AN AUTOMATED PROCEDURE FOR SWAT-LUD TO BE APPLIED AT THE CATCHMENT SCALE.

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Outlines

1. The **Landscape Units Darcy** model (LUD)
2. The LUD implementation in SWAT
3. The LUD model validation

For more (denitrification, etc) see Xiaoling SUN presentation this afternoon!
What is an LUD?

What are the model parameters?

How to find values for these parameters?
Reminder: HRU

Flow direction

Surface water to Groundwater is not simulated in SWAT
River to alluvial aquifer water exchanges,
- Flooding water infiltrating the LUs,
Landscape Unit model

- River to alluvial aquifer water exchanges,
- Flooding water infiltrating the LUs,

- LUD1: annual flooding area
- LUD2: 2 to 5 years flooding area
- LUD3: 10+ years flooding area
River to alluvial aquifer water exchanges,
Flooding water infiltrating the LUs,
At the alluvial plain scale.

**LUDs = subbasin containing HRUs**

**Landscape Unit model**

- River to alluvial aquifer water exchanges,
- Flooding water infiltrating the LUs,
- At the alluvial plain scale.
- River to alluvial aquifer water exchanges,
- Flooding water infiltrating the Lus,
- At the floodplain scale.
River to alluvial aquifer water exchanges,
Flooding water infiltrating the Lus,
At the floodplain scale.
# Landscape Units geometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Description</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l$</td>
<td>meters</td>
<td>LUD’s length along the river</td>
<td>$= \text{channel’s length}$</td>
</tr>
<tr>
<td>S_para</td>
<td>m/m</td>
<td>LUD’s slope parallel to the channel</td>
<td>$= \text{channel’s slope}$</td>
</tr>
</tbody>
</table>
| S_perp    | m/m  | LUD’s slope perpendicular to the channel | • LUD1 = channel’s slope x 2  
• LUD2 = channel’s slope x 5  
• LUD3 = channel’s slope x 10 |
| A         | m²   | LUD’s surface | • LUD1 = 10% alluvial surface 
• LUD2 = 20% alluvial surface 
• LUD3 = 70% alluvial surface |
| $L$       | meters | LUD’s width | $A / l$ |
| $h$       | meters | LUD’s mean height to the surface | Channel depth + ($L \times S_{\text{perp}}$) / 2 |
River / Alluvial aquifer interface

Darcy’s equation (1856):

\[ Q = K \times A \times \frac{\Delta H}{D} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K )</td>
<td>m.d(^{-1})</td>
<td>Hydraulic conductivity</td>
<td>( \text{LUD1} = 300 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( \text{LUD2} = 200 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( \text{LUD3} = 100 )</td>
</tr>
<tr>
<td>( A )</td>
<td>m(^2)</td>
<td>Area of interface</td>
<td>( h \times l )</td>
</tr>
<tr>
<td>( D )</td>
<td>m</td>
<td>Distance between the middle of two consecutive reservoirs</td>
<td>( \frac{L_{\text{LUD}<em>i}}{2} + \frac{L</em>{\text{LUD}_k}}{2} )</td>
</tr>
<tr>
<td>( \Delta H )</td>
<td>m</td>
<td>Difference of water levels</td>
<td>( gw_{\text{height}<em>i} - gw</em>{\text{height}_k} )</td>
</tr>
</tbody>
</table>
River / Alluvial aquifer processes

Denitrification:

Nitrate consume rate:

\[ R_{NO3} = -0.8 \left( \rho \frac{1-\varphi}{\varphi} \cdot k_{POC}[POC] \cdot \frac{10^6}{M_C} + k_{DOC}[DOC] \right) \cdot \frac{[NO3]}{k_{NO3} + [NO3]} \]

DOC consume rate: \[ R_{DOC} = -k_{DOC}[DOC] \]

POC consume rate: \[ R_{POC} = -k_{POC}[POC] \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varphi )</td>
<td>-</td>
<td>Sediment porosity</td>
</tr>
<tr>
<td>( \rho )</td>
<td>kg.dm(^{-3})</td>
<td>Dry sediment density</td>
</tr>
<tr>
<td>( k_{POC} )</td>
<td>d(^{-1})</td>
<td>Mineralisation rate constant of POC</td>
</tr>
<tr>
<td>( k_{DOC} )</td>
<td>d(^{-1})</td>
<td>Mineralisation rate constant of DOC</td>
</tr>
<tr>
<td>( k_{NO3} )</td>
<td>( \mu )M</td>
<td>Half-saturation for nitrate limitation</td>
</tr>
</tbody>
</table>

For more (denitrification, etc) see Xiaoling SUN presentation this afternoon!
The LUD implementation in SWAT

Where do changes occur in the source code?

