Doctorado en
Ingeniería del Agua
y Medioambiental

Progressive development of a hydrologic and inorganic nitrogen conceptual model to improve the understanding of small Mediterranean catchments behaviour

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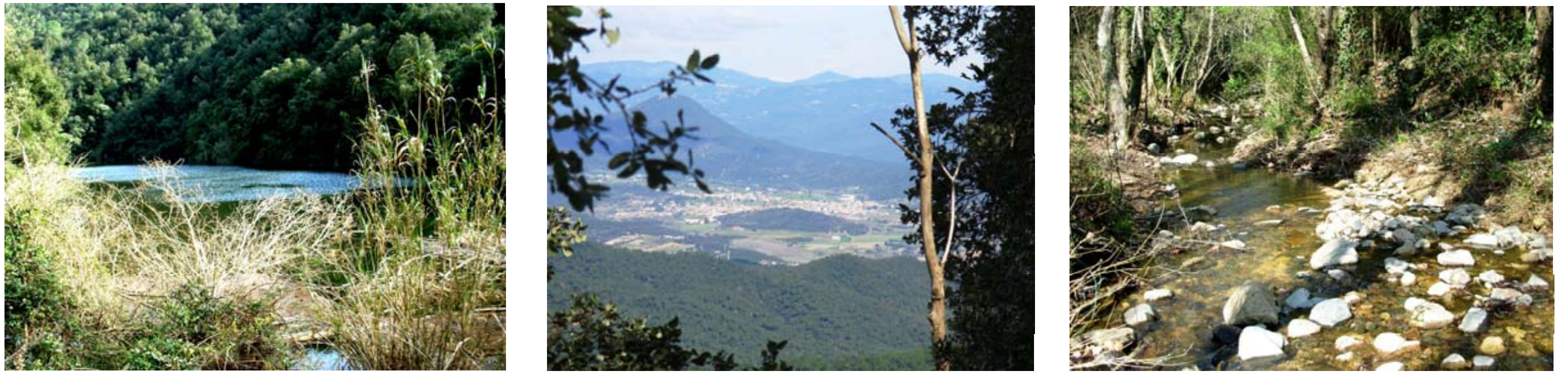


Valencia, 2nd July 2010

Research Framework

❑ Mediterranean forested ecosystems

- ➢ **Alternate dry and humid conditions** that have great influence on the catchment hydrological response and soil microbial activity (pulse dynamic)
- ➢ The **‘transfer of results’** from temperate-humid systems generally fails (Bonell, 1993)

❑ Investigative models

- ➢ Model applications are part of a **learning process**
  - About the *models* themselves
  - About the *environmental system*

Research Origins

☐ **INCA-N** model (Whitehead et al. 1998; Wade et al., 2002)

- ➢ It is a process-based model developed by the University of Reading (UK) for humid catchments
- ➢ Its ability to simulate discharge and nutrients in this sort of environments has been widely shown
- ➢ Its application to a **small Mediterranean forested catchment** named Fuirosos, Catalonia (Bernal et al. 2004) did not give satisfactory results
  - A **single parameter set** for 3 hydrological years fails to capture their **intra** and **inter-annual variability**

Research Philosophy

‘We generally learn most when a model or a theory is shown to be in conflict with reliable data so that some modification of the understanding on which the model is based must be sought’

(Beven, 2000)

Research Objective

❑ **Improve the understanding of Mediterranean systems**

- ➢ Identifying the **key** hydrological and biogeochemical **processes**
- ➢ Quantifying their **relative importance**
- ➢ Understanding **hydrological and nitrogen interactions** through sensitivity analysis

❑ **Progressive perceptual understanding approach** (Piñol et al. 1997; Beven, 2001)

- ➢ This study was started with a basic model then progressively modified in a thoughtful way to see if the model could be made more consistent with the perception of how the catchment worked
  - Fieldworks
  - Literature

Contents

1 - Study Site

2 - Hydrological behaviour modelling

(Medici et al., *Hydrol. Process*., 2008)

3 - Inorganic nitrogen behaviour modelling

(Medici et al., *HESS*, 2010)

4 - General Sensitivity Analysis of the developed models

(Medici et al., *in preparation*)

5 – Conclusions and Future research lines

The Fuirosos catchment

❑ Catchment area: 13 km^2

❑ Forest covers 90% of total area

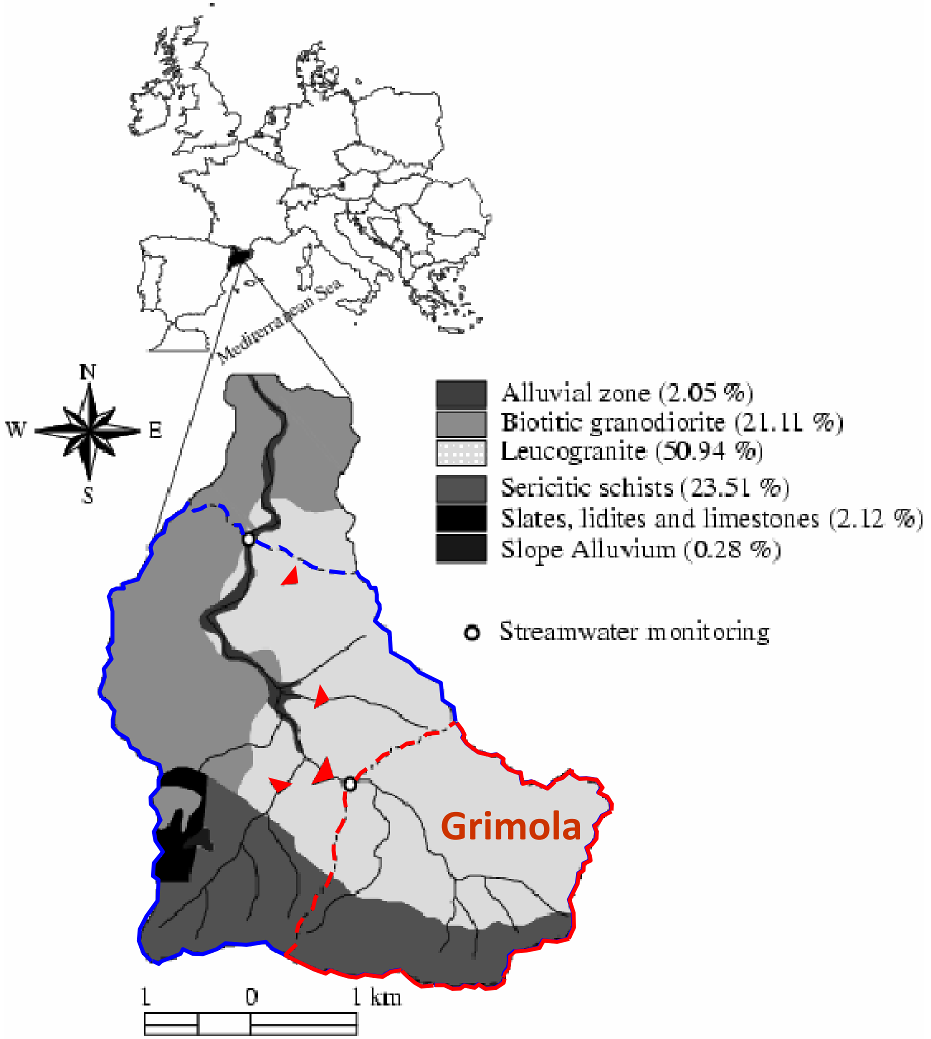
❑ Lithology:

- ➢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



Observed data *(Universitat de Barcelona, Dept. d'Ecologia)*

☐ Observed period for **discharge**:

- Model **calibration** period: **1999** - **2002**
- Model **temporal validation** period: **2002** - **2003**
- Model **spatial validation** period: **2000** - **2002** (Grimola)

☐ Observed period for **stream nitrate concentration**:

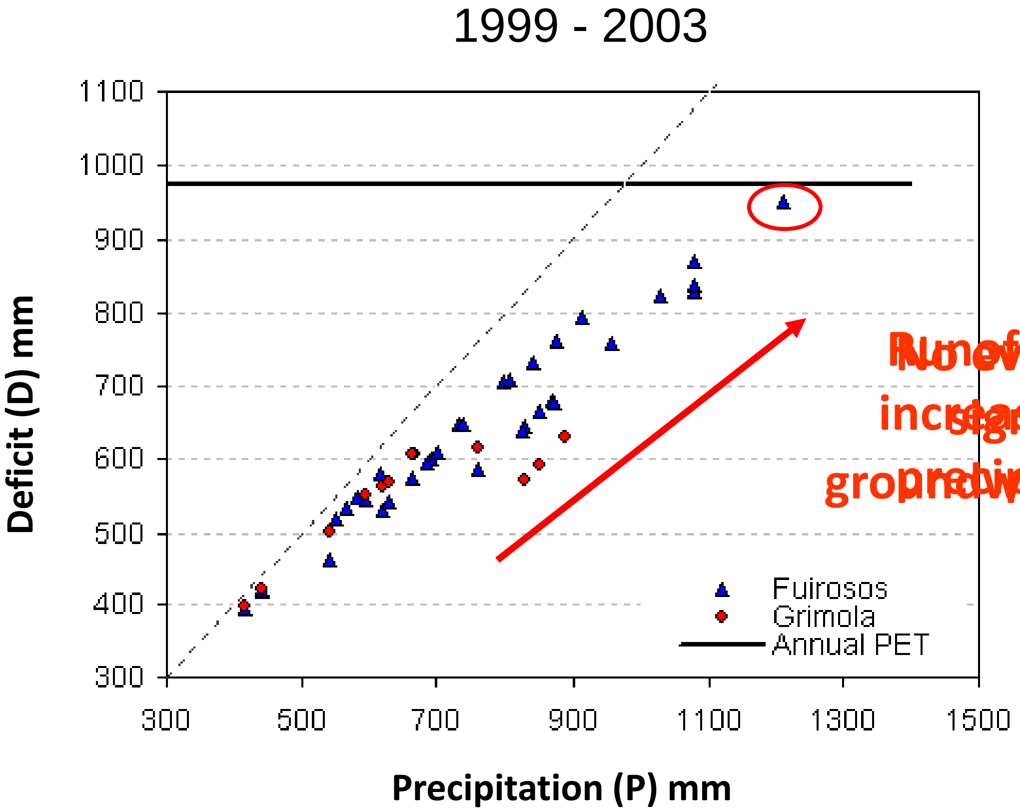
- Model **calibration** period: **1999** - **2002**
- Model **temporal validation** period: **2002** - **2003**

☐ Observed period for **stream ammonium conc.:**

- Model **calibration** period: **2000** - **2002**

Observed data analysis

☐ Relation between **annual precipitation** (**P**) and the **annual runoff deficit** (**D=P-Q**) for twelve consecutive months for Fuirosos and Grimola

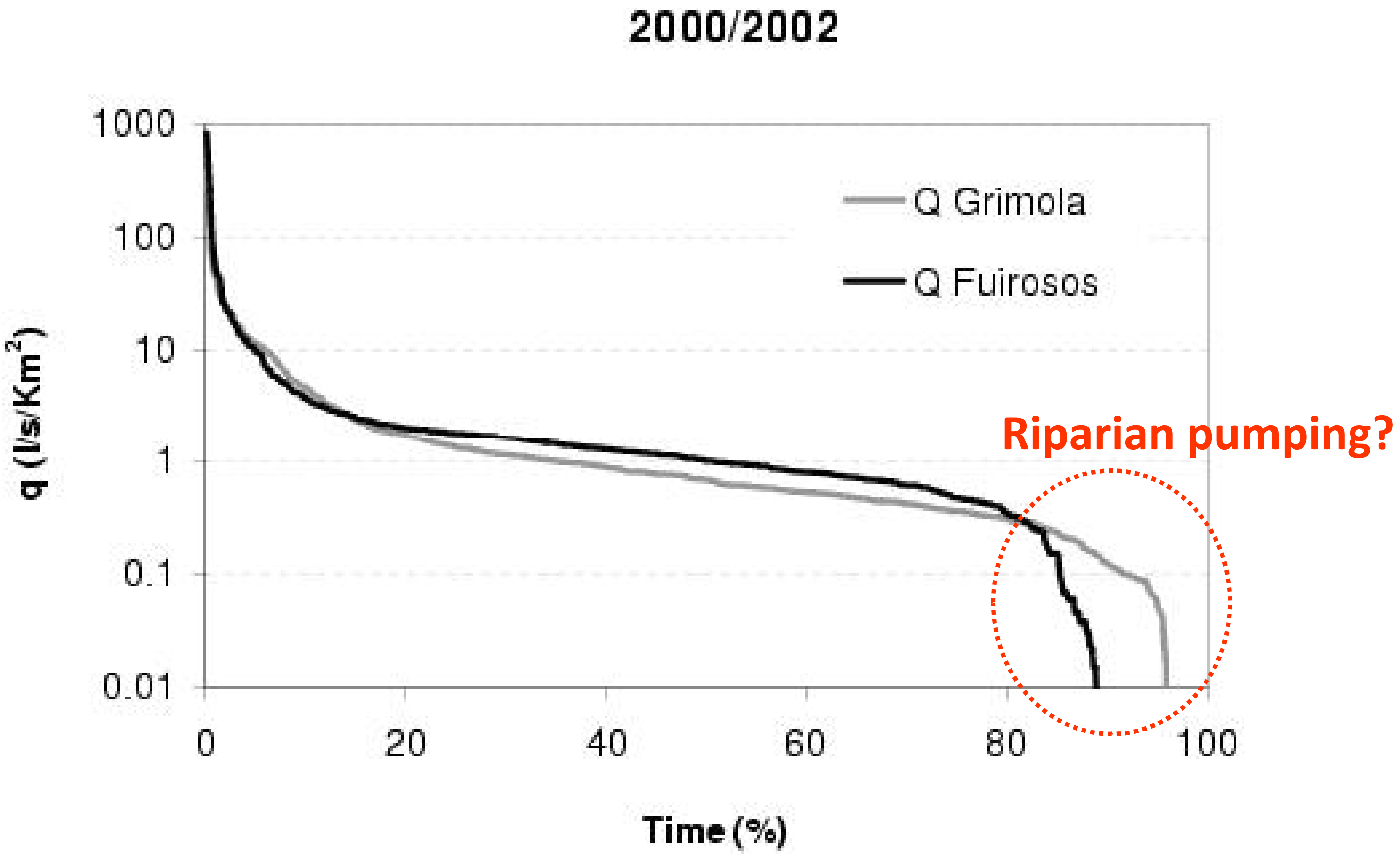


Runoff deficit increases with precipitation

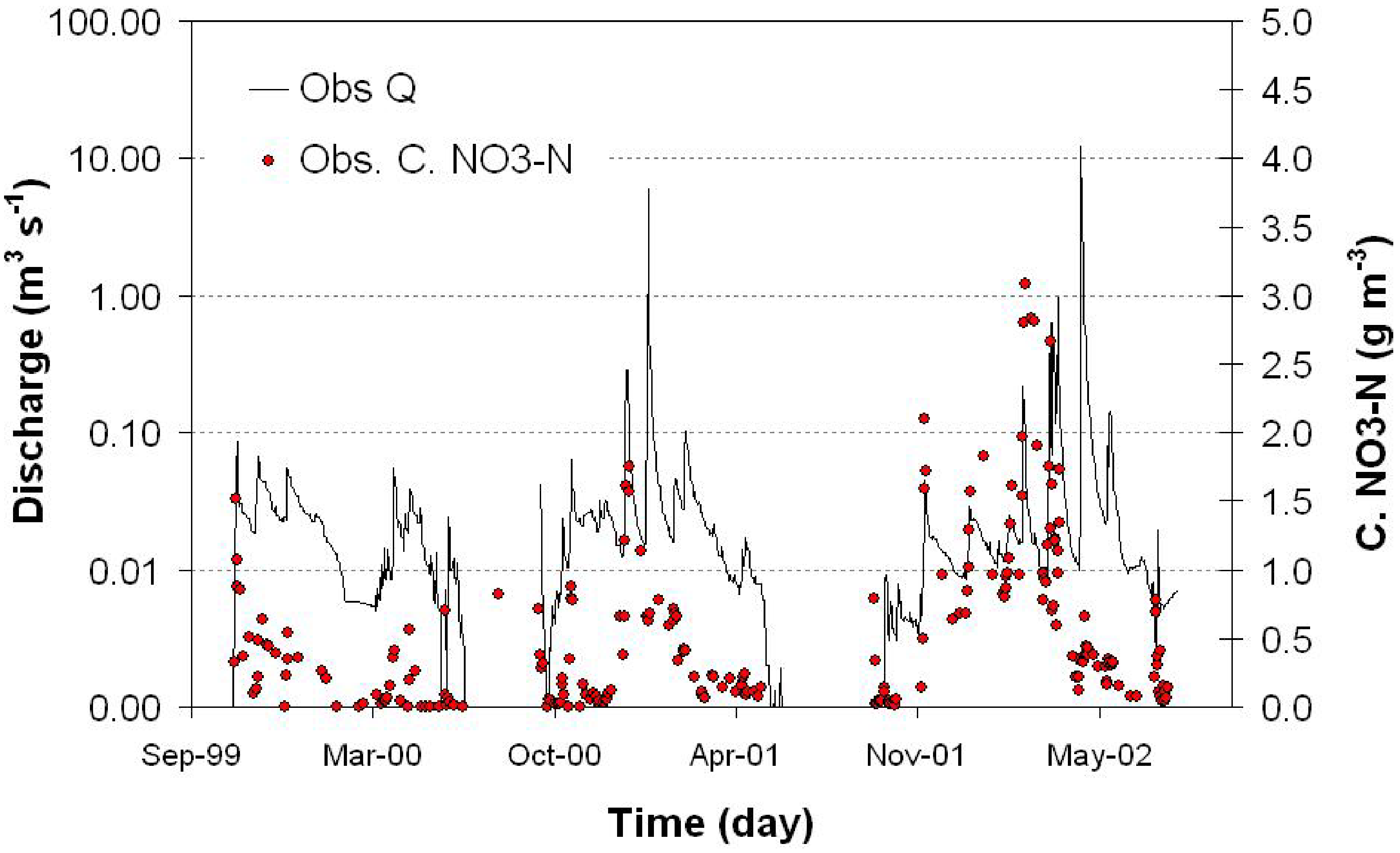
No evidence of significant groundwater outflow

