Application of a lumped nitrogen model to a small Mediterranean catchment, Fuirosos (Catalonia)

By:

C. Medici, A. Butturini, S. Bernal, F. Sabater, M. Martín, A. J. Wade and F. Francés

Universidad Politécnica de Valencia - Spain
Instituto de Ingeniería del Agua y Medio Ambiente
Grupo de Investigación de Hidráulica e Hidrología
http://lluvia.dihma.upv.es

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Introduction

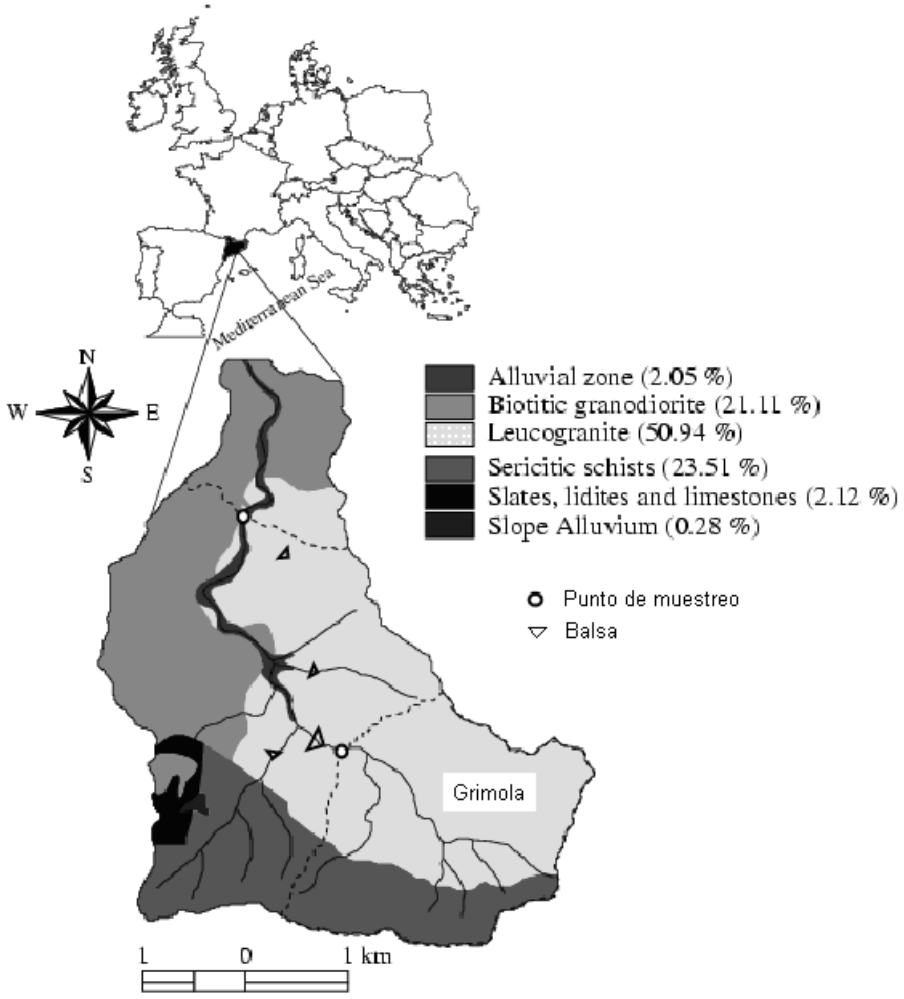
- Mediterranean ecosystems
  - Mediterranean catchments are characterized by a ***complex hydrological behaviour*** that presents high inter and intra-annual variability (Gallart et al., 2002)
  - ***Altering dry*** and ***humid conditions*** that have great influence on the catchment hydrological response (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

