Land use update function in SWAT – application in two macro watersheds in Brazil

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**Aim:**
- Investigation of effects of land use change on stream flow
- Inclusion of land use change in the model calibration and validation

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Land use change (Cerrado biome)

Cerrado: Natural scrubland savanna
- Tropical dry and wet climate (Aw Köppen)
- Suitable for rain fed agriculture

Fragmentation of the landscape
Original: Cattle ranging
Agricultural intensification: Double Cropping of soy and corn

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Land Use Change (Amazonian rainforest biome)

Rainforest, tropical monsoon climate (Am Köppen)

Main agricultural use: cattle ranging

Current development: July 2014

Slash and burn... Later pasture degradation

February 2015

High efficient grassland

Too wet for soy?

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We learned (mainly from micro-catchment studies):

- Forest removal rises stream flow
- Forest removal reduces ET
- Agricultural land use rises soil bulk density
  - decreases infiltration capacity
  - increases surface runoff
  - decreases storage capacity...

BUT WHAT DOES IT DO ON MACRO CATCHMENT SCALE?

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Historic land use change

Remainning forest cover

Rio das Mortes / Cerrado

Jamanxim / Rainforest

IBGE data

- Amazon Basin
- Mato Grosso

LANDSAT evaluation

△ Jamanxim, whole catchment
+ Jamanxim, 20 km vicinity of road
× Rio das Mortes


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Study watersheds

Rio das Mortes, Mato Grosso
Cerrado Biome

Jamanxim, Para
Amazon rainforest Biome

1988

2011

Legend
- Gauging Station
- Forest
- Pasture since pre 1998
- Pasture cleared 1998 to 2011
- Urban
- Water
- BR163 20 km vicinity
- Subbasins
- Stream network
- BR163
- Water stations (inmet)

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Historic discharge records for the Rio das Mortes catchment

Guzha et al 2013 showed a clear trend between the 70th and 80th of rising discharge

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Experimental setup

<table>
<thead>
<tr>
<th></th>
<th>Rio das Mortes (savanna)</th>
<th>Jamanxim (rainforest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LU-update % per annum in validation and calibration period; mean (min – max) for different subbasins</td>
<td>2.4 (1.7-3.4) (Cerrado to Non-Forest)</td>
<td>0.6 (0-4) (Forest to pasture)</td>
</tr>
</tbody>
</table>

**Carbiocial Story lines**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Rio das Mortes</th>
<th>Jamanxim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario trend 2030</td>
<td>3% natural, 23% pasture, 73% cropland</td>
<td>46% forest, 40% pasture, 13 cropland</td>
</tr>
<tr>
<td>Scenario sustainable 2030</td>
<td>3% natural, 12% pasture, 84% cropland</td>
<td>65% forest, 1% pasture, 34% cropland</td>
</tr>
<tr>
<td>Scenario intensification 2030</td>
<td>2% natural, 24% pasture, 73% cropland</td>
<td>30% forest, 57% pasture, 13% cropland</td>
</tr>
</tbody>
</table>

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Calibration and Validation: 
Rio das Mortes (Cerrado savannah) watershed 

- ANA discharge station 
- INMET climate records from 6 weather stations 
- 2.5% annual Cerrado deforestation (Landsat and reconstruction)
Calibration and Validation: Jamanxim (rainforest) watershed

- ANA discharge records
- CFSR Global weather (no INMET records in the whole watershed) –
- 0.6% annual rainforest deforestation (LANDSAT images)