Observed data analysis

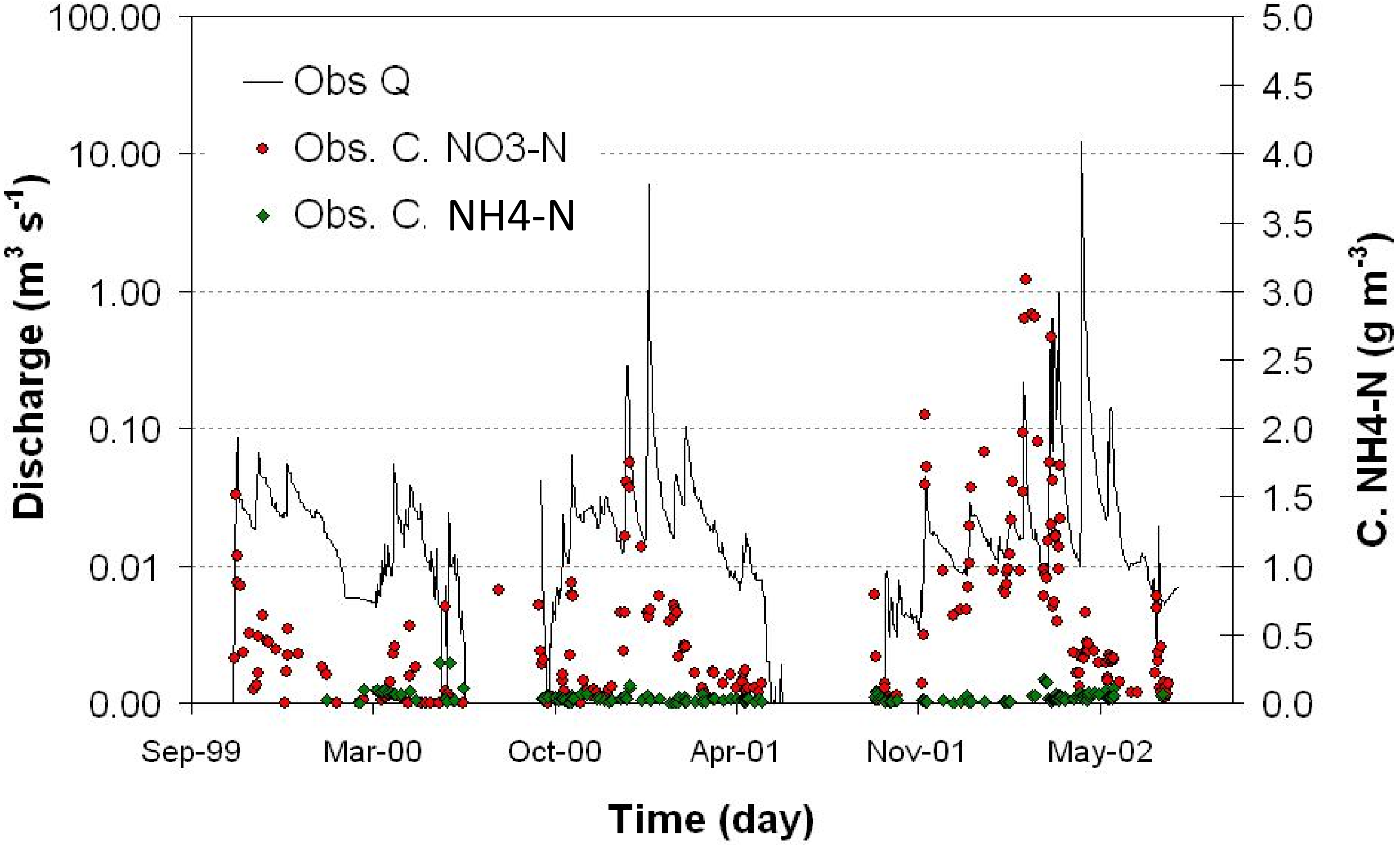
- ☐ Flow duration curve



Observed data: stream nitrate concentration



Observed data: stream ammonium concentration

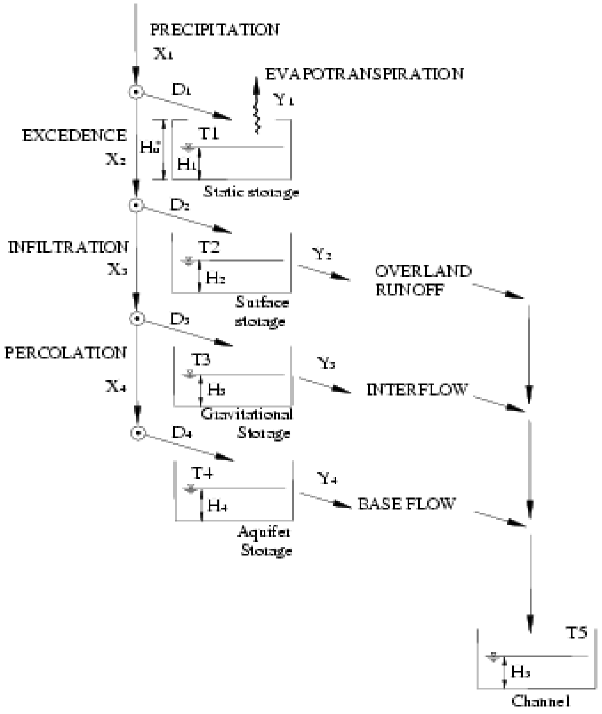


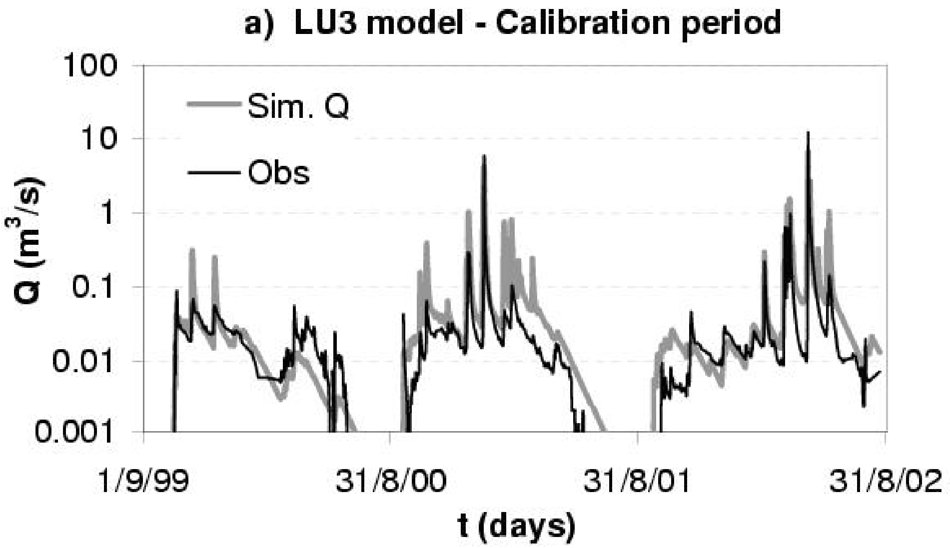
Hydrological modelling

Hydrological model evolution

6 parameters

LU3 model



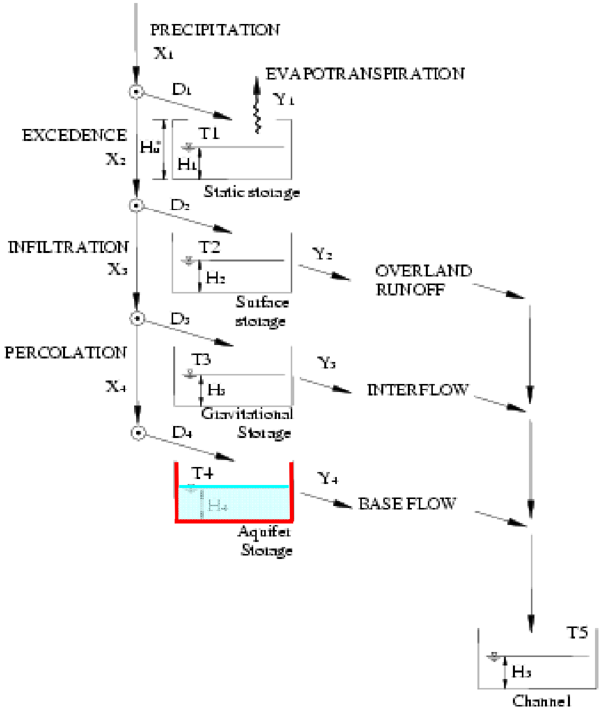


☐ Nash & Sutcliffe index	0.71
☐ Volume error	47.4%
☐ Number of days Q ≤ 0.001 m^3s^{-1} (against 220)	147
☐ Max. Sim. discharge peak (against 10.9 m^3s^{-1})	6.7 m^3s^{-1}

Hydrological model evolution

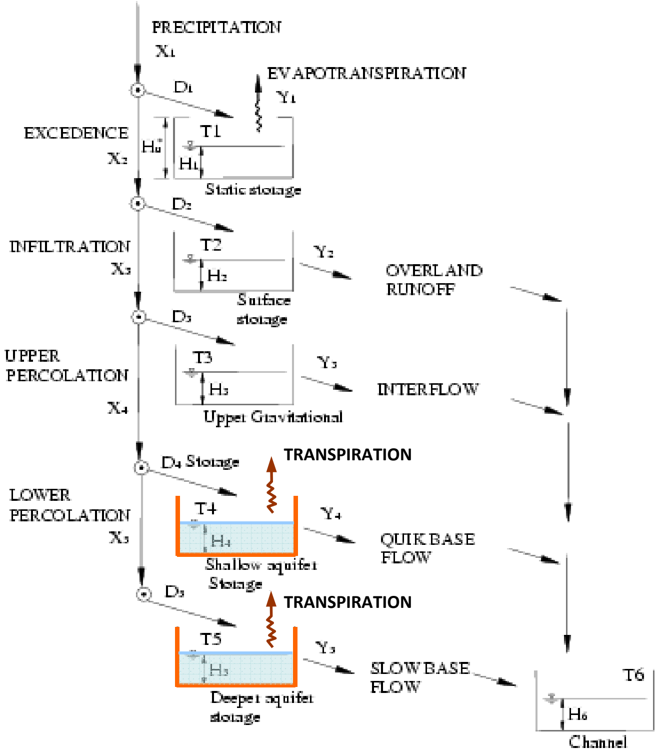
6 parameters

LU3 model

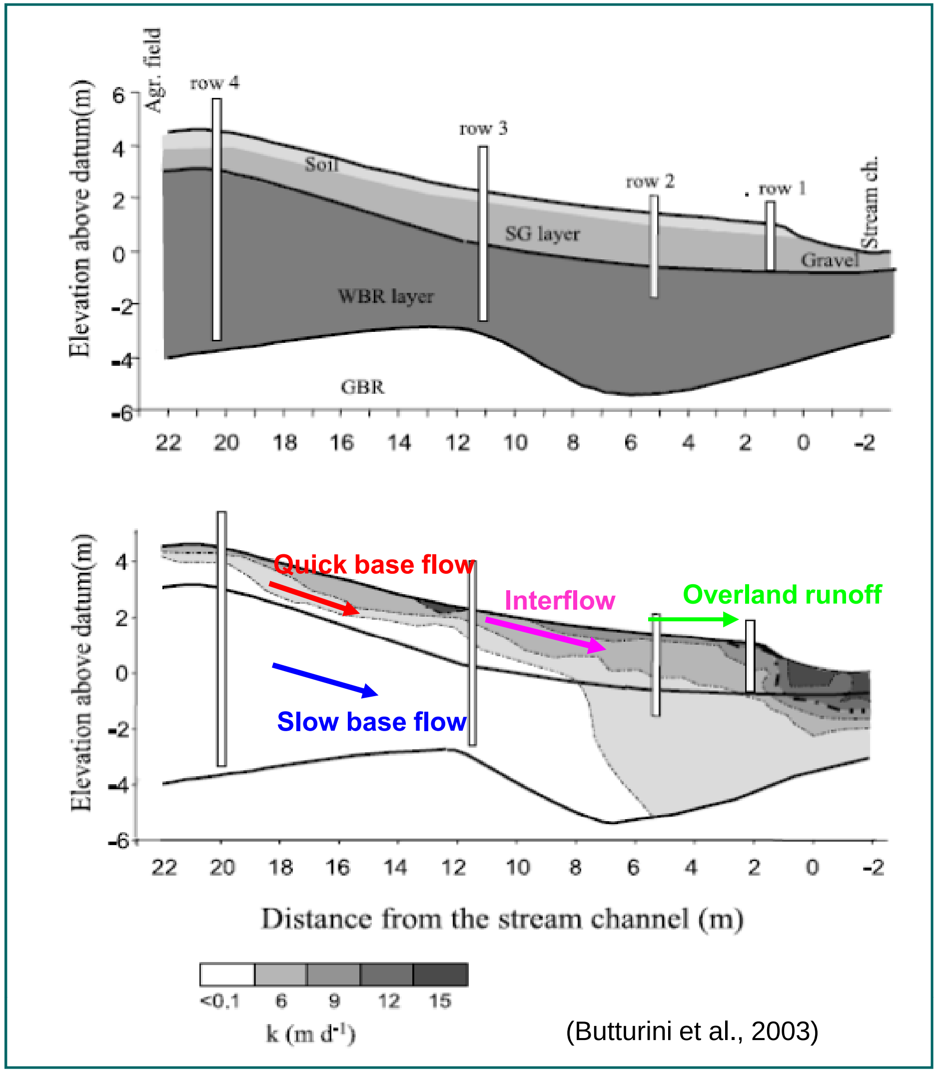


9 parameters

LU4 model



Fuirosos riparian zone



(Butturini et al., 2003)

Three main ranges for the saturated conductivity values:

-**Sandy-Gravel** layer ranged **12-19** m/day

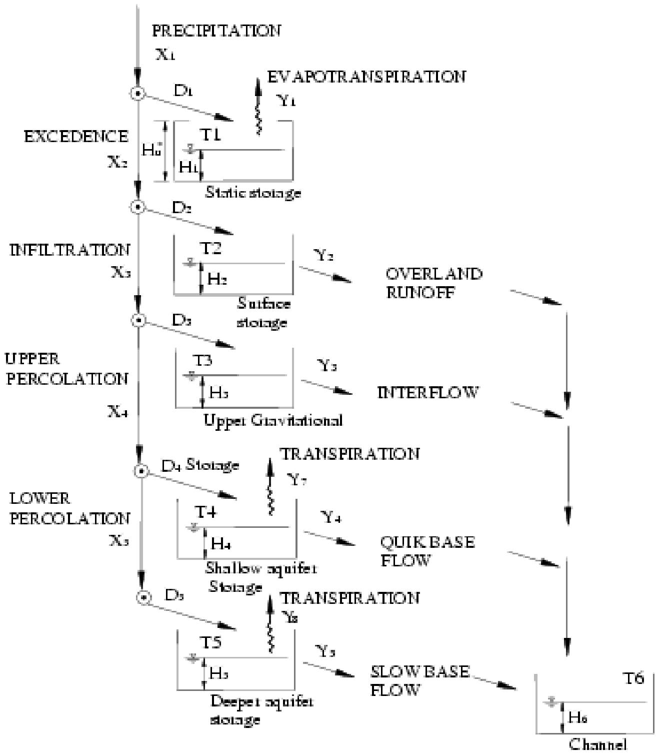
-**Upper** part of the underlying **WBR** layer averaged **4.8** ± 3.12 m/day

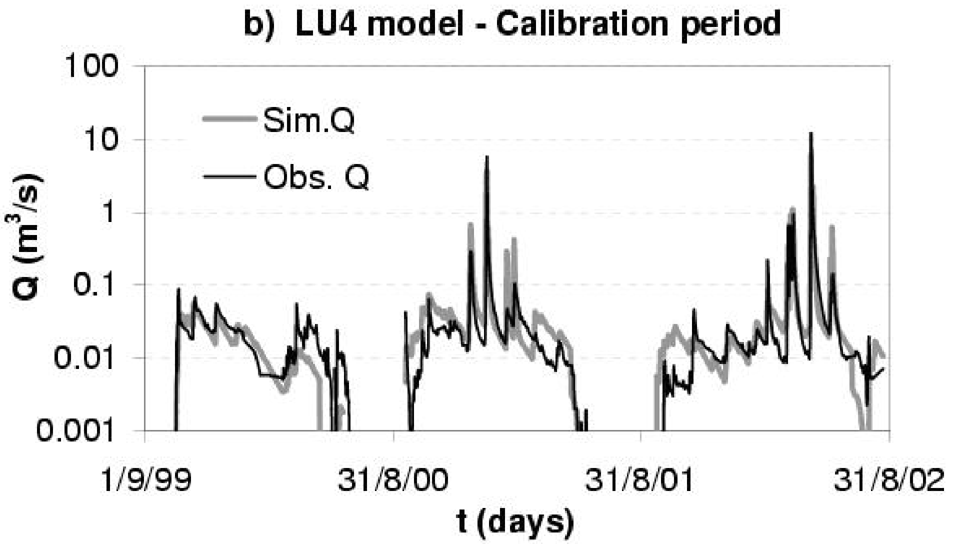
- **Deeper WBR** layer averaged **$9.6 \cdot 10^{-3}$** $\pm 3.7 \cdot 10^{-3}$ m/day.