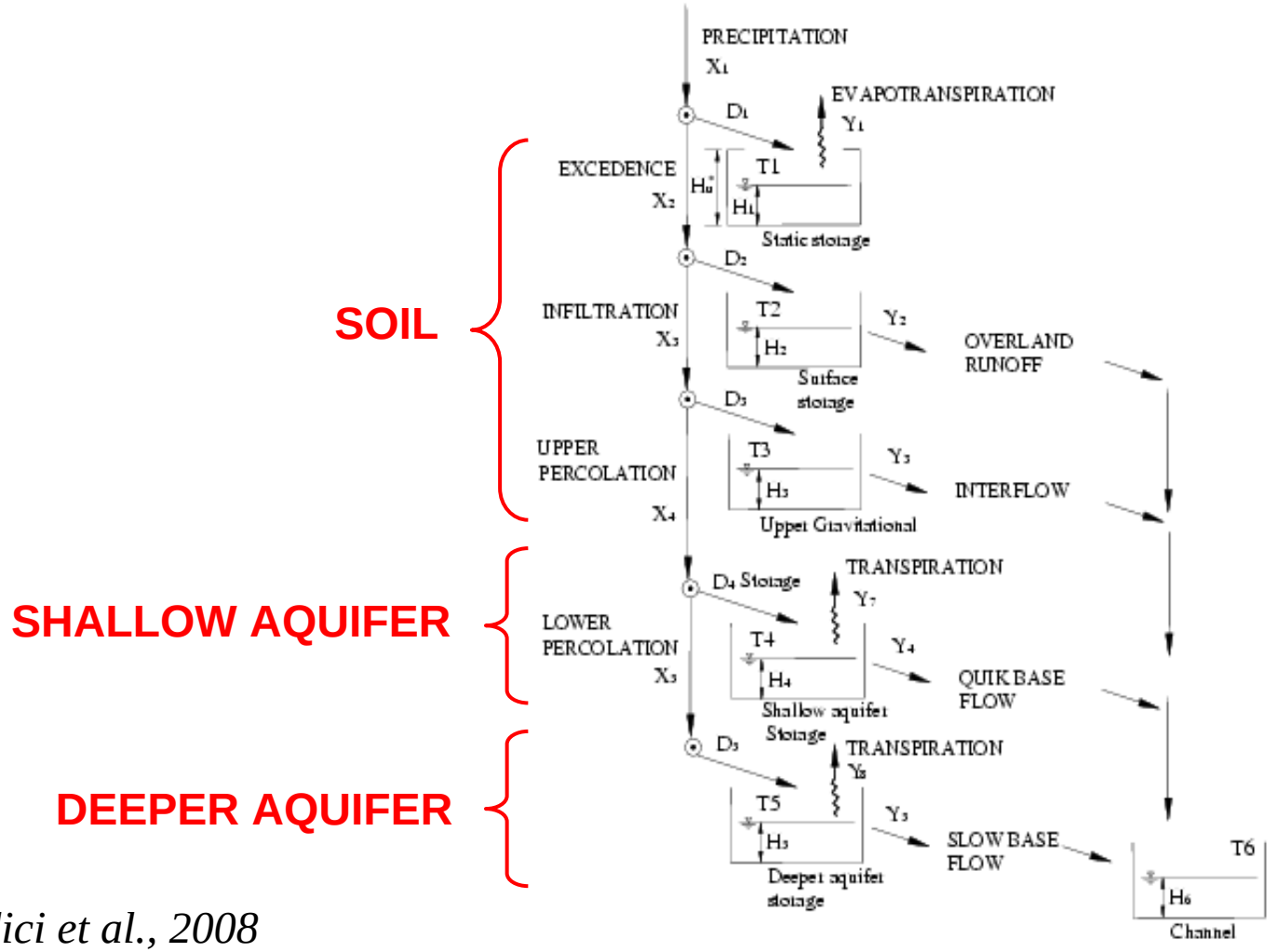
- The aim of this work was to develop a conceptual model of nitrogen dynamics capable of application in Mediterranean catchments.
  - Following the philosophy of the process-based INCA-N model (Wade et al., 2004) for which problems were observed when applied to Mediterranean systems (Bernal et al., 2004)
  - A recently developed hydrological model **LU4** (*LUmped 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 km^2
- 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



