Calibration of a lumped nitrogen model in a Mediterranean forested catchment named Fuirosos, Catalonia

By:

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Introduction

- Mediterranean ecosystems
  - Mediterranean catchments are characterized by a complex hydrological behaviour that presents high inter and intra-annual variability (Gallart et al., 2002)
  - Altering dry and humid conditions that have great influence on the catchment hydrological response (Medici et al., 2008) and soil microbial activity (Birch 1964, Austin et al., 2004, Reynolds et al., 2004)
  - Rainfall inputs to a dry soil represent pulses that trigger a cascade of biogeochemical and biological transformations (Schiwinning et al., 2004)
Objective

- The aim of this work was to develop a conceptual model of nitrogen dynamics capable of application in Mediterranean catchments.
  
  - Following the philosophy of the process-based INCA-N model (Wade et al., 2004) for which problems were observed when applied to Mediterranean systems (Bernal et al., 2004)
  
  - A recently developed hydrological model **LU4** (*L*umped *4* *hydrological responses* model, Medici et al., 2008) was extended through the inclusion of processes representing the inorganic nitrogen cycle, obtaining the **LU4-N** model
Study site: Fuirosos catchment

- Catchment area: 13 km²
- Forest covers 90% of tot. area
- Lithology:
  - Granodiorite
  - Leucogranite
  - Schists
  - Well-developed riparian zone at the valley bottom
- Mediterranean climate:
  - Mean annual Ppt: 750 mm
  - Mean annual PET: 975 mm
- Intermittent stream
LU4: Hydrological calibration

Medici et al., 2008
LU4: Hydrological calibration

Nash efficiency Index (E) = 0.7

Medici et al., 2008
The model provides a simplified conceptualization of nitrogen cycle in soil and shallow aquifer.

The model includes a soil moisture threshold for all the considered soil biological processes, expressed as a percentage of the maximum amount of water retained by upper soil capillary forces ($H_u^*$).
LU4-N model: Soil moisture thresholds

- **Mineralization:**
  - $S_1$ is the soil moisture factor
  - $H_1$ is the actual static storage water content (mm/day)
  - $H_u^*$ is maximum amount of water retained by upper soil capillary forces (mm)
  - $U_{Miner}$ is the soil moisture threshold for mineralization ($\%$), expressed as a percentage of $H_u^*$ (mm)

\[
\left( M_{NH_4} \right)_{Mineral} = K_{Miner} \cdot S_{1_{Miner}} \cdot TF
\]
Other soil processes:

- Nitrification
- Denitrification
- Immobilization
- Plant uptake
## LU4-N Model Parameters

<table>
<thead>
<tr>
<th>Moisture thresholds</th>
<th>LU4-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_{Mn}$</td>
<td>Mineralization soil moisture threshold</td>
</tr>
<tr>
<td>$U_{denitr}$</td>
<td>Denitrification soil moisture threshold</td>
</tr>
<tr>
<td>$U_{nitr}$</td>
<td>Nitrification soil moisture threshold</td>
</tr>
<tr>
<td>$U_{NO_{3}uptake}$</td>
<td>$NO_3$ Uptake soil moisture threshold</td>
</tr>
<tr>
<td>$U_{NH_{4}uptake}$</td>
<td>$NH_4$ Uptake soil moisture threshold</td>
</tr>
<tr>
<td>$U_{Immobil}$</td>
<td>Immobilization soil moisture threshold</td>
</tr>
</tbody>
</table>
Soil moisture effect

- 2001/2002

Higher mineralization after the summer drought

Nitrification pulses after soil rewetting
LU4-N: Nitrate calibration

- Global $E = 0.5$
  - $E_{1\text{year}} < 0.0$
  - $E_{2\text{year}} = 0.5$
  - $E_{3\text{year}} = 0.4$
LU4-N: Nitrate calibration

Nitrogen annual processes rate:

<table>
<thead>
<tr>
<th>N Processes</th>
<th>Measured values [Kg ha⁻¹ day⁻¹]</th>
<th>Sim values [Kg ha⁻¹ day⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net mineralization</td>
<td>32.4 – 80.1</td>
<td>62.2</td>
</tr>
<tr>
<td>Net nitrification</td>
<td>4.4 – 7.5</td>
<td>6.26</td>
</tr>
<tr>
<td>Immobilization</td>
<td>0.08</td>
<td>4.83</td>
</tr>
<tr>
<td>Nitrate uptake by vegetation</td>
<td>10.3 - 58</td>
<td>13.07</td>
</tr>
<tr>
<td>Ammonium uptake by vegetation</td>
<td>53 – 80.5</td>
<td>58.94</td>
</tr>
</tbody>
</table>

LU4-N: Nitrate validation

For the temporal validation the model could only reproduce the monthly nitrate loads.
Conclusions

- From the result obtained, the soil nitrogen cycle at Fuirosos, seems to be largely influenced by the rain episodes that induce catchment re-wetting.
  - According to the LU4-N model conceptualization microbial processes occur in pulses, stimulated by soil moisture increasing after rain
- The inclusion of thresholds also allowed reproducing the observed ratio between mineralization and nitrification characteristic of Mediterranean regions, which has been shown to be around 10:1 (Serrasoles et al., 1999).
Conclusions

- The ability of the LU4-N model to reproduce the observed NO$_3$ stream concentration for the three year calibration period suggest that the key factors and processes controlling the hydrological and N behaviour are included within the model conceptual scheme and that their mathematical representation seems reasonable.
Conclusions

- The temporal validation process call for caution when considering the result obtained
- The model sensitivity analysis (not showed in this presentation) pointed out the mineralization as a key process
- Intermittent streams and their associated riparian zone have been highlighted as ‘hot spots’ for biogeochemical processes in arid and semiarid regions (McIntyre et al., 2009)
Further research step:

- Mineralization better representation, taking into account a semidistributed spatial description (i.e. introducing a riparian zone) may lead to more satisfactory results especially for the validation year.
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