Hydrological model evolution

9 parameters

LU4 model



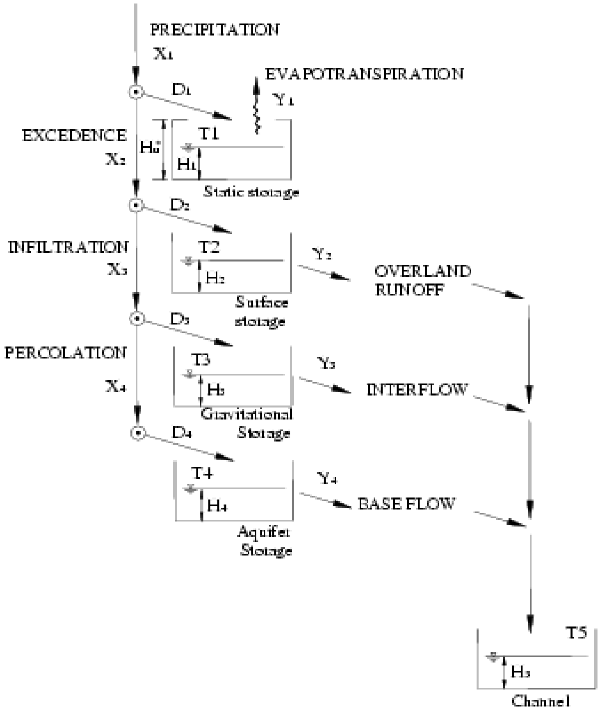


☐ Nash & Sutcliffe index	0.72
☐ Volume error	-1.3%
☐ Number of days Q ≤ 0.001 m^3s^{-1} (against 220)	248
☐ Max. Sim. discharge peak (against 10.9 m^3s^{-1})	6.3 m^3s^{-1}

Hydrological model evolution

6 parameters

LU3 model



9 parameters

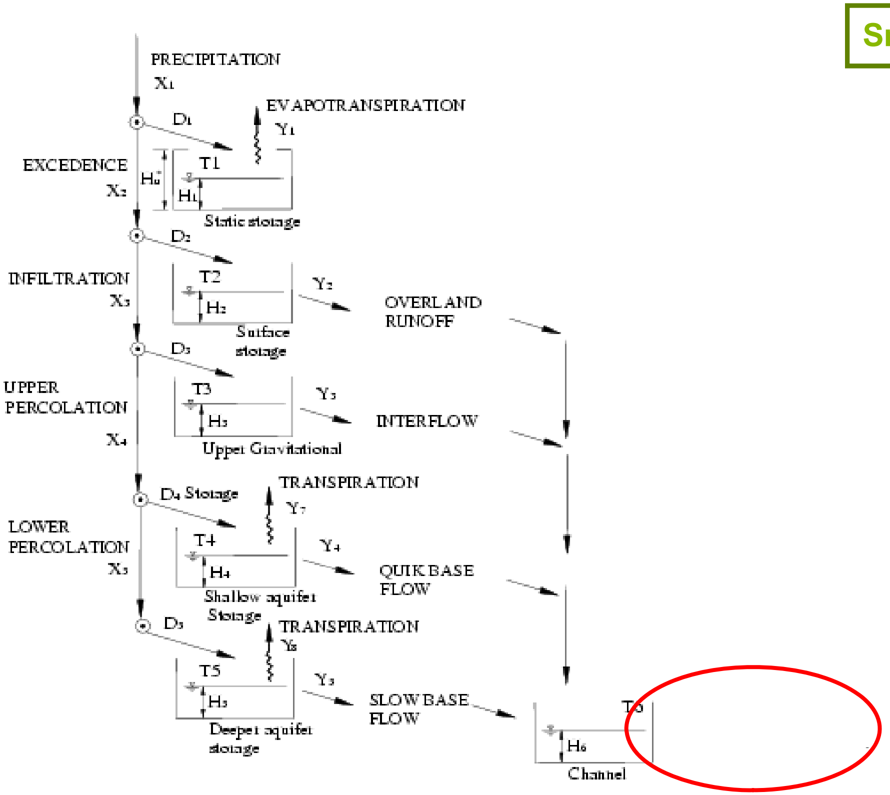
LU4 model

SD4-R model

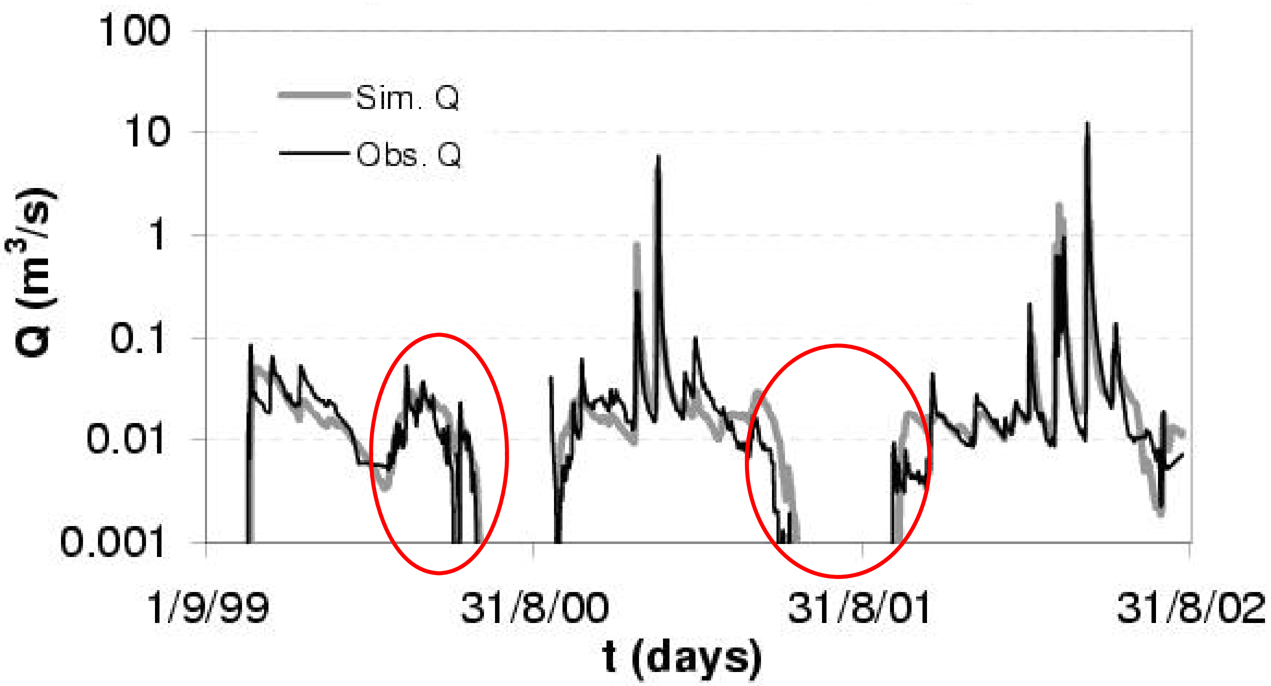
30 parameters

Riparian Zone

Small Ponds

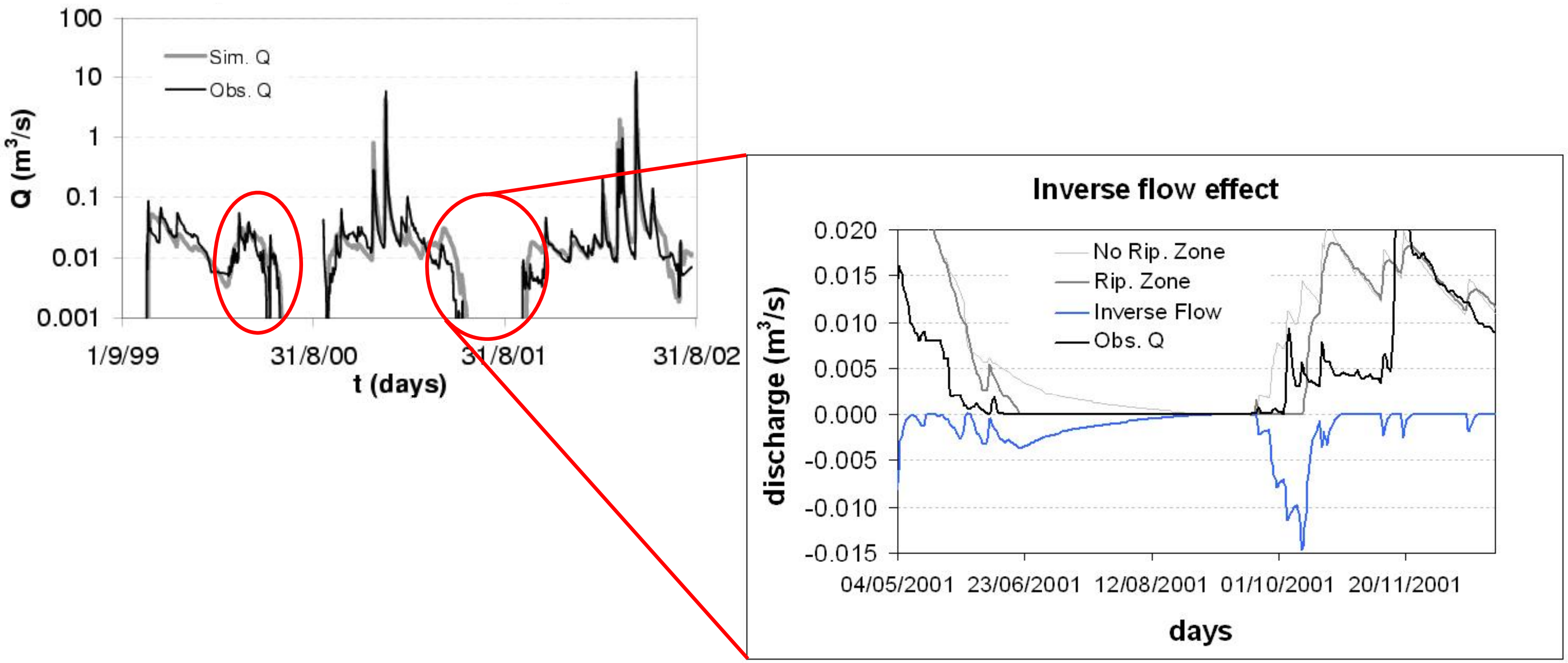


SD4-R rainfall-runoff semi-distributed model



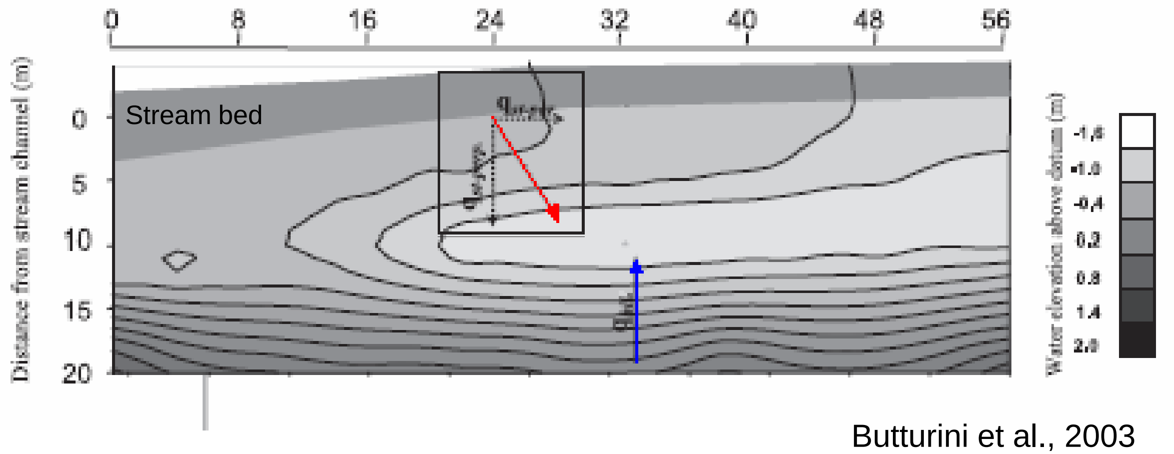
☐ Nash & Sutcliffe index	0.78
☐ Volume error	-1.0%
☐ Number of days Q ≤ 0.001 m^3s^{-1}	212 (against 220)
☐ Max. Sim. discharge peak	8.6 m^3s^{-1} (against 10.9 m^3s^{-1})

SD4-R rainfall-runoff semi-distributed model

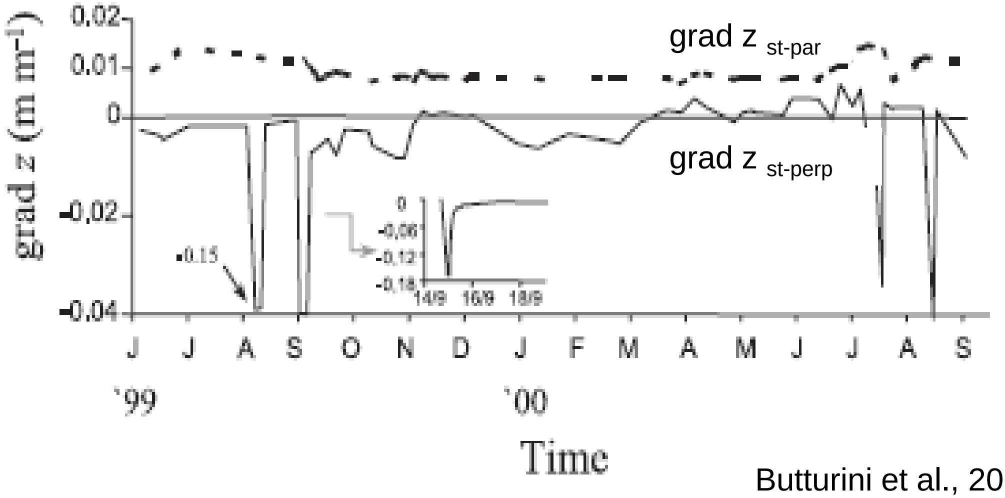


☐ Nash & Sutcliffe index	0.78
☐ Volume error	-1.0%
☐ Number of days Q ≤ 0.001 m^3s^{-1}	212 (against 220)
☐ Max. Sim. discharge peak	8.6 m^3s^{-1} (against 10.9 m^3s^{-1})