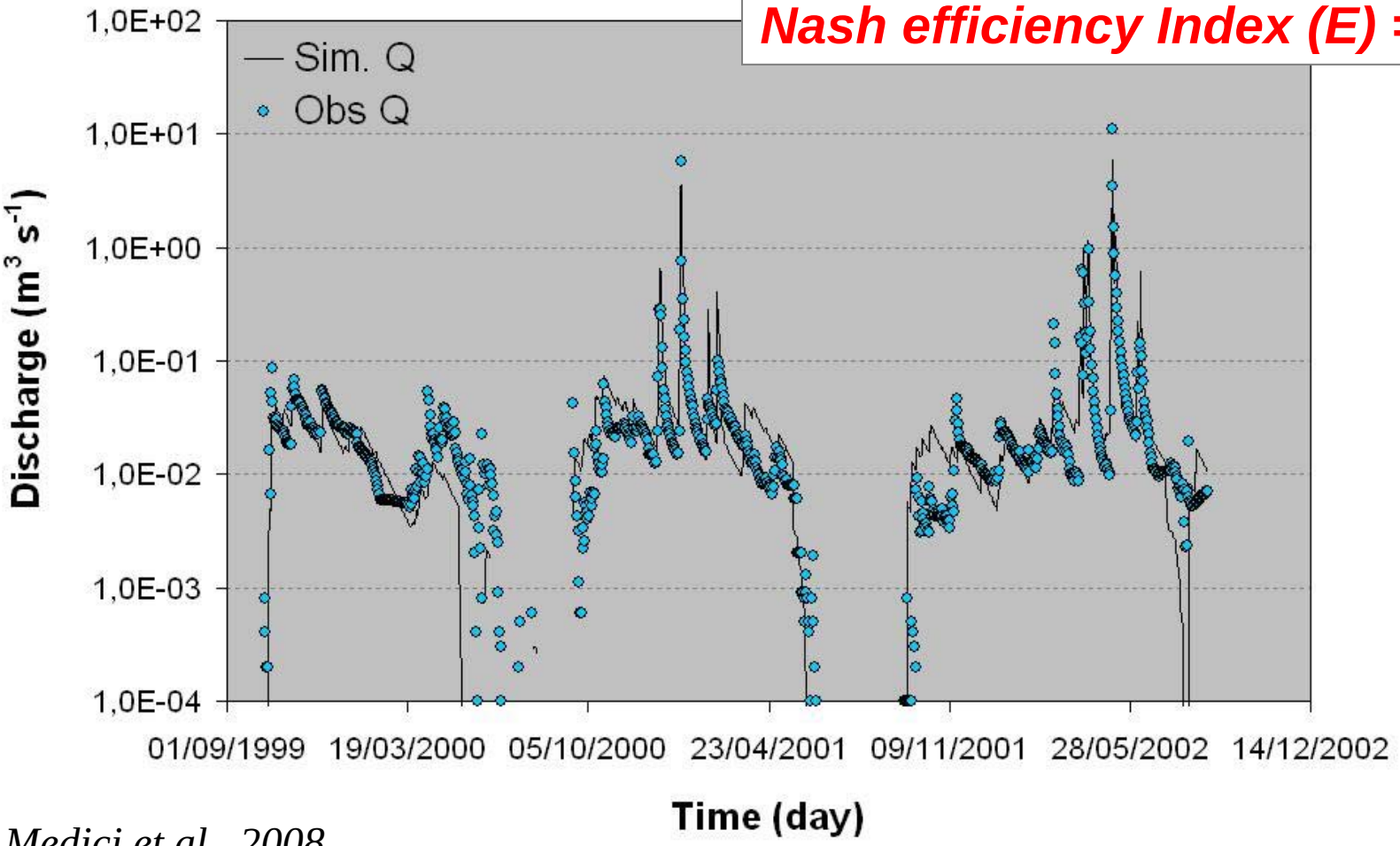
LU4: Hydrological calibration



Medici et al., 2008

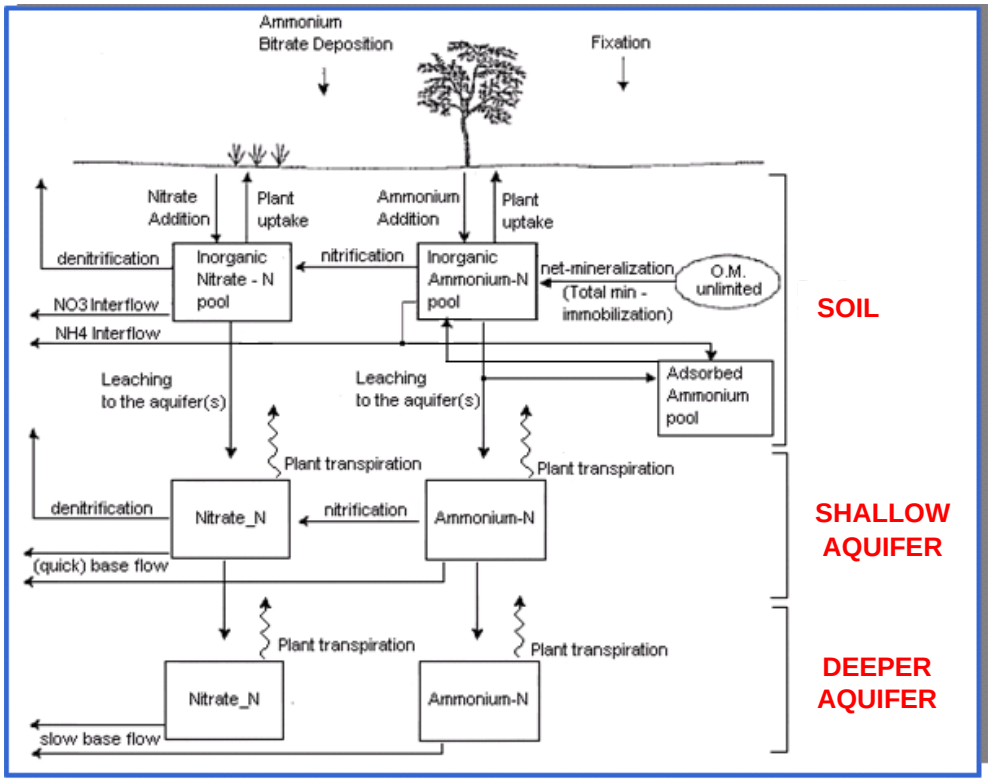
LU4: Hydrological calibration

Nash efficiency Index (E) = 0.7



Medici et al., 2008

LU4-N model : INCA-based Nitrogen Cycle



- 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:

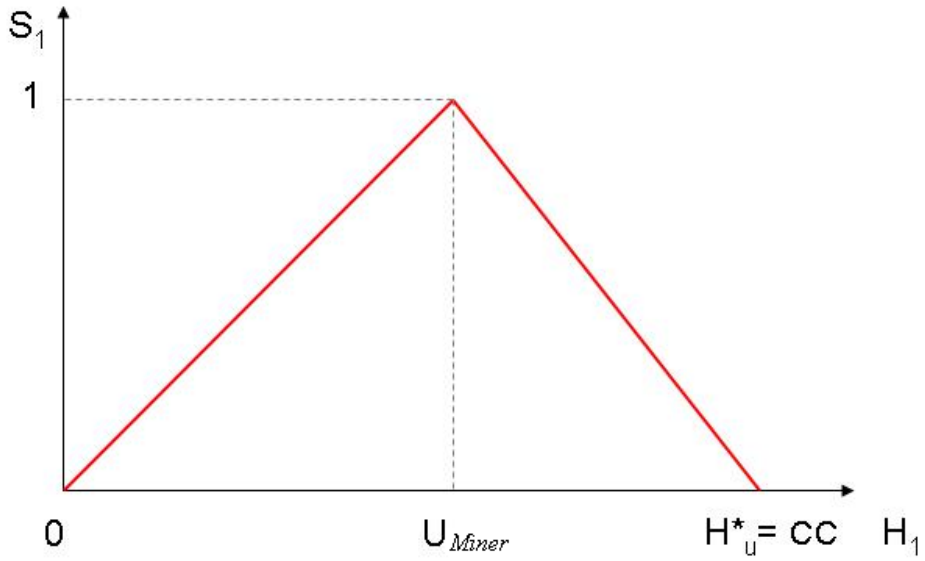
$$\left(M_{NH_4}\right)_{Mineral.} = K_{Miner} \cdot S_{1\_Miner} \cdot TF$$

  - M_{NH4} ammonium mineralized mass (kg ha^{-1} day^{-1})
  - S_1 is the soil moisture factor
  - K_{Miner} is the mineralization constant rate (Kg ha^{-1} day^{-1})
  - TF is the temperature corrector factor (Whitehead et al., 1998)

LU4-N model: Soil moisture thresholds

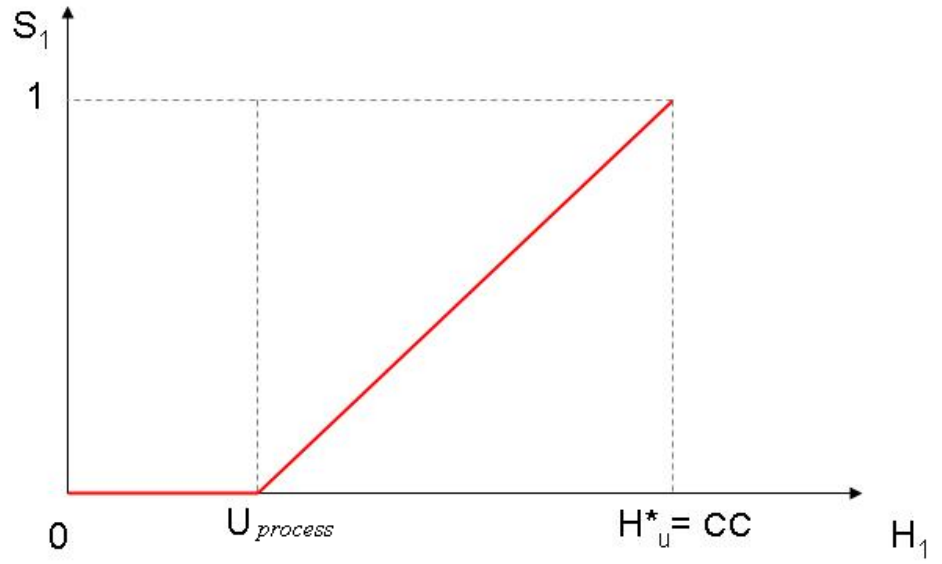
- Mineralization:
  - S_1 is the soil moisture factor
  - H_1 is the actual static storage water content (mm/day)
  - H_u^* is maximum amount of water retained by upper soil capillary forces (mm)
  - U_{Miner} is the soil moisture threshold for mineralization (%), expressed as a percentage of Hu* (mm)

$$\left(M_{NH_4}\right)_{Mineral.} = K_{Miner} \cdot S_{1\_Miner} \cdot TF$$



LU4-N model: Soil moisture thresholds

- Other soil processes:
  - Nitrification
  - Denitrification
  - Immobilization
  - Plant uptake