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<table>
<thead>
<tr>
<th>catchment</th>
<th>Rio das Mortes</th>
<th>Jamanxim</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area [km²]</strong></td>
<td>17,556</td>
<td>37,403</td>
</tr>
<tr>
<td><strong>Dominant natural vegetation</strong></td>
<td>Cerrado and Gallery Forest</td>
<td>Rainforest</td>
</tr>
<tr>
<td><strong>Dominant soils types</strong></td>
<td>Latosoło, Neosolo</td>
<td>Latosoło, Argisolo</td>
</tr>
<tr>
<td><strong>Main period of deforestation</strong></td>
<td>1975-1990</td>
<td>2000-2010</td>
</tr>
<tr>
<td><strong>Current degree of deforestation</strong></td>
<td>~70%</td>
<td>~26%</td>
</tr>
<tr>
<td><strong>No of subbasins in the model (min-max [km²])</strong></td>
<td>20 (260-1500)</td>
<td>17 (890-4500)</td>
</tr>
<tr>
<td><strong>No of HRUs</strong></td>
<td>240</td>
<td>135</td>
</tr>
<tr>
<td><strong>Thresholds</strong></td>
<td>2% LU, 5% soil, 5% slope</td>
<td>2% LU, 5% soil, 5% slope</td>
</tr>
<tr>
<td>**Climate * **</td>
<td>Aw after Köppen</td>
<td>Am after Köppen</td>
</tr>
<tr>
<td></td>
<td>Tropical wet and dry with 4-5 months dry season</td>
<td>Tropical monsoon climate with 3 months dry season</td>
</tr>
<tr>
<td>**Annual rainfall [mm] * **</td>
<td>Primavera d. Leste: 1784</td>
<td>Novo Progresso: 2232</td>
</tr>
<tr>
<td>**Mean temperature [°C] * **</td>
<td>Primavera d. Leste: 22.0</td>
<td>Novo Progresso: 25.8</td>
</tr>
<tr>
<td><strong>Mean slope [%]</strong></td>
<td>2.9</td>
<td>12.9</td>
</tr>
<tr>
<td>**Fraction of slope: 0-2</td>
<td>2-5</td>
<td>5-max [%] **</td>
</tr>
</tbody>
</table>

* (“Climate-Data.org” 2015)

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Challenges:

- Data acquisition
  - Historical land use distribution/classification
  - Climate records
  - Discharge records
- Parametrisation
  - Evergreen vegetation
    - Cerrado Savanna
    - Rainforest
  - Soils
  - Management

LUC Rio das Mortes

No meta data on Q station - no trace...

Missmatch of Q and P around 2000

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Challenges:

- Data acquisition
- Historical land use distribution/classification
- Climate records
- Discharge records

- Landsat versus statistical information
- Sparse and records with gaps – "mismatch Q and P"
- Limited additional information (e.g. Rating curve), Weak defined cross-section

LUC Rio das Mortes

No meta data on Q station – no trace...

Missmatch of Q and P around 2000

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Challenges:

Vegetation:
- Dormancy
- Limited literature on Cerrado savanna / active mechanisms to deal with water stress

Soil:
- "old" map with Brazilian classification
- Sparse profile data for soil type parametrisation
- Limited own data from micro-watershed studies

Parametrisation
- Evergreen vegetation
  - Cerrado Savanna
  - Rainforest
- Soils
- Management

Vegetation:

- Dormancy
- Limited literature on Cerrado savanna / active mechanisms to deal with water stress

Soil:

- "old" map with Brazilian classification
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### Calibration Vegetation and Soil dependent

<table>
<thead>
<tr>
<th>parameter</th>
<th>description</th>
<th>Land use dependent</th>
<th>Soil class dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW_delay [days]</td>
<td>Groundwater delay</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>GW_revap</td>
<td>Groundwater revaporation</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Sol_K [mm h(^{-1})]</td>
<td>Soil hydraulic conductivity</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>CN2</td>
<td>Curve Number</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

- Matrix of parameter calibration dependent on vegetation and soil
- Automatic calibration with SWAT-CUP SUFI-2
- Calibration: 2 iterations with each 1500 runs

Plus other parameters: such as GW_DELAY, Alpha BF etc...
Calibration Validation and Test results:

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<tr>
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<th>Jamanxim</th>
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</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>NSE: 0.68</td>
<td>NSE: 0.80</td>
</tr>
<tr>
<td>Validation: land use update</td>
<td>NSE: 0.63</td>
<td>NSE: 0.85</td>
</tr>
<tr>
<td>Test: steady land use</td>
<td>NSE: 0.48</td>
<td>NSE: 0.81</td>
</tr>
</tbody>
</table>
Rio das Mortes Calibration, Validation and Test
Jamanxim: Calibration, Validation and Test
CONCLUSION:
• Especially in periods with rapid and fundamental land use change even simple land use update improves model performance (effect is more pronounced for Rio das Mortes catchment)

FURTHER WORK:
• Quantification of the „improvement“
• Investigation of seasonality in runoff
• Did we get it right for the right reasons? More investigation into the water balance components (soft data)
• Climate feedback in the rainforest
• Scenarios (Storylines and Management)
THANKS!

Any questions?
Scenarios 2030
Rio das Mortes
Jamanxim: Changes in Q are mainly changes in ET