Inverse flow

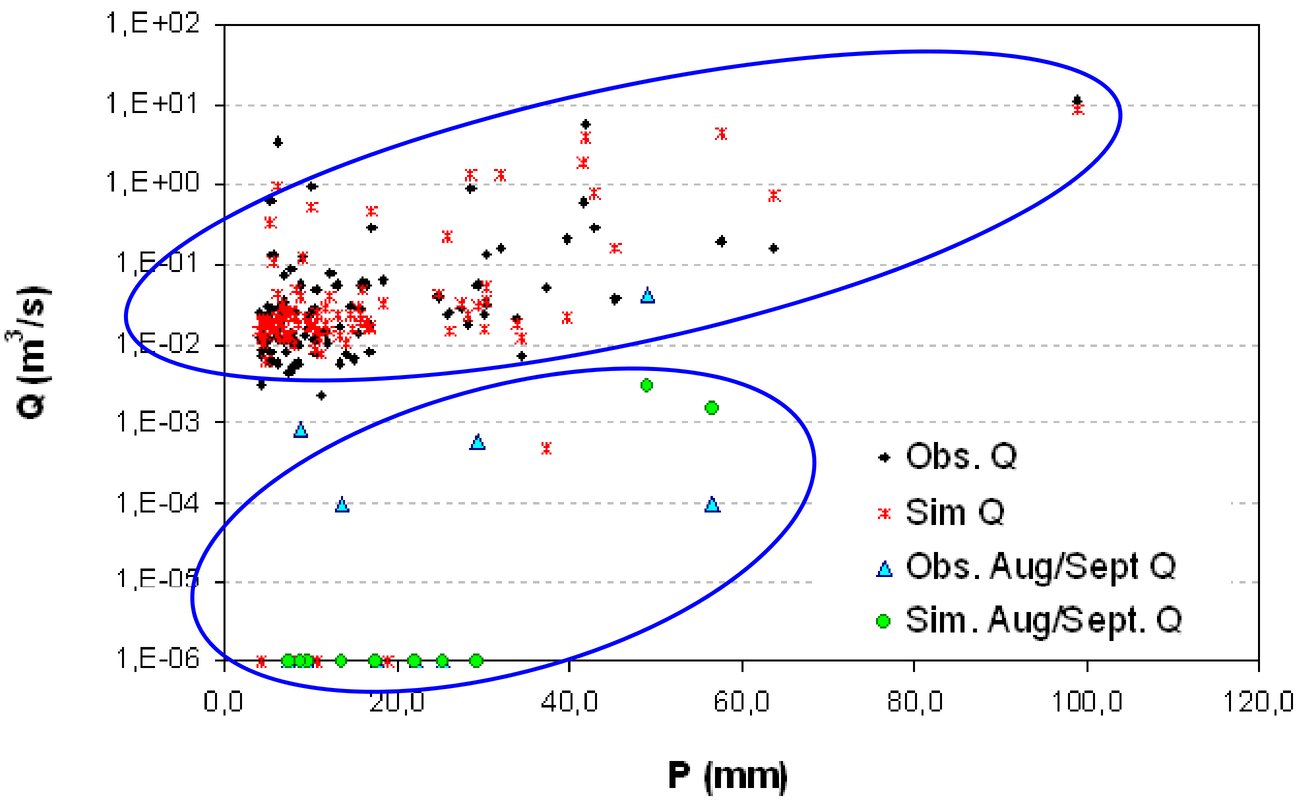


Butturini et al., 2003



Butturini et al., 2003

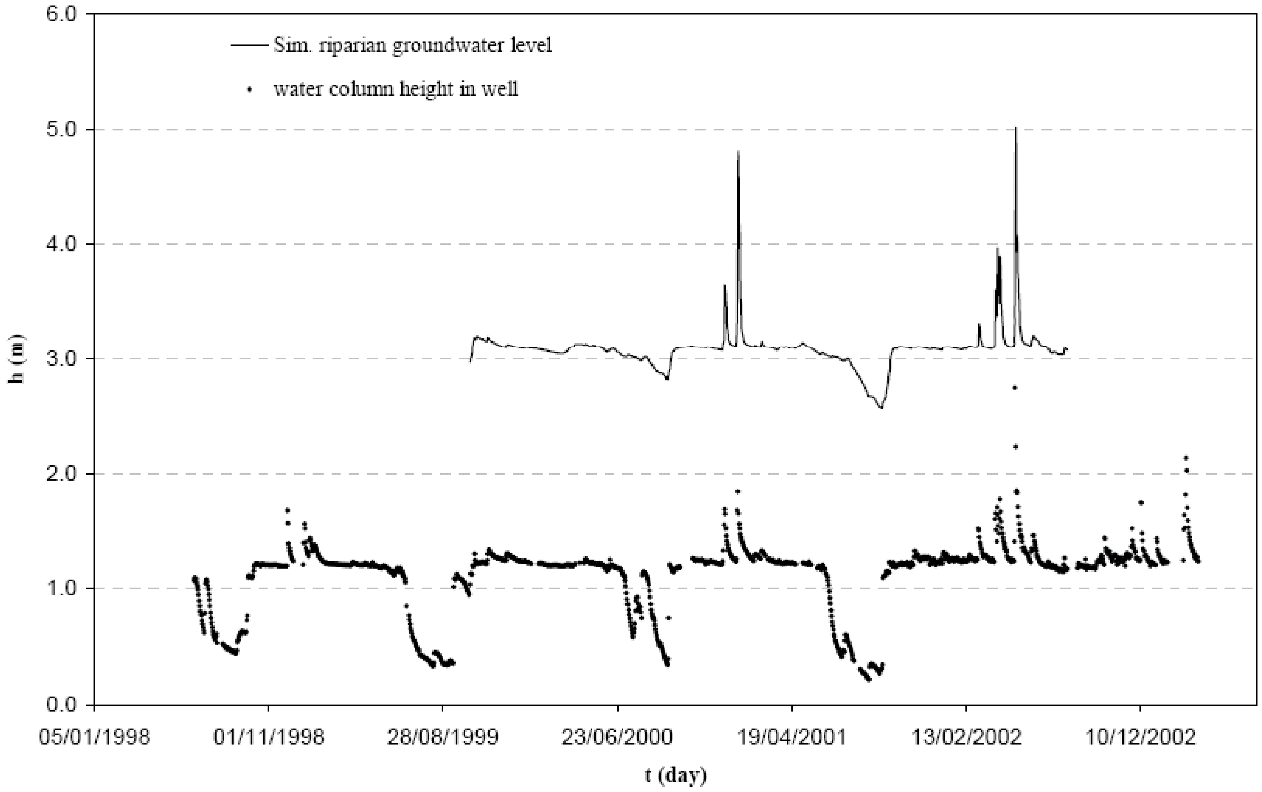
Wetting-up non linear response



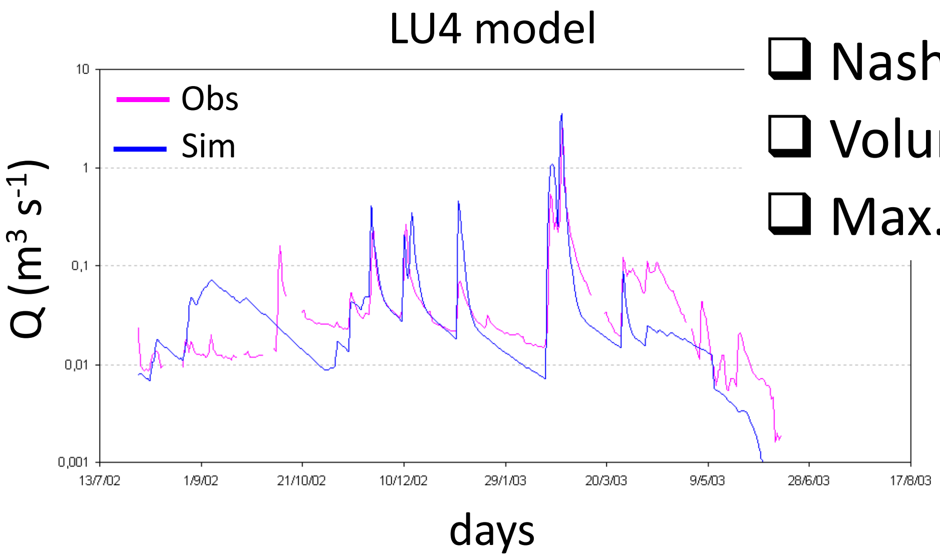
The simulated stream responses to precipitation episodes occurring just after the drought period fall far below the general trend obtained for the remaining part of the year, as pointed out by Butturini et al., 2002.

Riparian aquifer qualitative validation

- ☐ Water level temporal dynamics comparison between:
  - ➢ Observed in a well located in the riparian area close to river
  - ➢ Simulated riparian aquifer tank

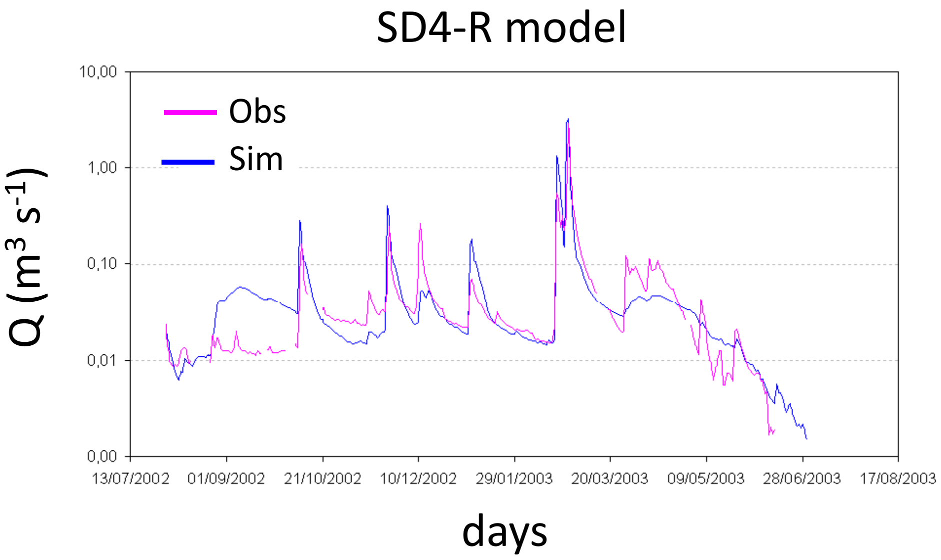


Temporal validation (2002-2003)



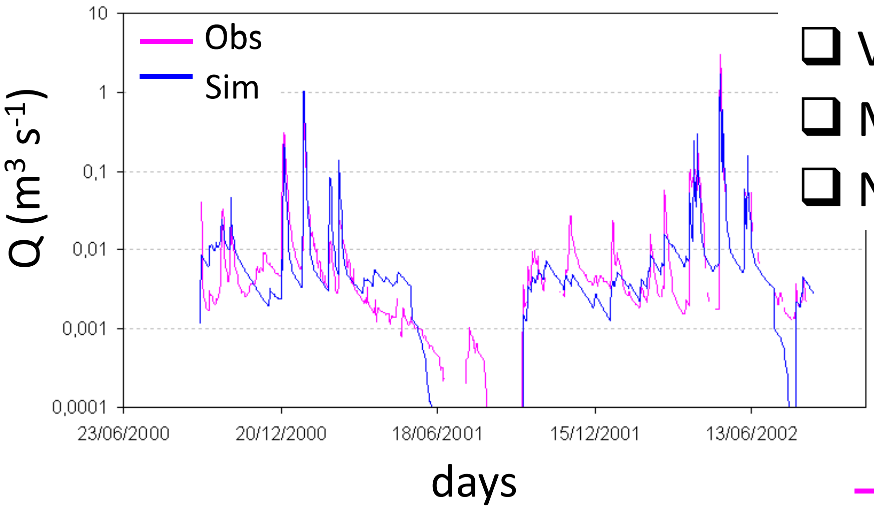
- ☐ Nash 0.75 (excluding February 2003)
- ☐ Volume error 25%
- ☐ Max. Sim. Q 3.5 m^3s^{-1} (2.7 m^3s^{-1})

- ☐ Nash 0.8
- ☐ Volume error 23.6%
- ☐ Max. Sim. Q 3.3 m^3s^{-1}



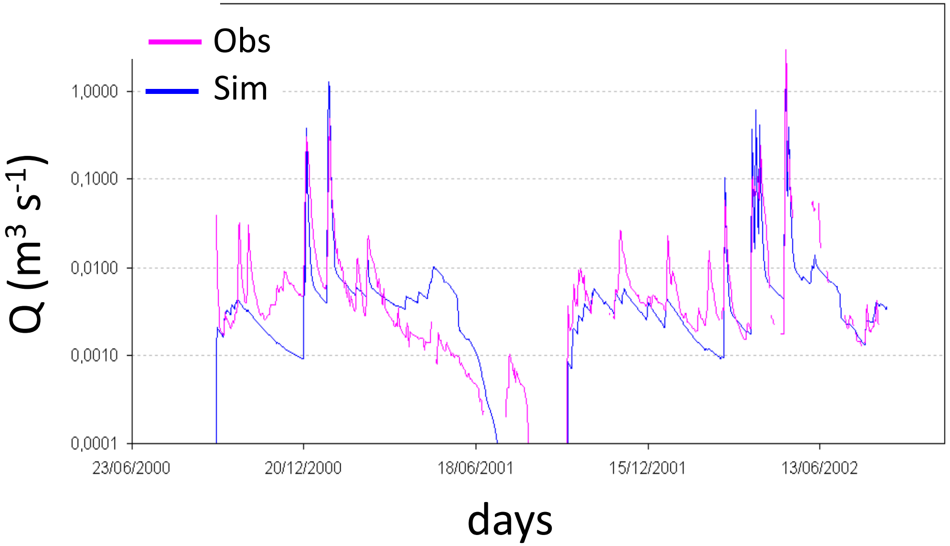
Spatial validation at Grimola (2000-2002)

LU4 model



- ❑ Nash 0.6
- ❑ Volume error -5%
- ❑ Max. Sim. Q 1.7 m^3s^{-1} (2.7 m^3s^{-1})
- ❑ N. days Q ≤ 0.001 m^3s^{-1} 212 (Obs. 220)

SD4-R model



- ❑ Nash 0.7
- ❑ Volume error -4.2%
- ❑ Max. Sim. Q 2.5 m^3s^{-1}
- ❑ N. days Q ≤ 0.001 m^3s^{-1} 75

Summarising

☐ The perceptual model including **four different catchment hydrological responses** is the most suitable to simulate discharge at Fuirosos

☐ The best results were obtained with the semi-distributed **SD4-R model** that includes in its conceptualization:

- The riparian zone
- Soil spatial variability
- Evapotranspiration process spatial variability

Inorganic nitrogen modelling

Inorganic nitrogen modelling

❑ In the second part of the work the previous **4-responses models** were **extended** to include processes representing the inorganic nitrogen cycle **to simulate the nitrate and ammonium concentration** observed in the Fuirosos stream

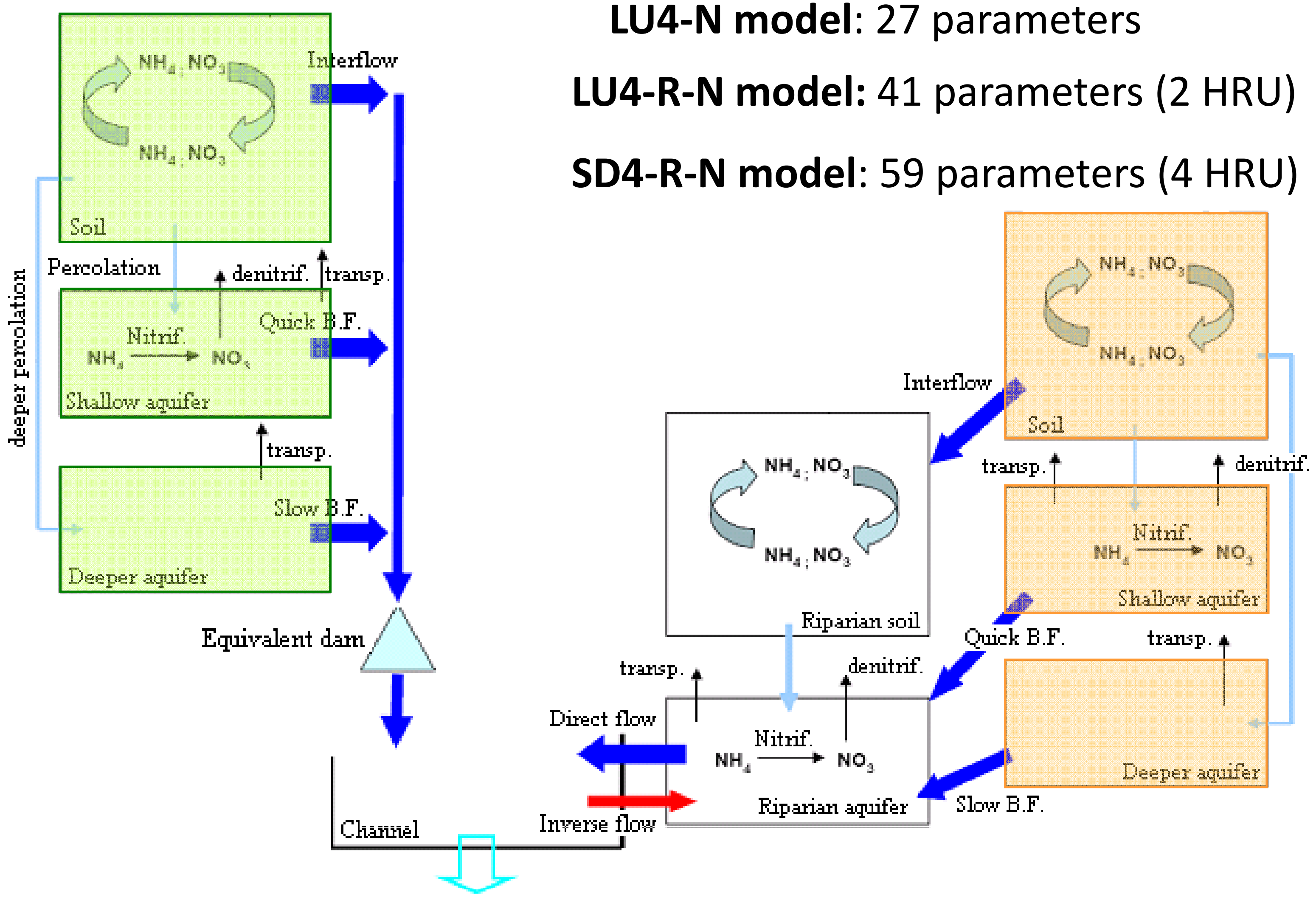
➢ The INCA-N model was used as a basis for the equation implemented, but **additional mechanisms** were added to take into account **specific aspects** of this Mediterranean **catchment** (since the INCA-N conceptualization, initially adopted, did not give good results at Fuirosos)

N-model evolution

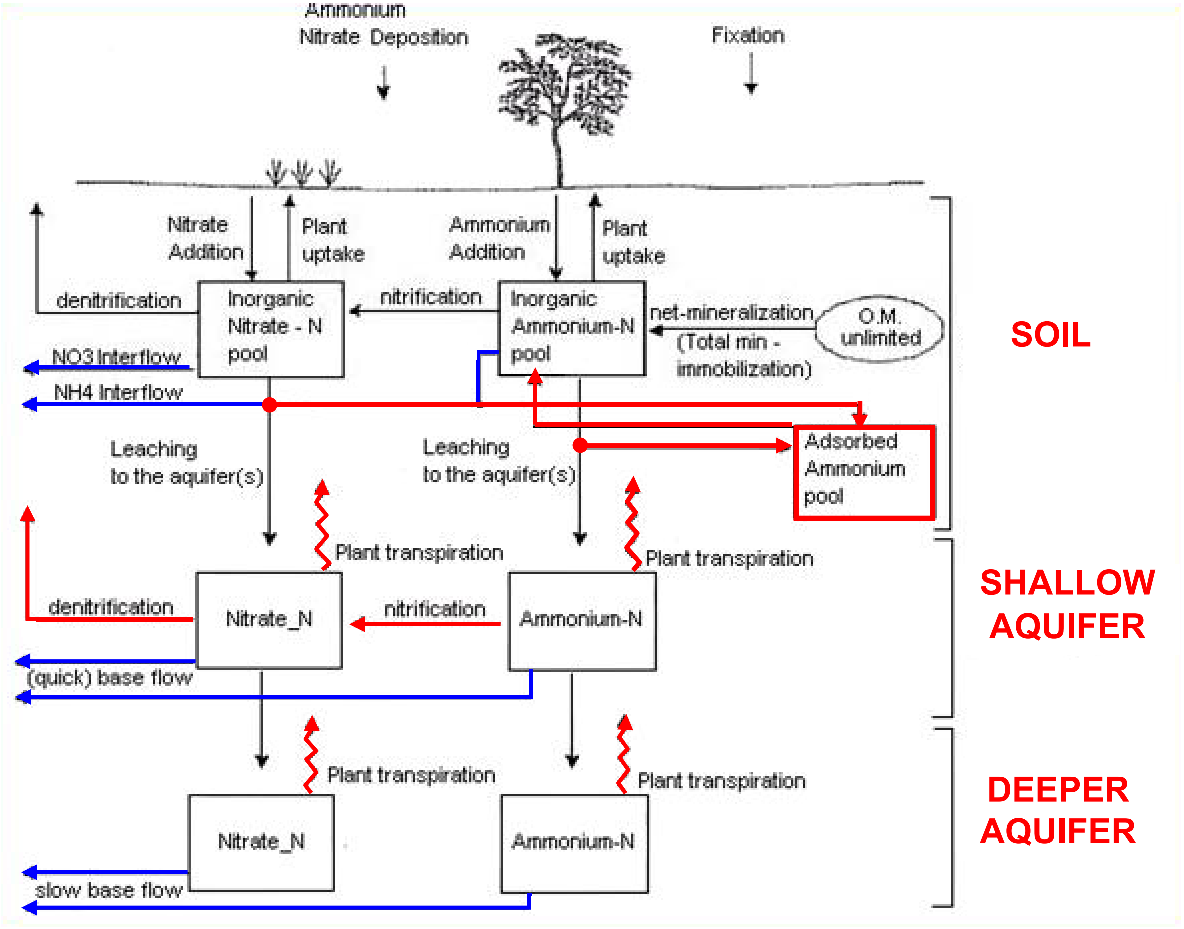
LU4-N model: 27 parameters

LU4-R-N model: 41 parameters (2 HRU)

SD4-R-N model: 59 parameters (4 HRU)



INCA-based Nitrogen cycle



SOIL

SHALLOW AQUIFER

DEEPER AQUIFER

(Modified from Whitehead et al. 1998)