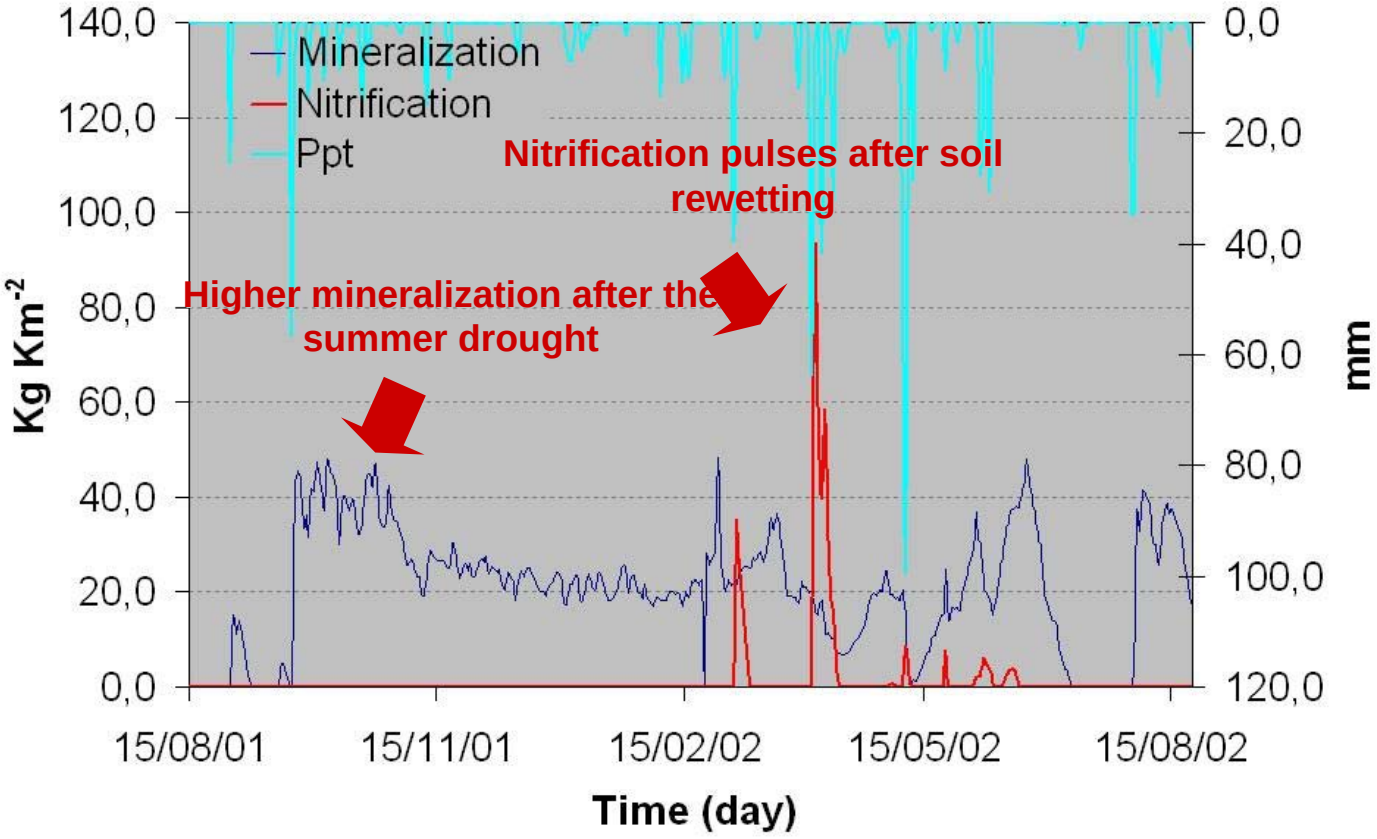


LU4-N Model Parameters

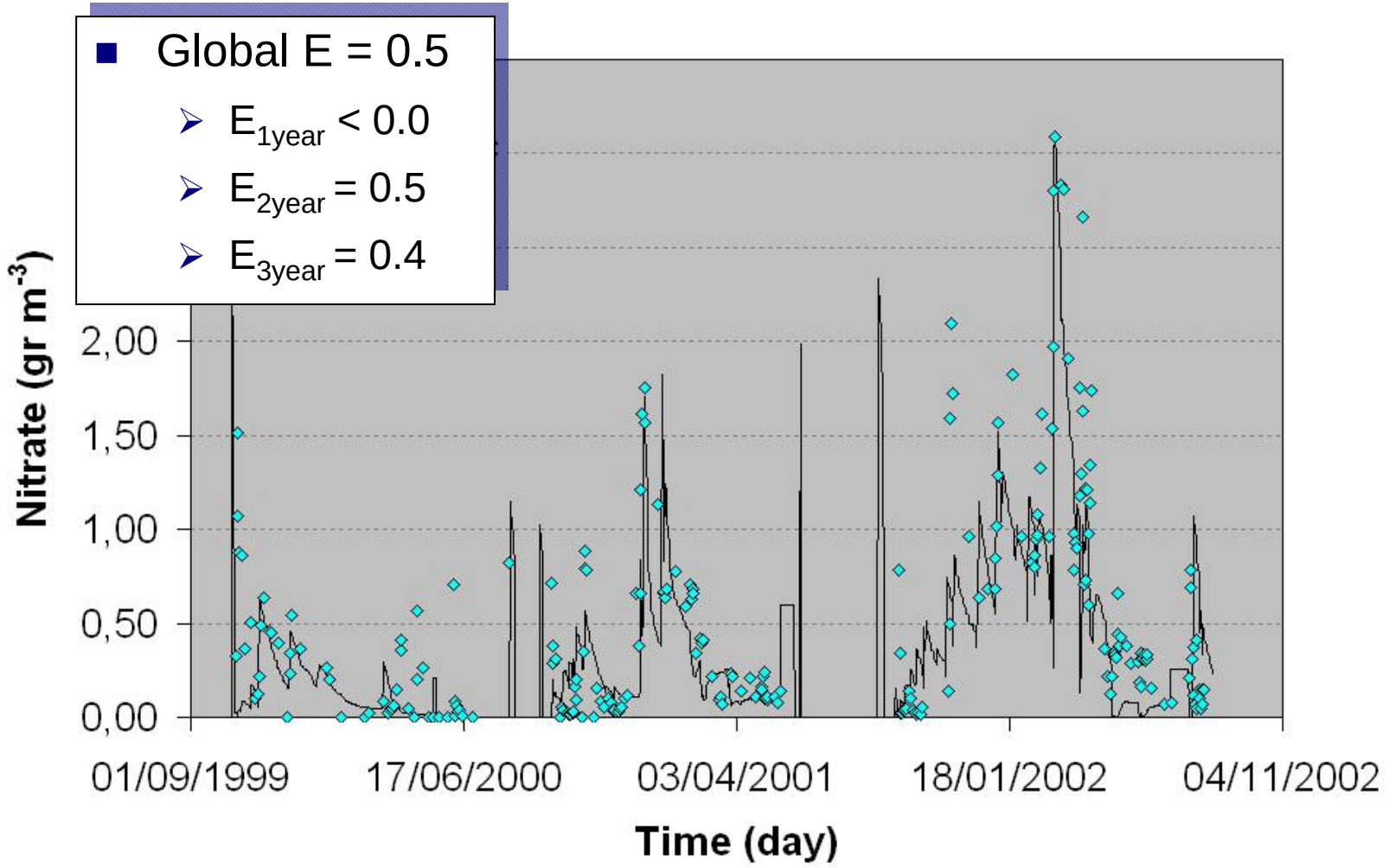
Moisture thresholds		LU4-N
U_{Min}	*Mineralization soil moisture threshold*	43%
U_{denitr}	*Denitrification soil moisture threshold*	80%
U_{nitr}	*Nitrification soil moisture threshold*	51%
$U_{NO_3uptake}$	*NO_3 Uptake soil moisture threshold*	0%
$U_{NH_4uptake}$	*NH_4 Uptake soil moisture threshold*	0%
$U_{Immob.}$	*Immobilization soil moisture threshold*	38%