How to automatically construct LUDs?

How to populate LUDs with HRUs?
LUD implementation in SWAT

Several subroutines **specific to LUD model:**
- `routeunit`:
  - Groundwater and nitrate sum from HRUs to LUDs,
- `routels`:
  - No groundwater flow between landscape units (now done in `route_ru`).

Several subroutines **added:**
- `route_ru`:
  - DOC / nitrate masses and concentrations in LUD groundwater,
  - Nitrate from soil to groundwater with infiltrated flood water,
  - Darcy equation,
  - Nitrate and DOC exchanges between LUDs.
- `rtday_ru`:
  - Flooding,
  - Infiltration.
- `rchinit_ru`,
- `rtout_ru`,
- `gwmod_ru` : groundwater volume and height in each HRU from corresponding LUD (without flood water),
- `gw_no3_ru` : nitrate content in groundwater for each HRU,
- `denit_gw` : denitrification in each LUD.
SWAT LUD: project creation

Reading parameters from old SWAT project:
• .fig,
• .sub,
• .hru,
• .sol

Computing all LUD parameters:
• Length,
• Slope,
• Conductivity, Surface,
• Width,
• Mean depth.

Rearranging subbasins and HRUs to fit the LUD model.
• Compute new subbasin’s and HRU’s surfaces.

Rewriting needed files:
• Old subbasins without alluvial aquifers,
• Old subbasins with alluvial aquifers
• New LUD subbasins with new HRUs
• figfile

Will be implemented in ARCSWAT
Untouched, modified and added input files in a SWAT LUD project compared to a standard SWAT project.
LUD approach validation

How well does the model work?
First LUD results

For more (denitrification, etc) see Xiaoling SUN presentation this afternoon!
Conclusions & Perspectives

- Model validated at:
  - Meander scale (Monbequi)
  - Alluvial plain scale
  - Subbasin scale

- Against:
  - Water levels
  - Nitrate

- Create LUD project from ArcSWAT

- Include river sinuosity in hydraulic conductivity parameter

- Calculate LUD’s area from flooded areas

- Calculate mean depth from aquifer geometry
SWAT LUD: alluvial HRUs redistribution

Alluvial HRU = with alluvial soil

Old subbasin with alluvial soil
Total surface = $S$

Other HRUs (with alluvial soil but urban, etc)
Total surface = $S_{other}$

Alluvial HRUs (forest, pasture, agri only)
Total surface = $S_{allu}$

Forest HRUs
Surface = $S_{for}$

Pasture HRUs
Surface = $S_{past}$

Agriculture HRUs
Surface = $S_{agri}$

1) each LUD surface is fixed: % of total $S_{allu}$ (see below)
2) Then distribution of HRUs from LUD1 to LUD3
   1) All forest HRUs in LUDs closest to river
   2) Then pasture HRUs
   3) Finally agriculture HRUs

LUD1
10% $S_{allu}$

LUD2
20% $S_{allu}$

LUD3
70% $S_{allu}$

New (smaller) subbasin without alluvial soil
New surface = $S_{other}$
LUD implementation

Modifications **(CYAN)** to the **command** subroutine (executing the figfile).

The diagram shows the execution flow of the subroutine from top to bottom.
LUD implementation

Modifications (CYAN and BOLD) to the subbasin subroutine.

The diagram shows the execution flow of the subroutine from top to bottom.
LUD implementation

Modifications (CYAN) to the route_ru subroutine.

The diagram shows the execution flow of the subroutine from top to bottom.

- Calculate COD content (mass in g) in each LUD before flooding
- Calculate nitrate and DOC concentration in each LUD groundwater after flooding
- Nitrate from soil to groundwater with infiltrated flood water
- Average Saturated Conductivity between LUD
- Calculate gw_q with Darcy's equation
- Calculate the net changed water volume in LUDs
- Compute Nitrate and DOC exchanges between LUDs
Added **route_ru** subroutine with modifications in bold compared to the route subroutine.

The diagram shows the execution flow of the subroutine from top to bottom.