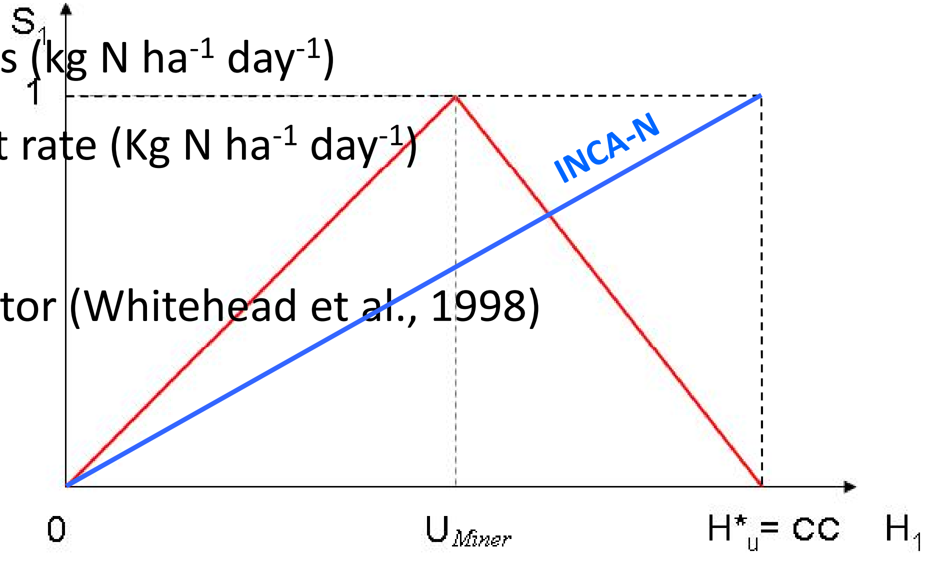
Soil moisture thresholds

- ☐ Mineralisation:

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

  - ➢ 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 mineralisation (%), expressed as a percentage of H_u^* (mm)

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



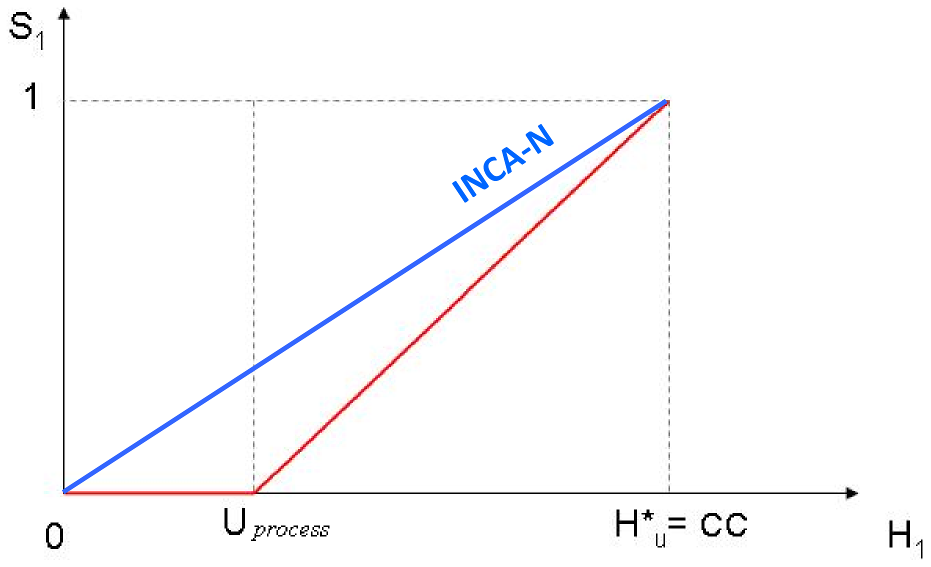
H_1: Soil water content

- This is consistent with Bernal et al., (2003, 2005) and McIntyre et al., (2009)

Soil moisture thresholds

☐ Other soil processes: a **minimum soil moisture content** is needed for the process to be activated

- ➢ Nitrification
- ➢ Denitrification
- ➢ Immobilization
- ➢ Plant uptake

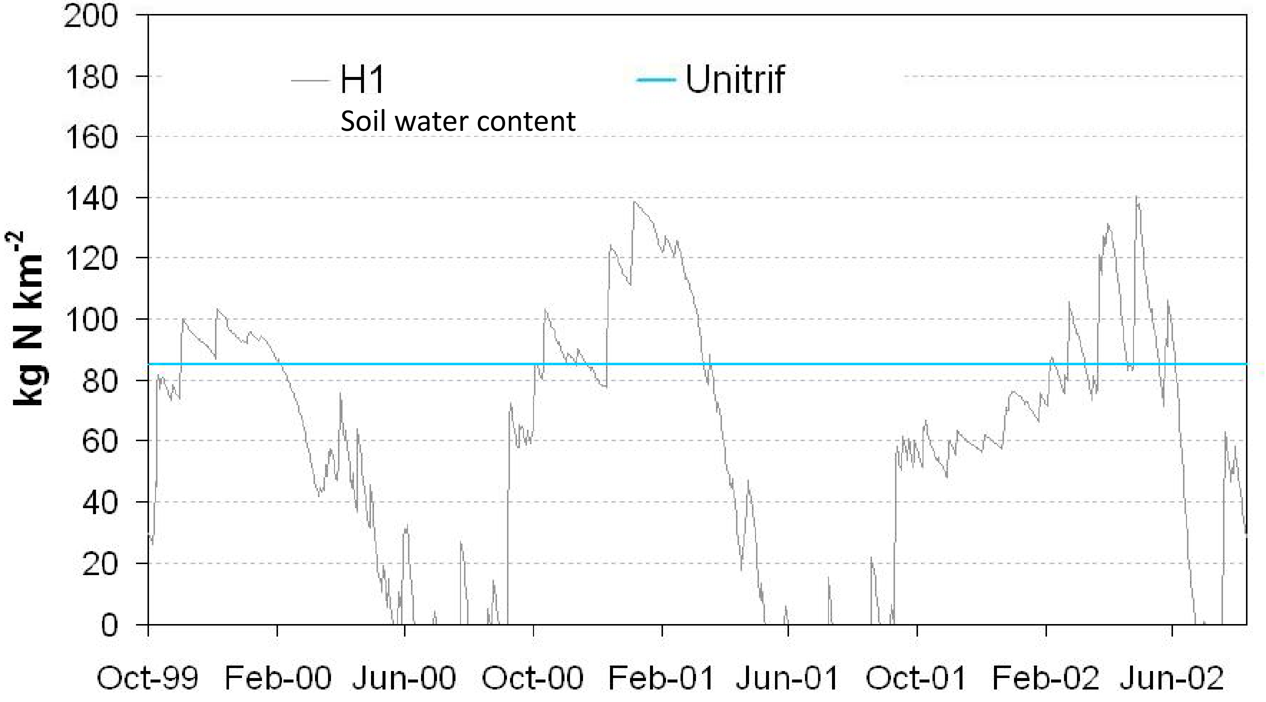


H_1: Soil water content

- This is consistent with Mummey et al., (1994) and Schwinning et al., (2004)

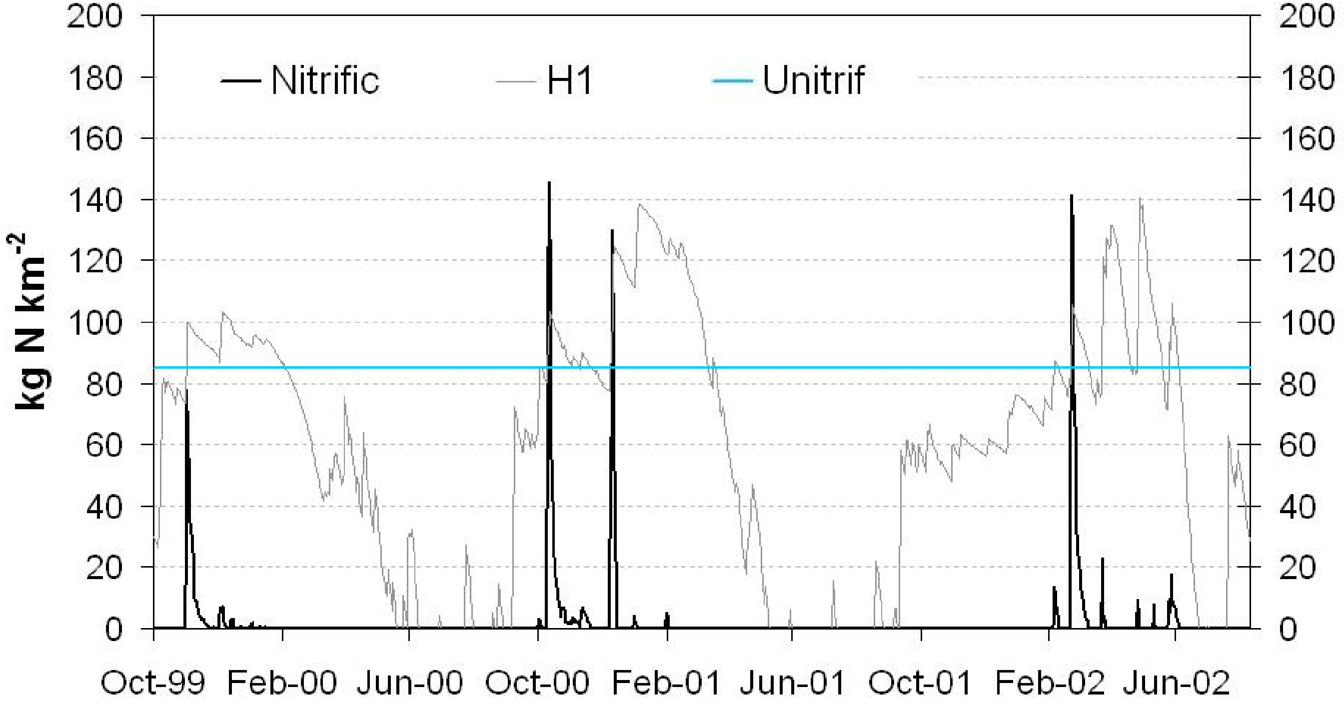
Soil moisture simulated effect (SD4-R-N)

Leucogranite



Soil moisture simulated effect (SD4-R-N)

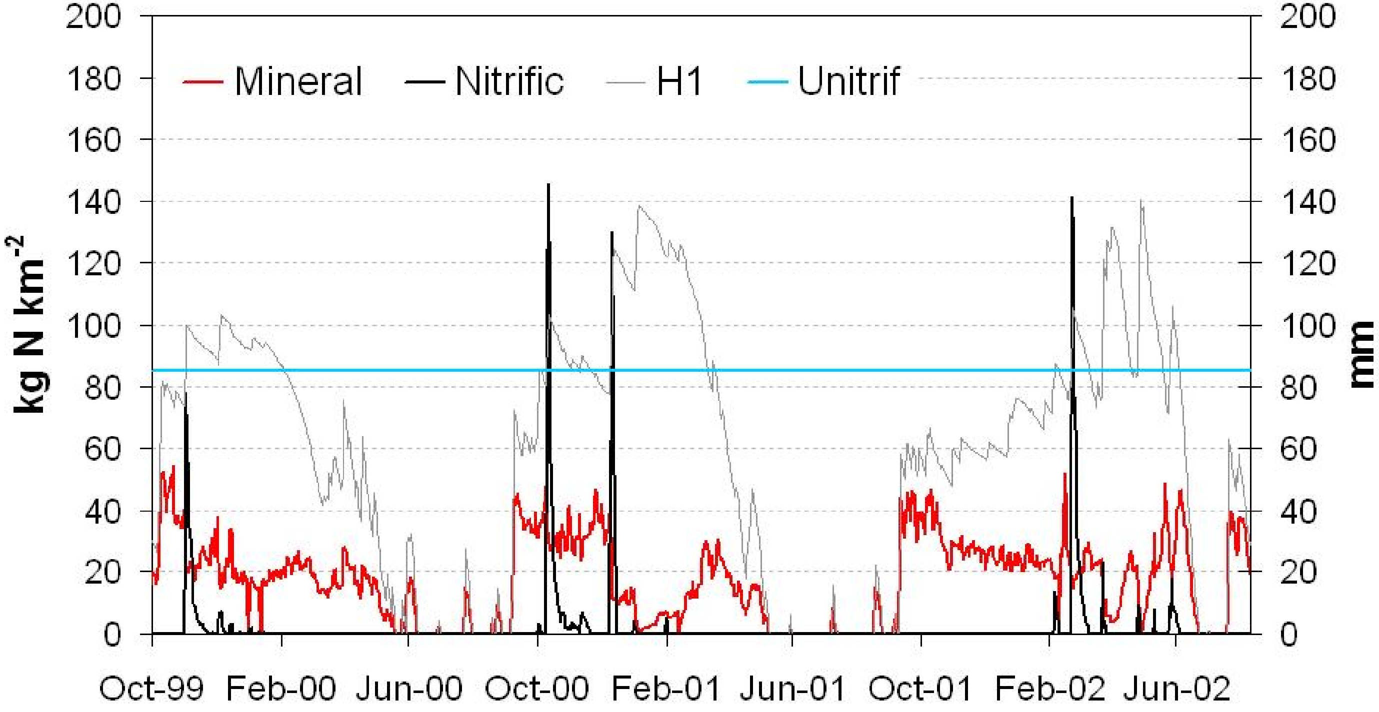
Leucogranite



The **nitrification pulse dynamic** reproduced, in terms of average annual loads, a **M**ineralisation:**N**itrification **(M:N)** ratio of **8:1**, which is consistent with 10:1 obtained by Serrasolses et al (1999)

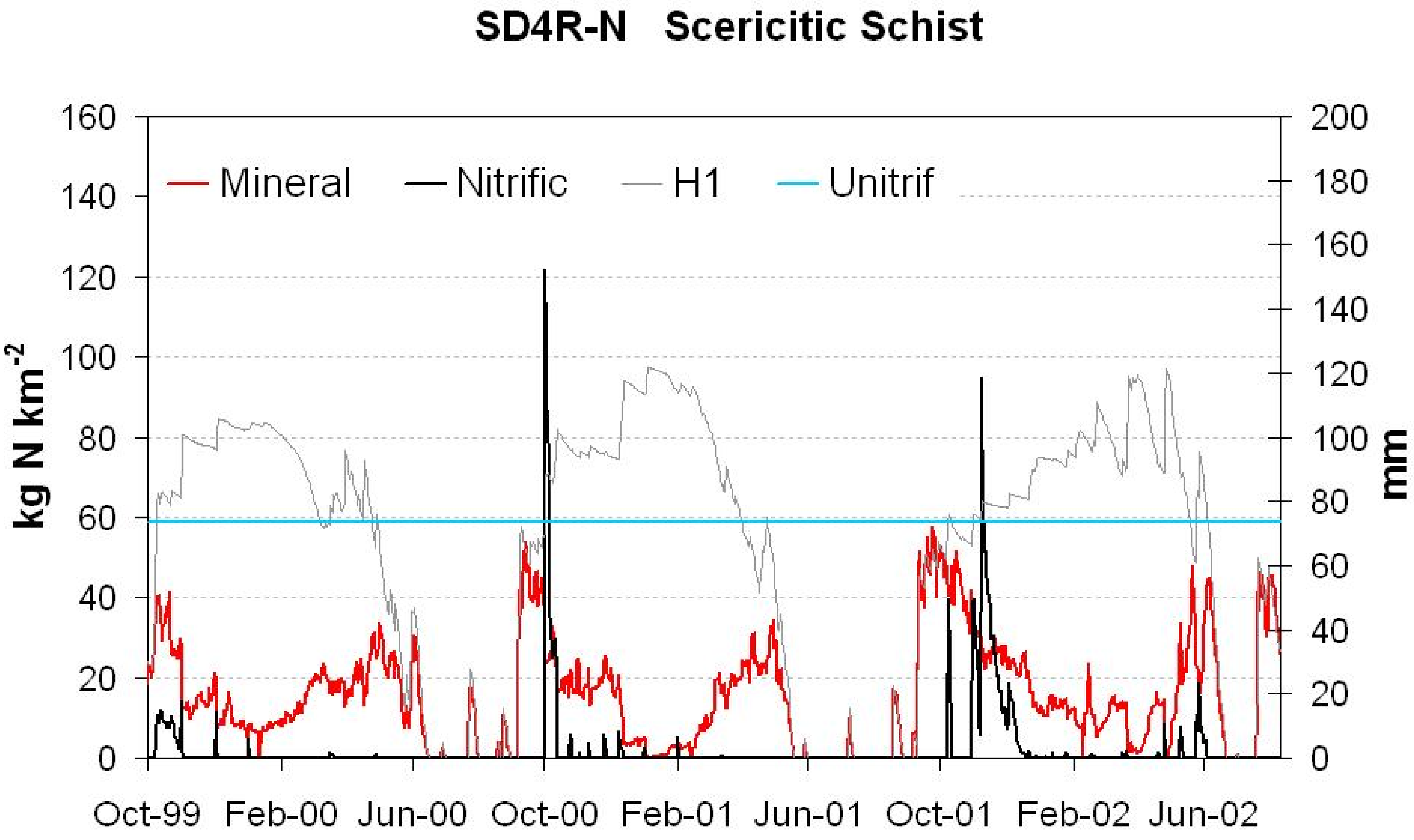
Soil moisture simulated effect (SD4-R-N)