Soil moisture effect

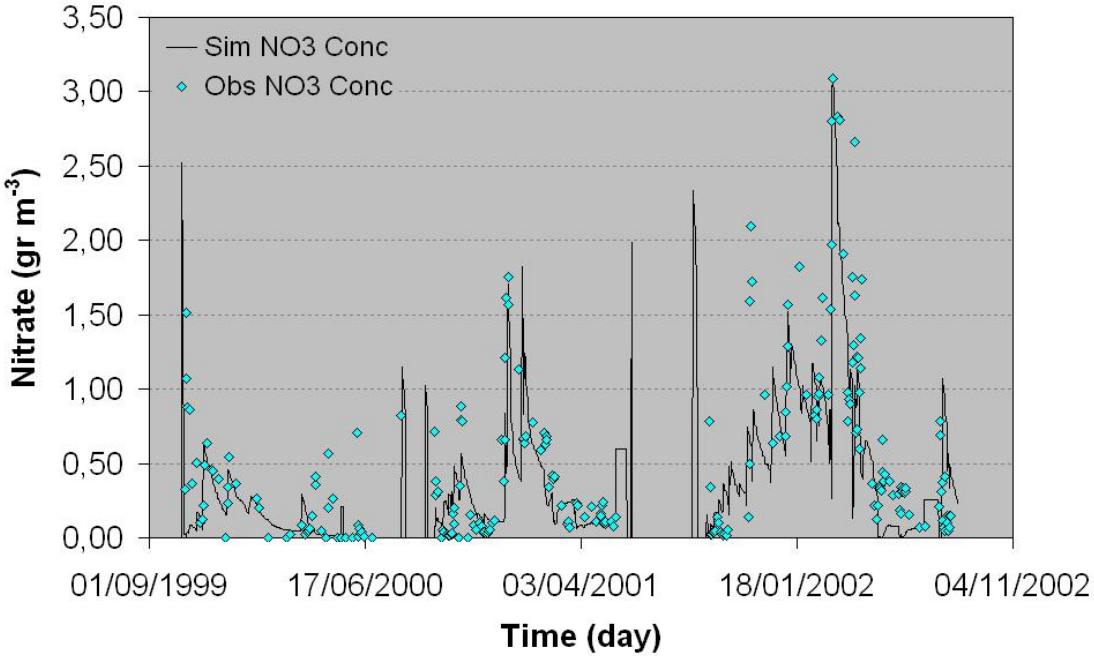
- 2001/2002



LU4-N: Nitrate calibration



LU4-N: Nitrate calibration



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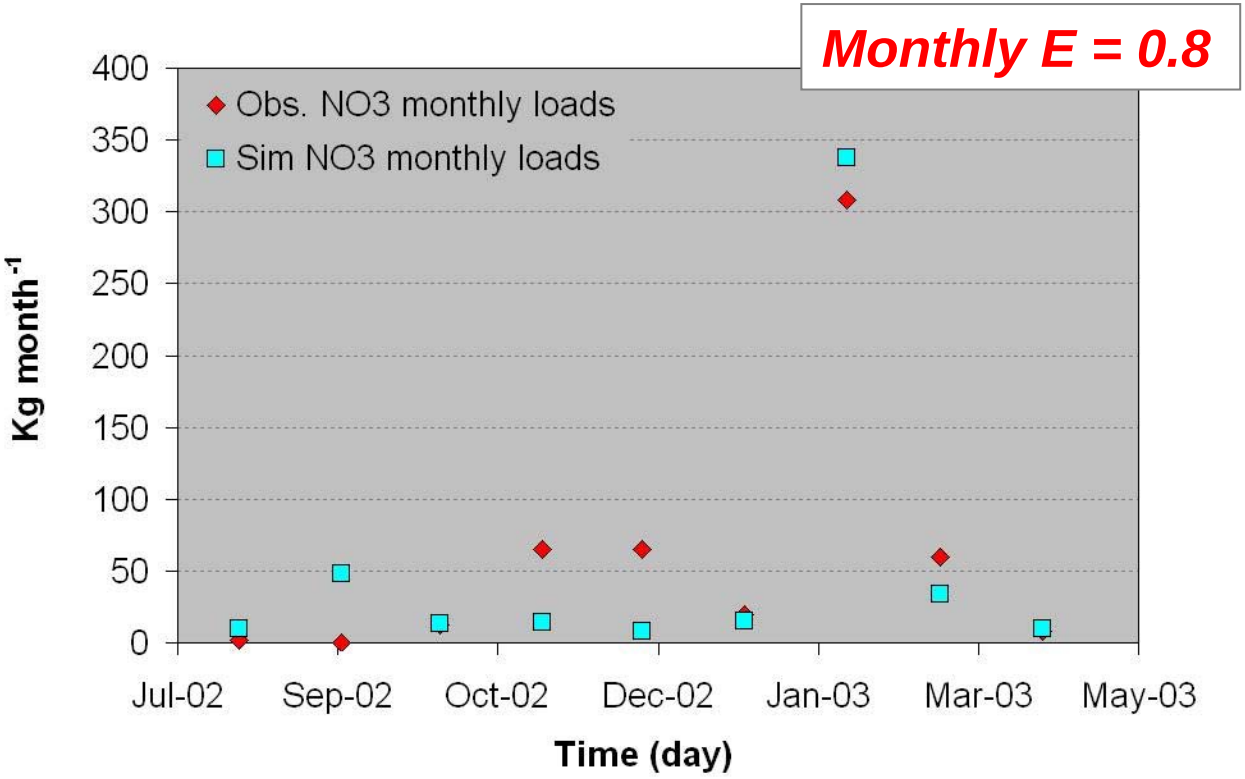
Nitrogen annual processes rate:

