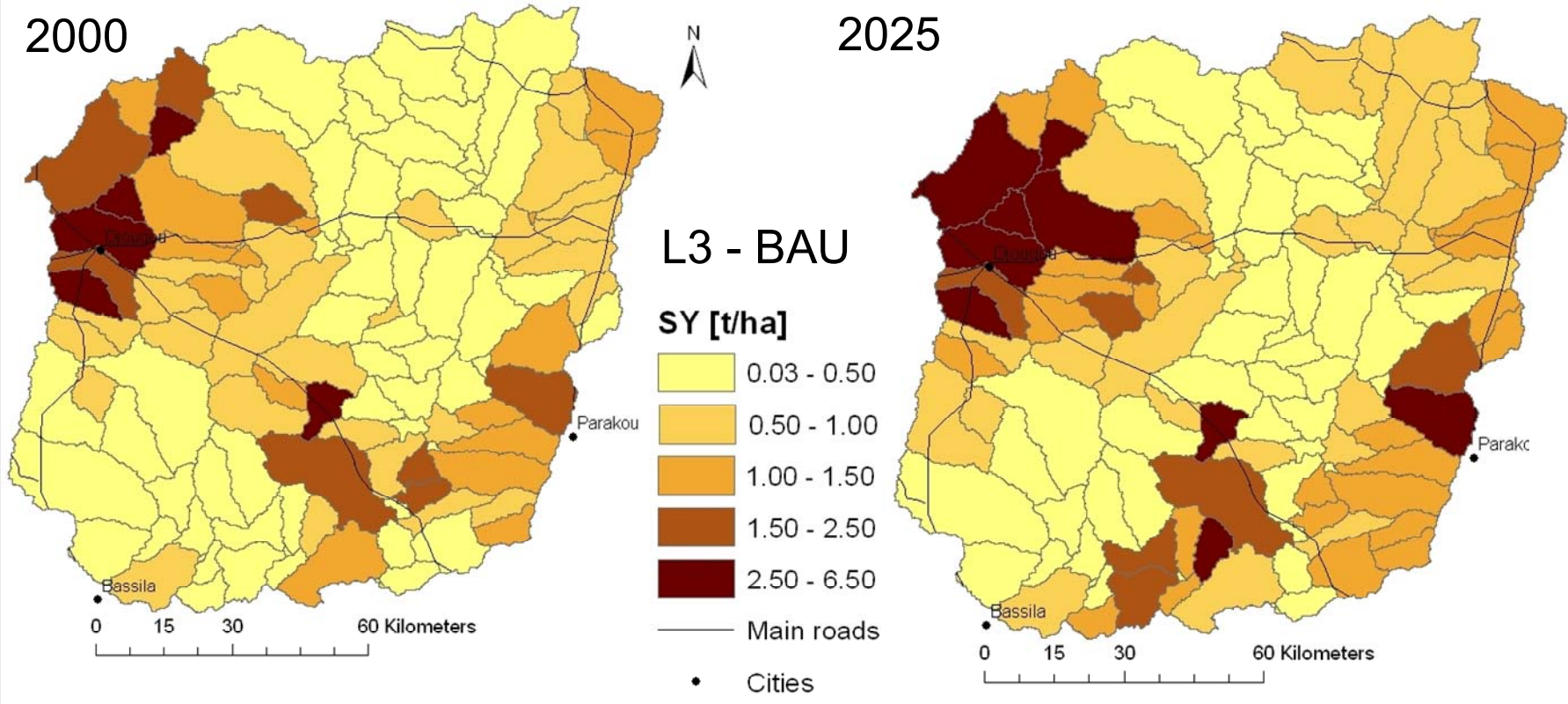
- based on results from LUCC model CLUE-S (logistic regression & decision rules)
- driving forces (e.g. population density, protected areas, distance roads/markets)
- demand: field area per capita = f (land use intensity), population growth
- disaggregation scheme




Data source: M.Judex & H.P.Thamm

# Landuse scenario - results




| | Fields_dis agg [%] | SY [t/ha] | WY [mm] | ΔFields_dis agg [%] | ΔSY [%] | ΔWY [%] |
|---|---|---|---|---|---|---|
| **L1 (Growth)** | 16 | 0.22 | 222 | +20 | -7 | 0 |
| **L2 (Stagnation)** | 21 | 0.28 | 230 | +58 | 17 | 4 |
| **L3 (BAU)** | 18 | 0.25 | 225 | +34 | 6 | 1 |

# Conclusions

- SWAT was successfully calibrated and validated for a subhumid tropical catchment
- climate scenarios: decrease of WY and SY, 2 of 3 land use scenarios: significantly increase of SY
- recent and future hotspots of soil erosion were identified

# Outlook

- Combined scenarios (climate/land use)
- Uncertainty analysis
- SDSS: Integration of erosion and crop modeling results; for various stakeholders in Benin
  - Execution of SWAT and EPIC in the SDSS
  - Scenario analysis (climate, land use, plant management)
  - User-friendly, flexible: import of other SWAT projects possible

Thank you to my collegues from the IRD CATCH project
and the IMPETUS project for providing data and valuable comments!

# Thank you for your attention!

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# Climate scenarios - results

## Upper Ouémé

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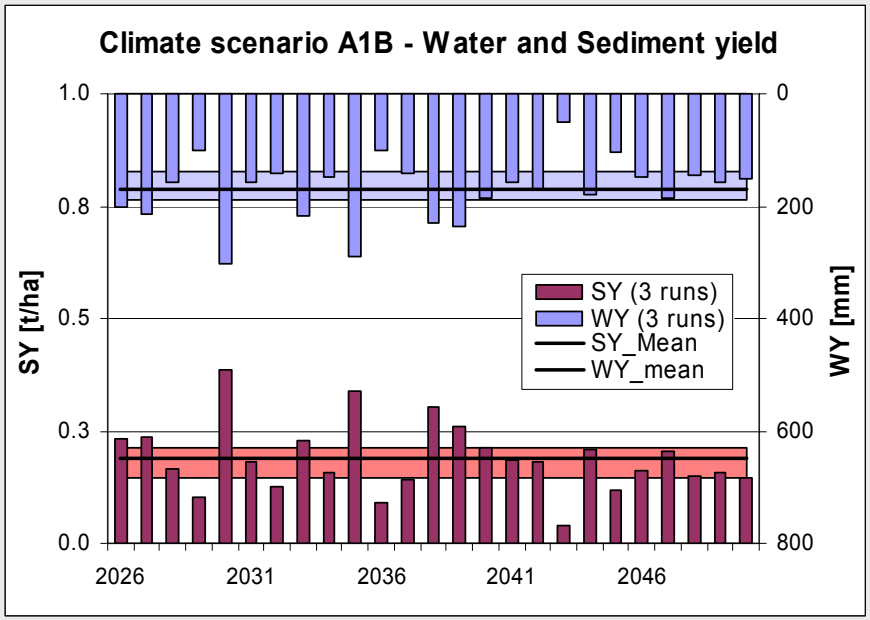
Donga-Pont ↓↓

Terou-Igbo ↑

## A1B: 2026-2050




## B1: 2026-2050