Leucogranite

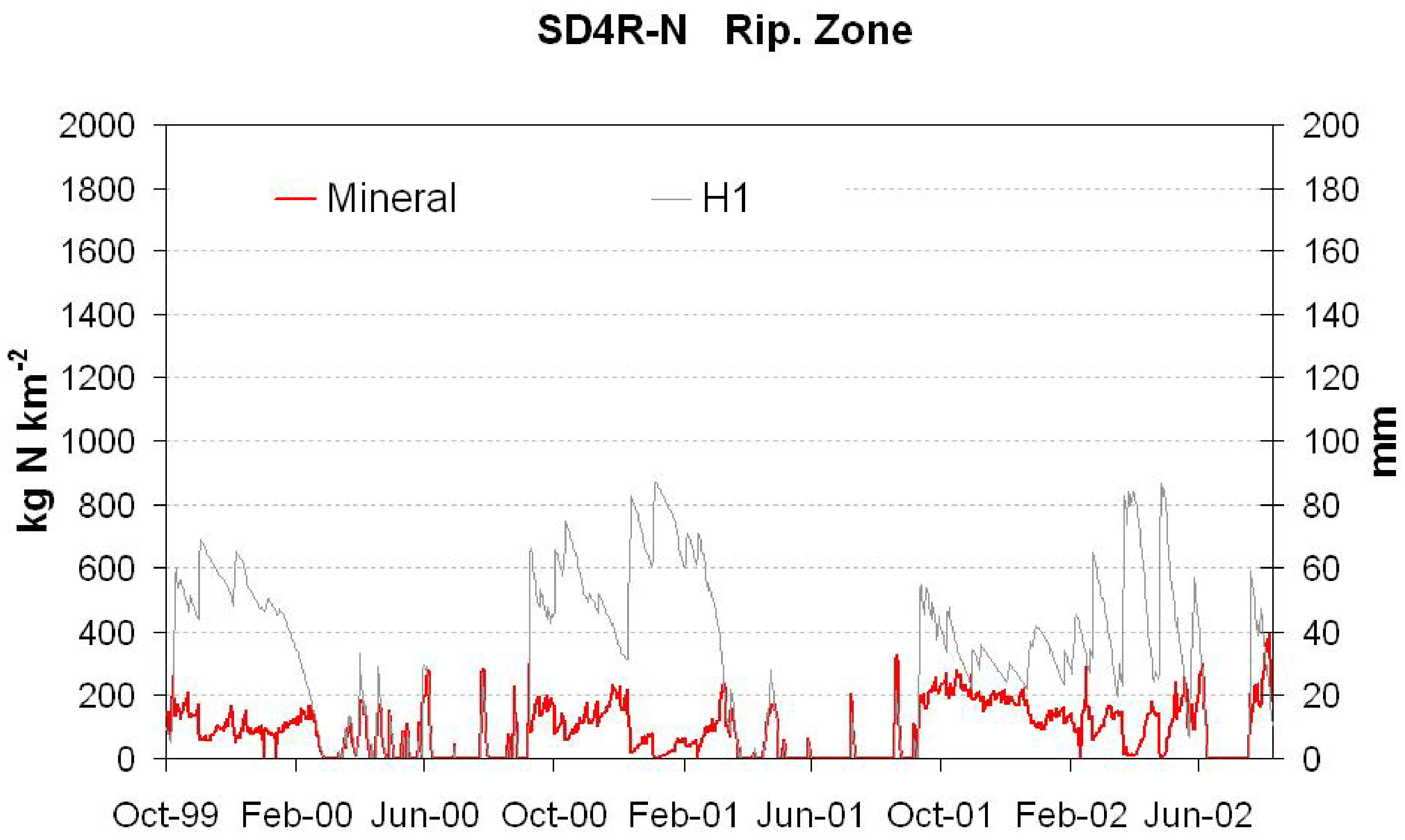


Simulated **mineralisation** is **higher** immediately **after the summer drought period**. This is consistent with McIntyre et al. 2009 that observed higher mineralisation rates under moderate soil moisture conditions

Soil moisture simulated effect (SD4-R-N)

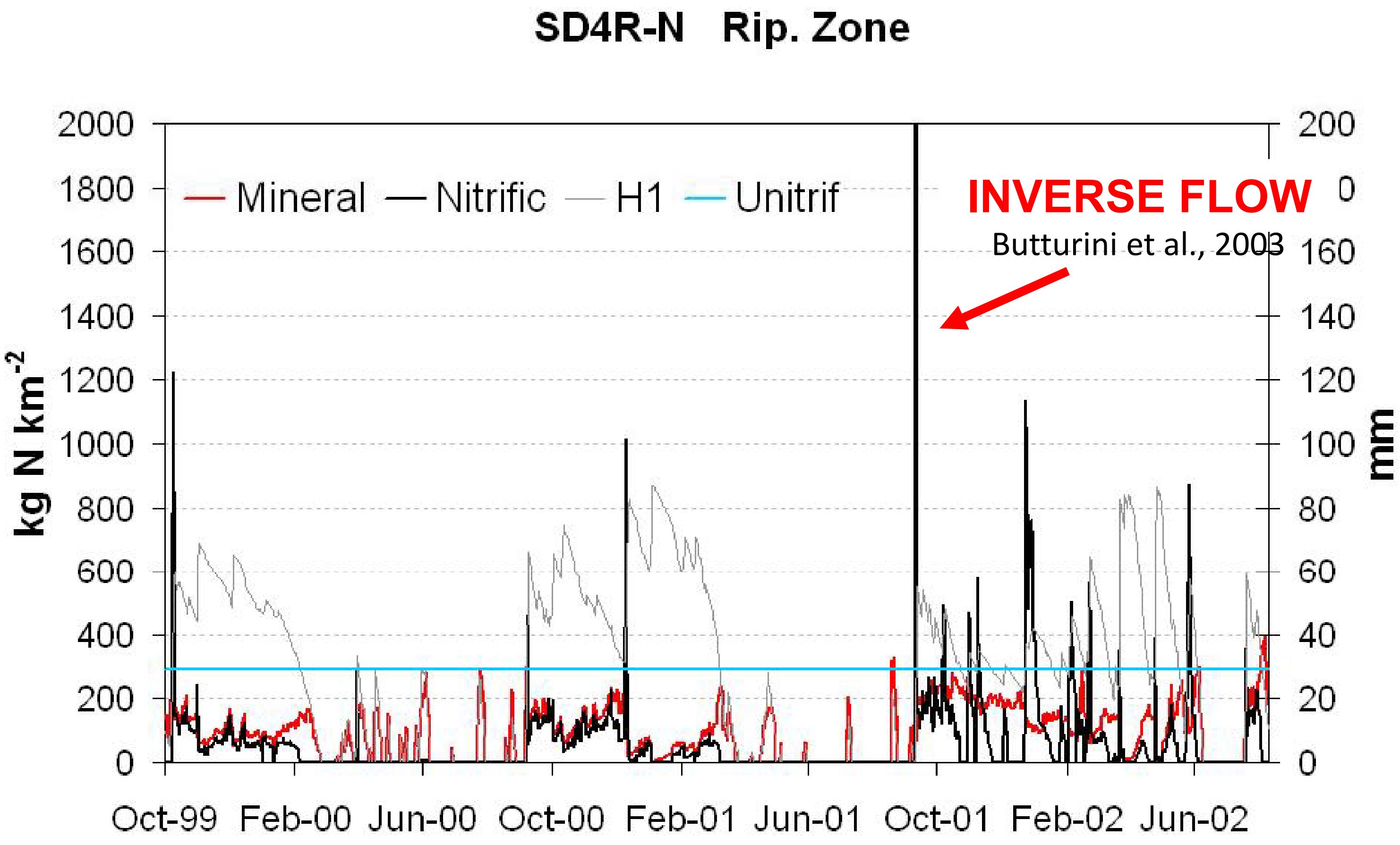


Soil moisture simulated effect (SD4-R-N)



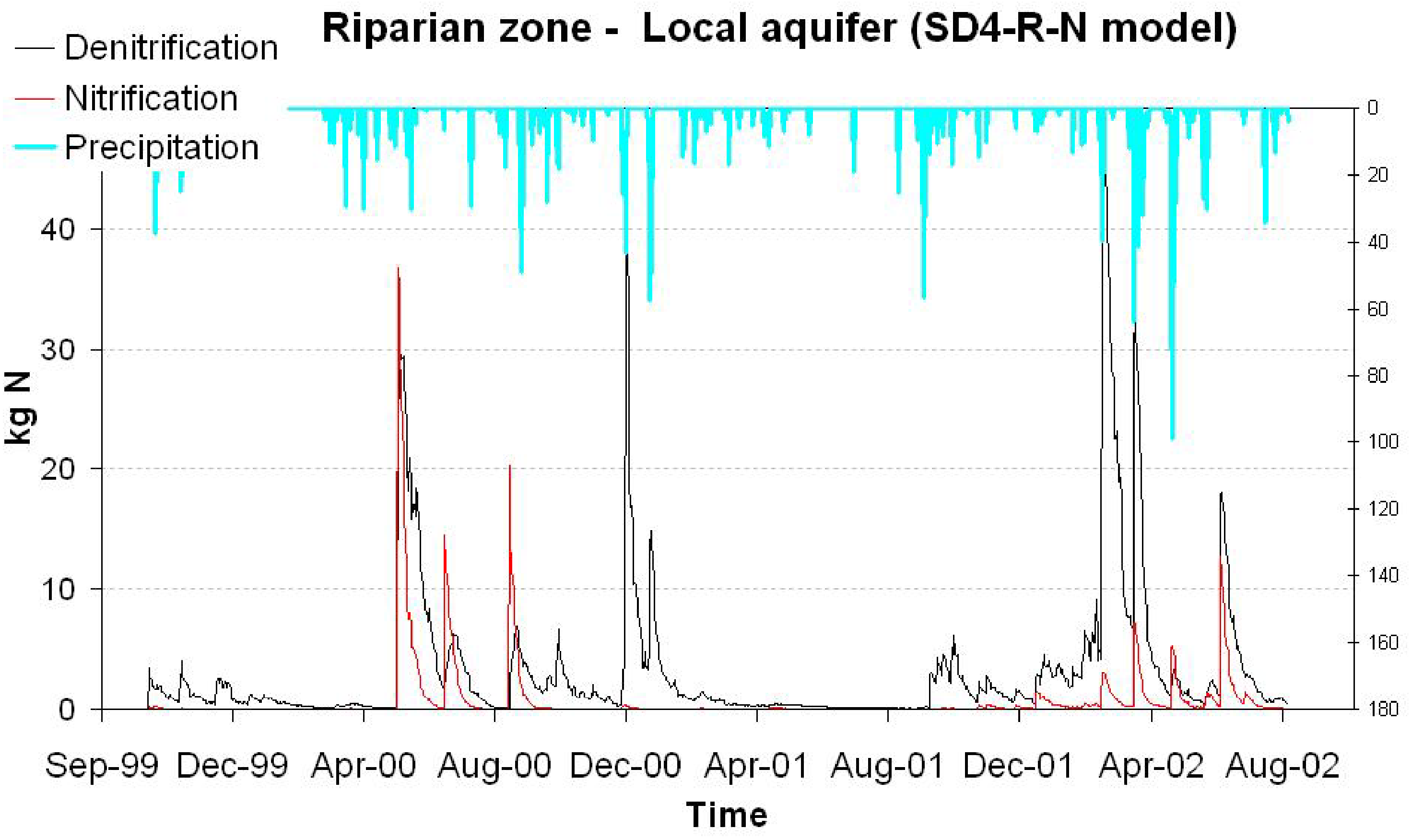
Higher mineralisation rates in the riparian area then in the rest of the catchment

Soil moisture simulated effect (SD4-R-N)



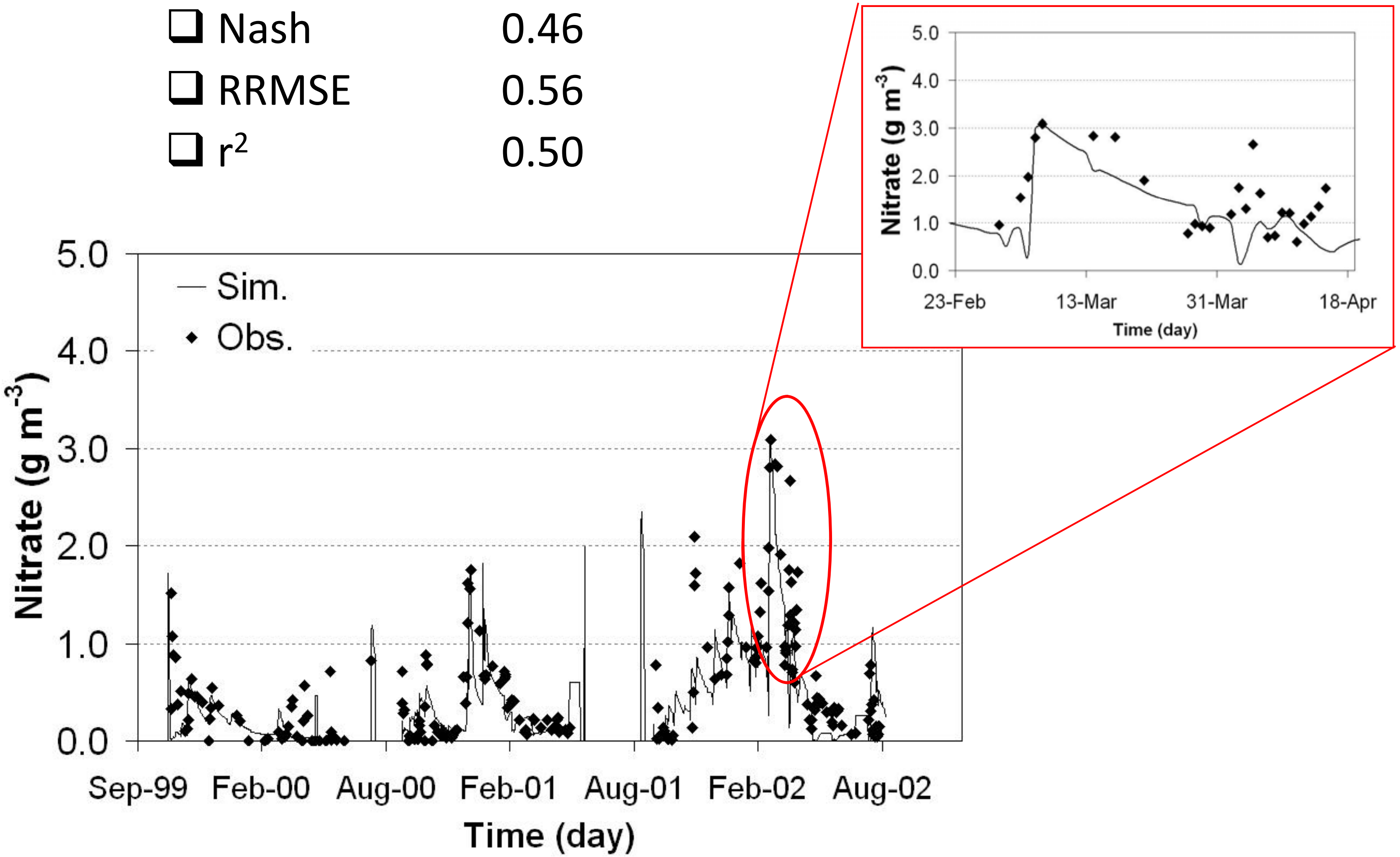
Nitrification follows much more closely the pattern of mineralisation

Soil moisture simulated effect (SD4-R-N)