N Processes	Measured values [Kg ha⁻¹ day⁻¹]*	Sim. values [Kg ha⁻¹ day⁻¹]
Net mineralization	32.4 – 80.1	62.9
Net nitrification	4.4 – 7.5	6.26
Immobilization	0.08	4.83
Nitrate uptake by vegetation	10.3 - 58	13.07
Ammonium uptake by vegetation	53 – 80.5	58.94

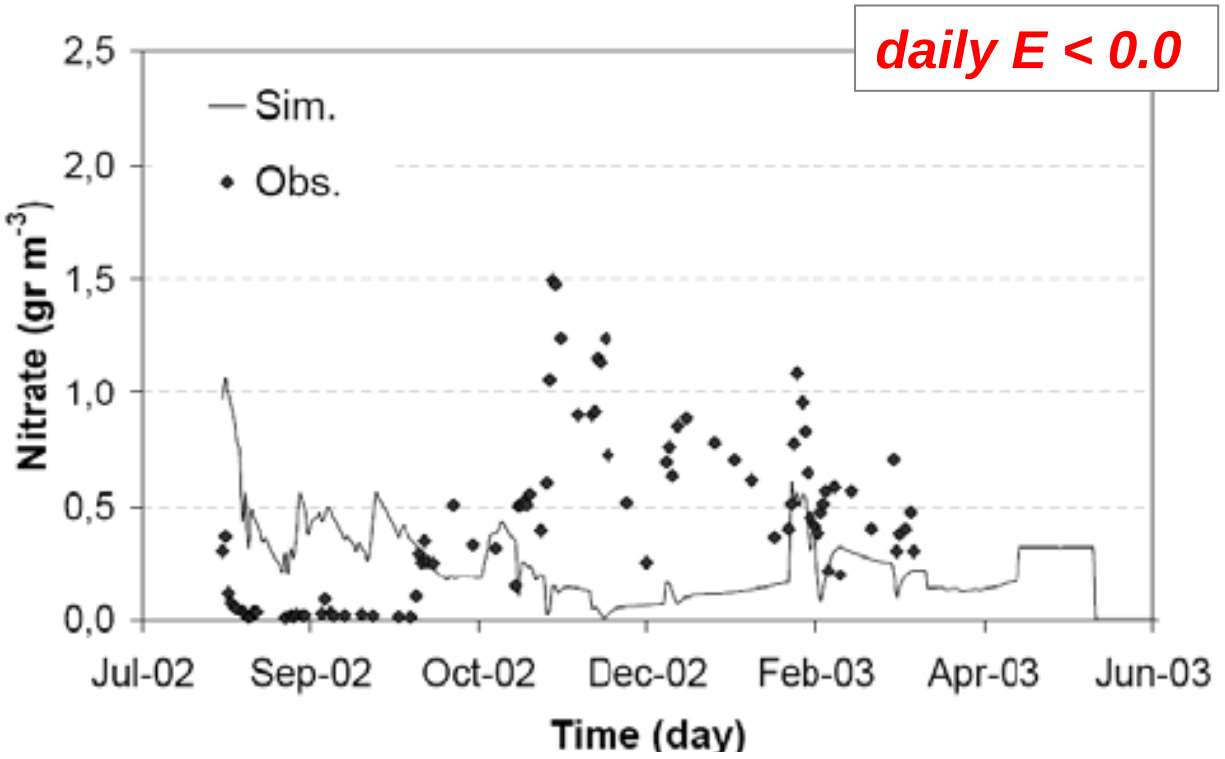
* After Bernal et al., (2004)

LU4-N: Nitrate validation



- For the temporal validation the model could only reproduce the monthly nitrate loads

LU4-N: Nitrate validation



- For the temporal validation the model could only reproduce the monthly nitrate loads

Conclusions

- From the results, the soil nitrogen cycle at Fuirosos, seems to be largely influenced by the rain episodes that induce catchment re-wetting.
- The inclusion of soil moisture thresholds 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)
  - Pulse dynamic of microbial processes, triggered by soil moisture increasing after rain

Conclusions

- The LU4-N model ability to reproduce the observed NO_3 stream concentration for the 3-year calibration period, suggests that the key factors and processes controlling the hydrological and N behaviour are included within the model.
- The temporal validation process call for caution when considering the result obtained

Conclusions

- 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 (Butturini et al., 2003, McIntyre et al., 2009)

Further research step:

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