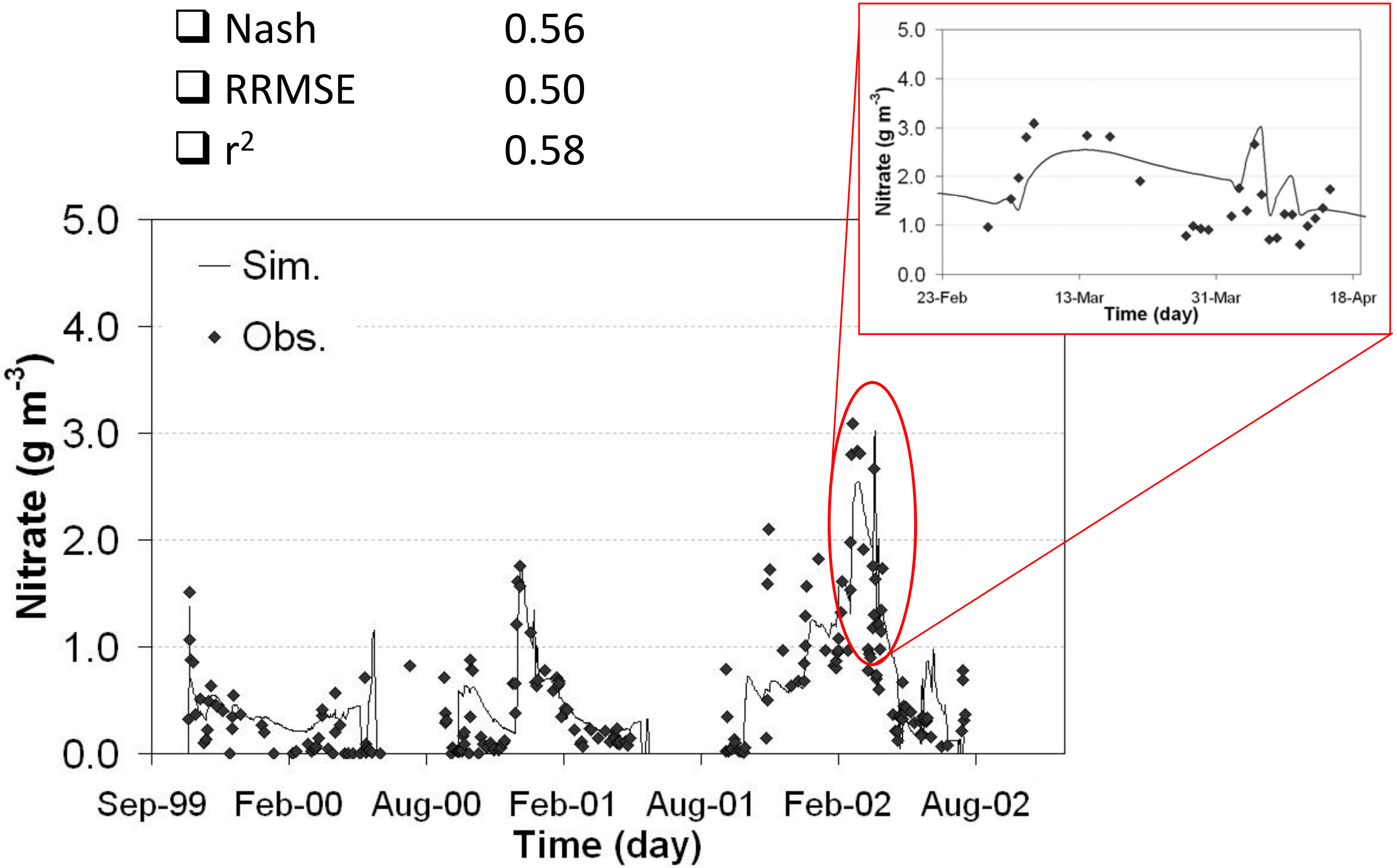
LU4-N model nitrate calibration results

- ☐ Nash 0.46
- ☐ RRMSE 0.56
- ☐ r^2 0.50



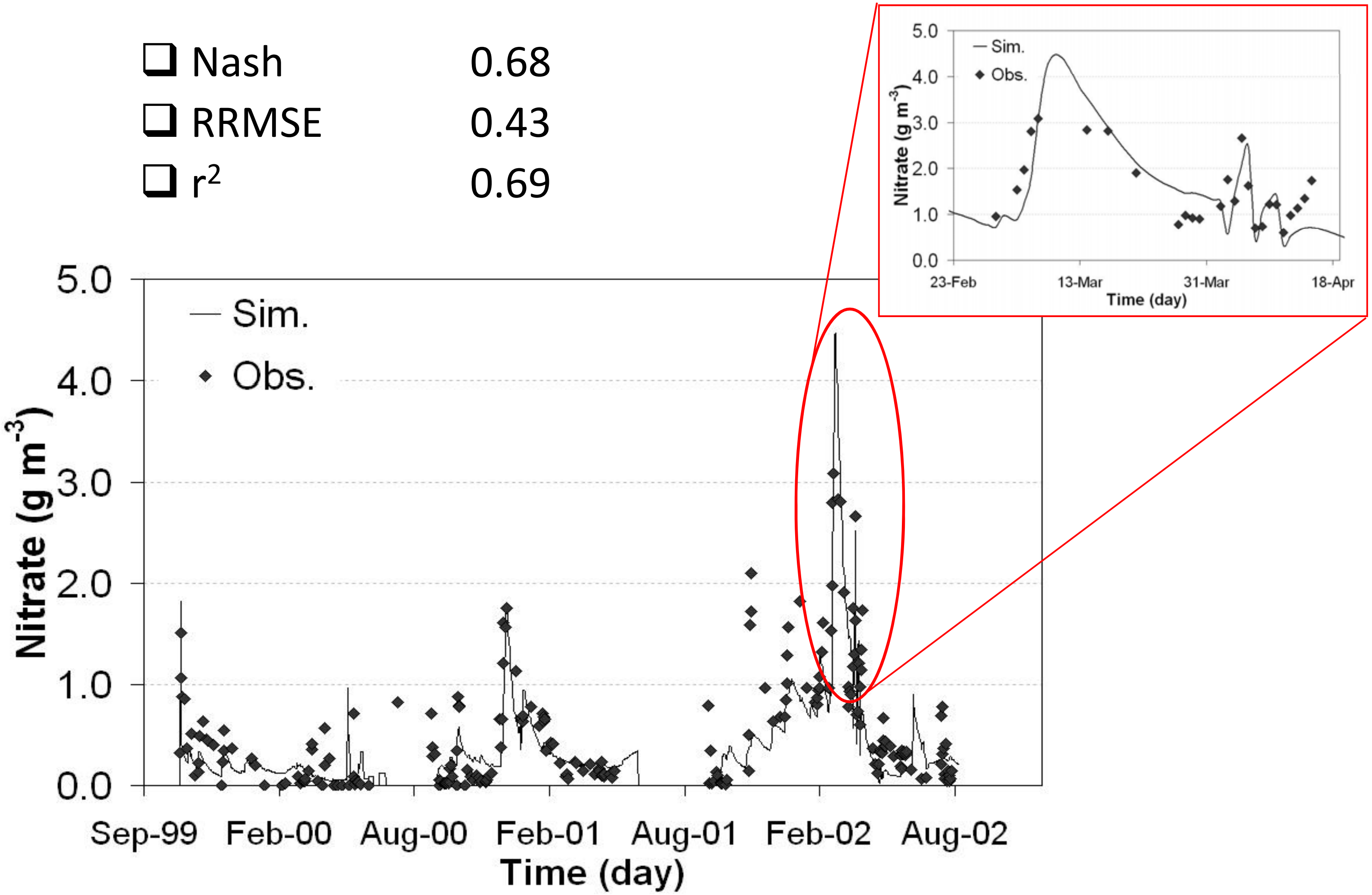
LU4-R-N model nitrate calibration results

☐ Nash	0.56
☐ RRMSE	0.50
☐ r^2	0.58



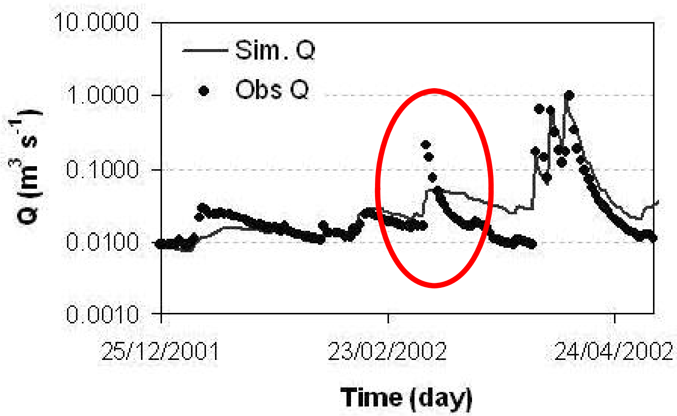
SD4-R-N model nitrate calibration results

☐ Nash	0.68
☐ RRMSE	0.43
☐ r^2	0.69

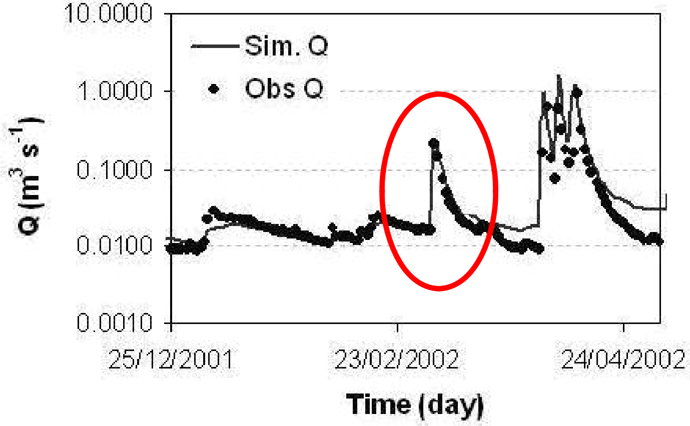


March 2002 discharge event

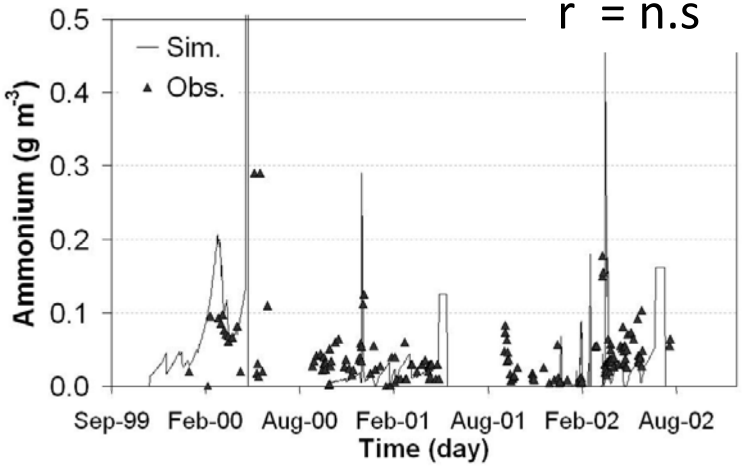
LU4-R-N



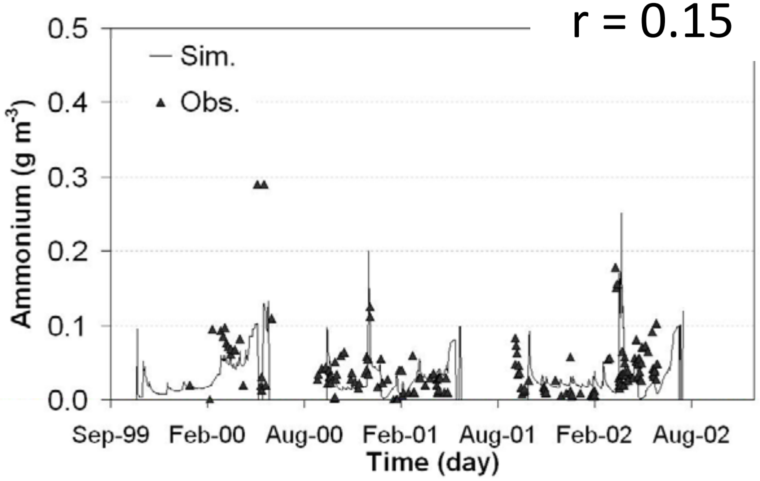
SD4-R-N



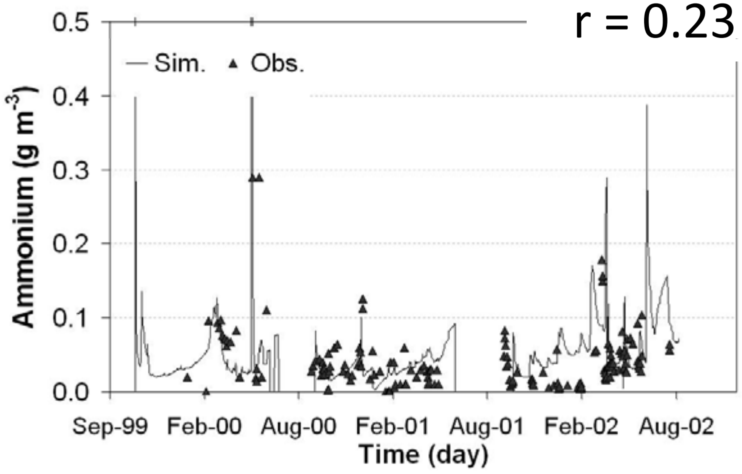
Ammonium calibration results



r = n.s



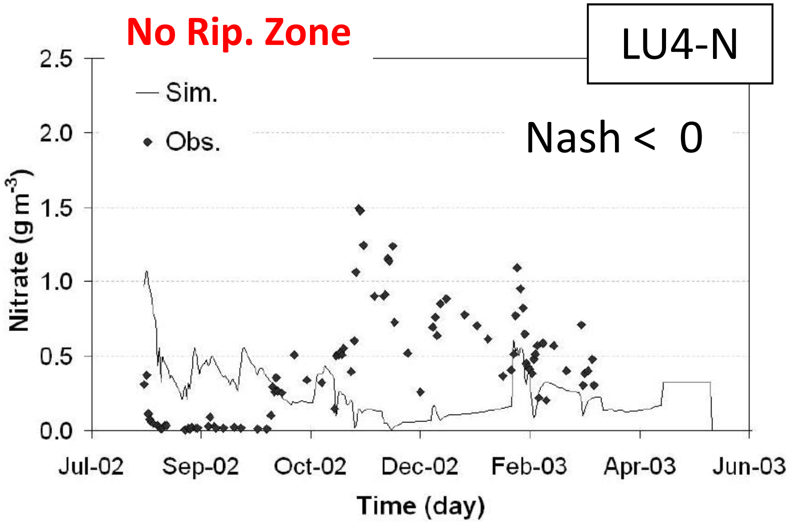
r = 0.15



r = 0.23

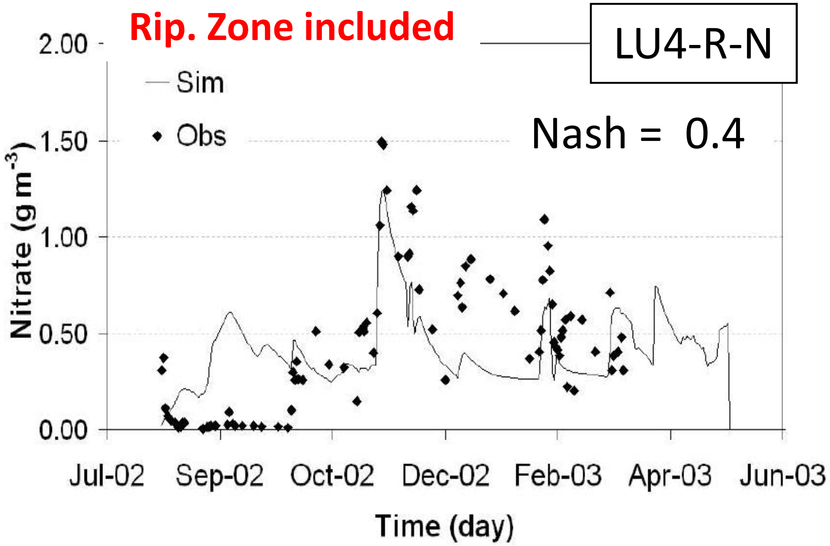
r = Pearson correlation coeff.

Temporal validation for nitrate


No Rip. Zone

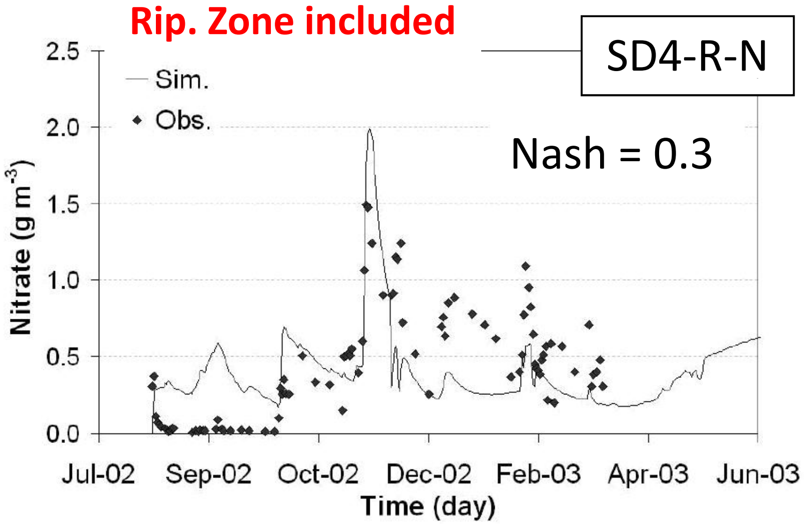
LU4-N

Nash < 0


Rip. Zone included

LU4-R-N

Nash = 0.4


Rip. Zone included

SD4-R-N

Nash = 0.3

Summarising

- ☐ The **semi-distributed models** that include the **riparian zone** were the only ones that could reproduce the two highest nitrate peaks observed and that gave acceptable temporal validation results

- ☐The best results were obtained once again with the semi-distributed **SD4-R-N model**
  - ➢ Same inorganic nitrogen model spatial conceptualization of the LU4-R-N model
  - ➢ Most complex rainfall-runoff model spatial conceptualization that leads to more consistent discharge simulations.

General Sensitivity Analysis

General Sensitivity Analysis

❑ The progression from the simplest conceptual model (LU4-R) to the most complex (SD4-R-N) is reflected by an increase in the number of parameters to be calibrated from 27 to 59.

- ➢ Could the models be simplified removing **insensitive parameters**?
- ➢ Does **additional model complexity** actually give a **better capability** to model the hydrology and nitrogen dynamics of the Fuirosos catchment?
- ➢ Could **concentration data** help to constrain rainfall-runoff models parameters?

General Sensitivity Analysis

- ☐ To assess these issues a **General Sensitivity Analysis**, GSA (Hornberger and Spear, 1980) and the **Generalized Likelihood Uncertainty Estimation** methodology, GLUE (Beven and Binley, 1992), were applied to the three catchment scale nitrogen models of varying complexity developed in this work.
  - ➢ based on **100,000 Monte Carlo** (MC) simulations
  - ➢ The idea is to **randomly select** the model **parameters** from **uniform probability distributions** spanning specified ranges of each parameter to obtain a **sample of model simulations** from throughout the feasible parameter space

General Sensitivity Analysis

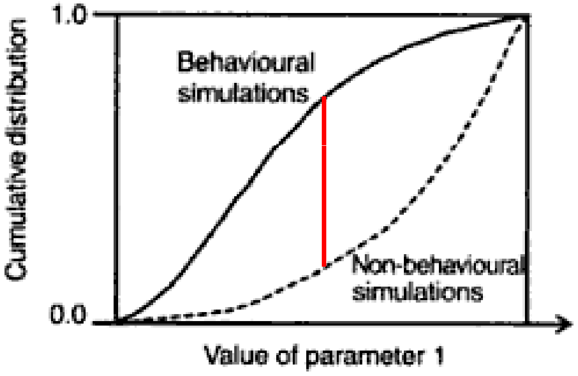
- ☐ The Monte Carlo simulation are then classified, according to some chosen criteria, into those that are considered **behavioural** and those that are considered **non-behavioural** in respect of the system being studied
  - ➢ **Behavioural** simulations might be those with a **high value** of a certain variable or **performance measure**; Non-behavioural simulations might be those with a low value.

General Sensitivity Analysis

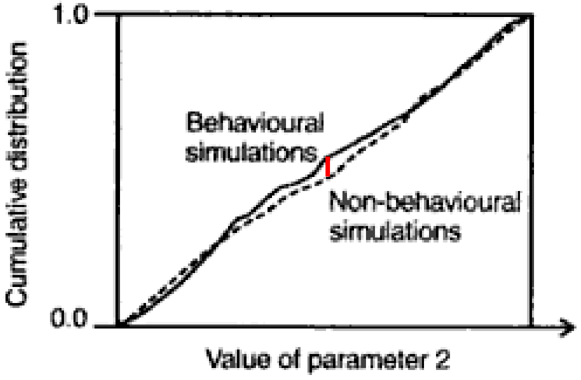
❑ The final results were analysed statistically to identify the key models parameters

➢ **Kolmogorov-Smirnov** two-sample test: analysis based on the separation between the cumulative probability distribution for m behaviours and n non-behaviours (Hornberger and Spear, 1980)

INFLUENTIAL PARAMETER



NON-INFLUENTIAL PARAMETER



Objective functions adopted

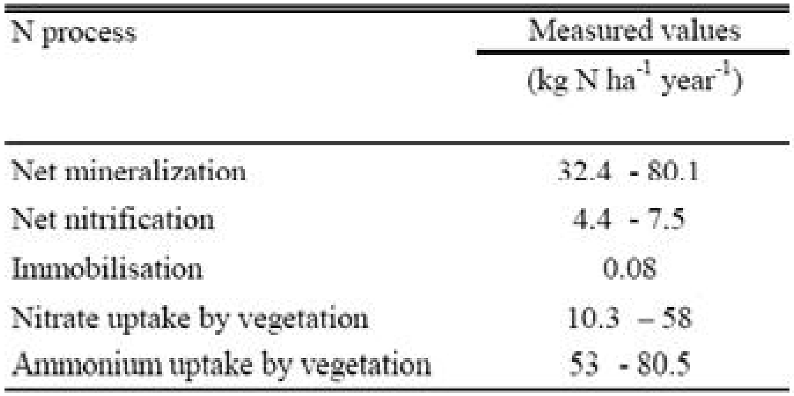
☐ Nash and Sutcliffe efficiency index (**E**)

- $\mathbf{E_{TOT}}$ → efficiency index for the 3-year calibration period (1999 - 2002)
- $\mathbf{E_{1yr}}$, $\mathbf{E_{2yr}}$ and $\mathbf{E_{3yr}}$ → efficiency indexes for each year individually
- $\mathbf{E_{123}} = E_{1yr} + E_{2yr} + E_{3yr}$ (multi-objective approach)

☐ Relative Root Mean Squared Error (**RRMSE**), as defined by Franchello et al., (2004).

Behavioural criteria adopted

- ☐ Discharge
  - $E_{tot}(Q) \geq \mathbf{0.77}$
  - $RRMSE(Q) \leq \mathbf{0.5}$
  - $E^*_{123}(Q) \geq \mathbf{1.5}$ ($E_{123}(Q) \geq 1.5$ plus E_{1yr}, E_{2yr} and $E_{3yr} \geq 0.5$)
- ☐ Nitrate
  - $RRMSE(NO_3) \leq 0.6$ and $RRMSE(NH_4) \leq 1.2$

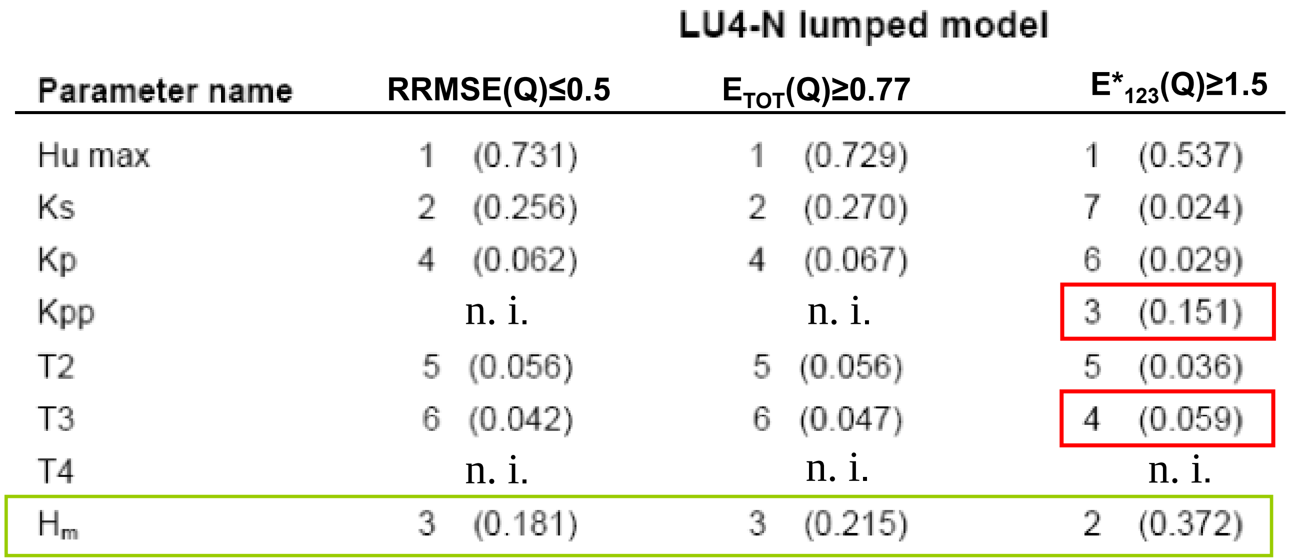


N process	Measured values (kg N ha^{-1} $year^{-1}$)
Net mineralization	32.4 - 80.1
Net nitrification	4.4 - 7.5
Immobilisation	0.08
Nitrate uptake by vegetation	10.3 – 58
Ammonium uptake by vegetation	53 - 80.5

Nitrogen annual process rates: values from previous studies in forests of *Quercus ilex* in Catalonia (Spain), after Bernal et al., 2004

LU4-N model discharge influential parameters

- ❑ Sensitivity ranking



LU4-N lumped model

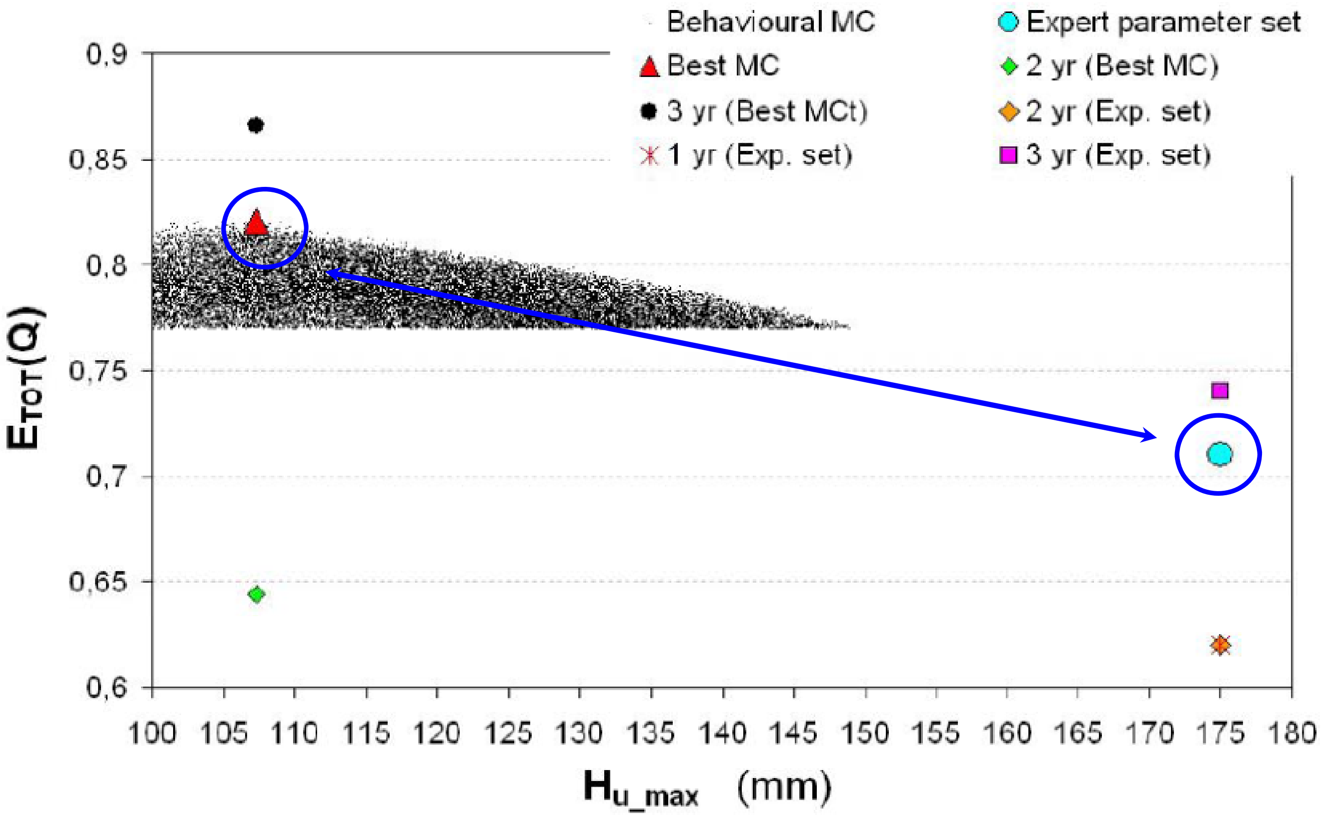
Parameter name	**RRMSE(Q)≤0.5**	**E_{TOT}(Q)≥0.77**	**E^*_{123}(Q)≥1.5**
Hu max	1 (0.731)	1 (0.729)	1 (0.537)
Ks	2 (0.256)	2 (0.270)	7 (0.024)
Kp	4 (0.062)	4 (0.067)	6 (0.029)
Kpp	n. i.	n. i.	3 (0.151)
T2	5 (0.056)	5 (0.056)	5 (0.036)
T3	6 (0.042)	6 (0.047)	4 (0.059)
T4	n. i.	n. i.	n. i.
H_m	3 (0.181)	3 (0.215)	2 (0.372)

n. i. = non influential

p-value ≤ 0.001; Models parameters significant at 99.9% (0.04) level or greater (Single objective approach)
p-value ≤ 0.01; Models parameters significant at 99% (0.024) level or greater (Multi-objective approach)

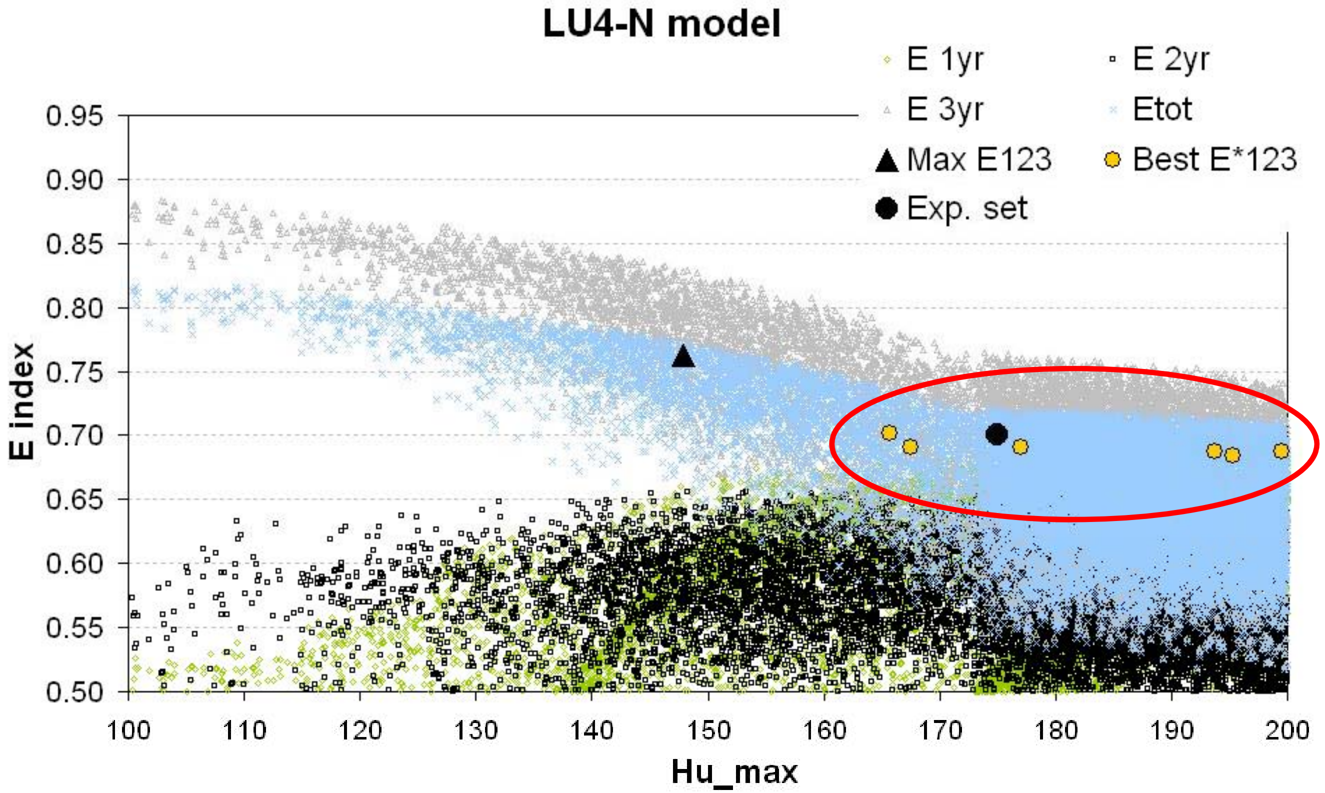
Scatter plot against $E_{TOT}(Q)$

- ❑ It allows the identification of the 'optimum' parameter value, which is quite far away from the expert calibrated one



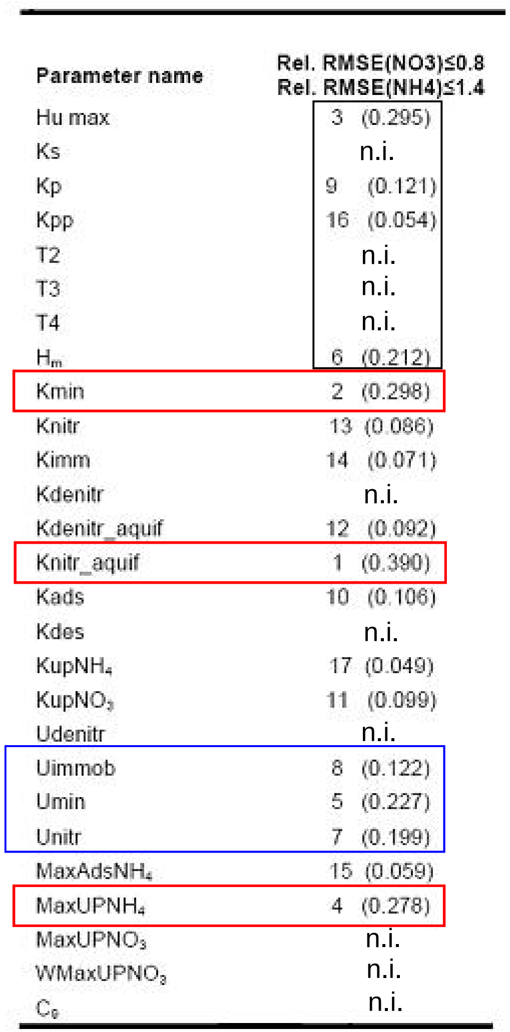
Scatter plot against $E^*_{123}(Q)$

- ❑ Scatter plot of the most sensitive parameter against each annual E index (E_{1yr}, E_{2yr} and E_{3yr}) as well as $E_{tot}(Q)$



LU4-N model nitrate influential parameters

Sensitivity ranking



Parameter name	Rel. RMSE(NO3)≤0.8 Rel. RMSE(NH4)≤1.4
Hu max	3 (0.295)
Ks	n.i.
Kp	9 (0.121)
Kpp	16 (0.054)
T2	n.i.
T3	n.i.
T4	n.i.
H_m	6 (0.212)
Kmin	2 (0.298)
Knitr	13 (0.086)
Kimm	14 (0.071)
Kdenitr	n.i.
Kdenitr_aquif	12 (0.092)
Knitr_aquif	1 (0.390)
Kads	10 (0.106)
Kdes	n.i.
$KupNH_4$	17 (0.049)
$KupNO_3$	11 (0.099)
Udenitr	n.i.
Uimmob	8 (0.122)
Umin	5 (0.227)
Unitr	7 (0.199)
$MaxAdsNH_4$	15 (0.059)
$MaxUPNH_4$	4 (0.278)
$MaxUPNO_3$	n.i.
$WMaxUPNO_3$	n.i.
C_0	n.i.

⇨ The results clearly highlight that the rainfall-runoff model parameters affect inorganic nitrogen simulation.

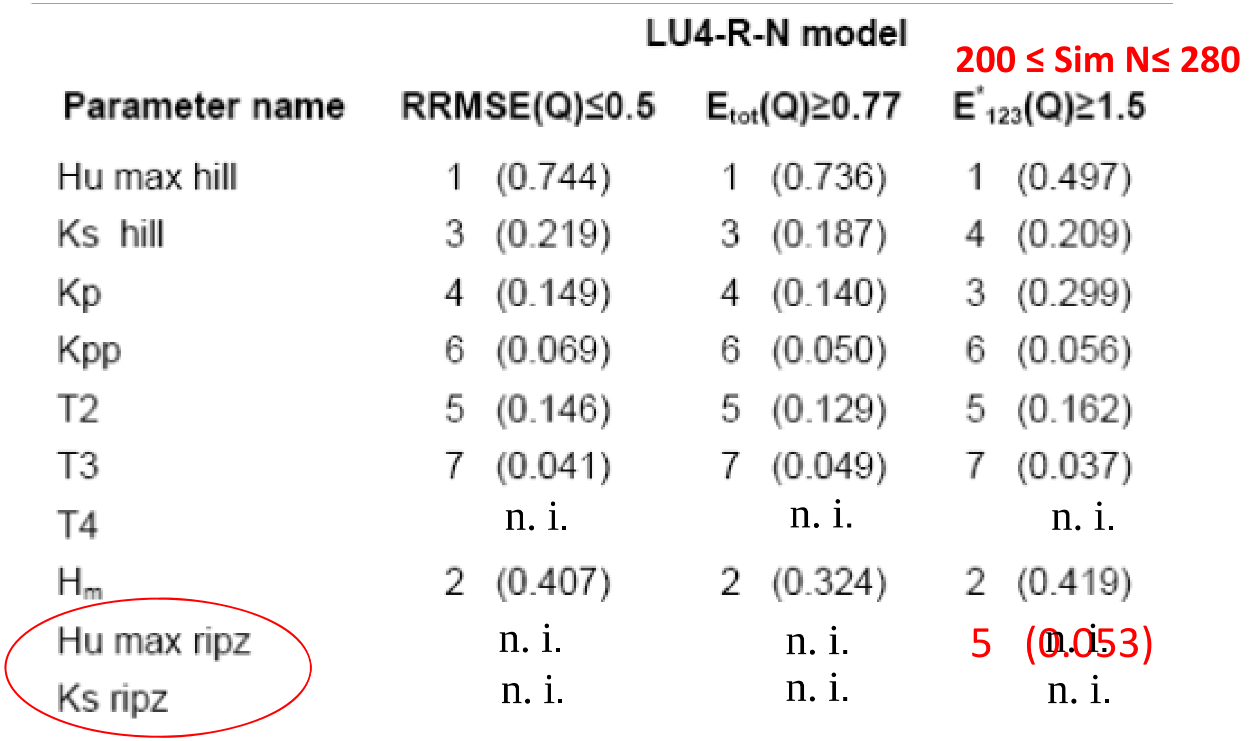
⇩

This result should be taken into account for the **model calibration strategy**

p-value ≤ 0.05; Models parameters significant at 95% (0.044) level or greater

LU4-R-N model discharge influential parameters

❑ Sensitivity ranking



200 ≤ Sim N≤ 280

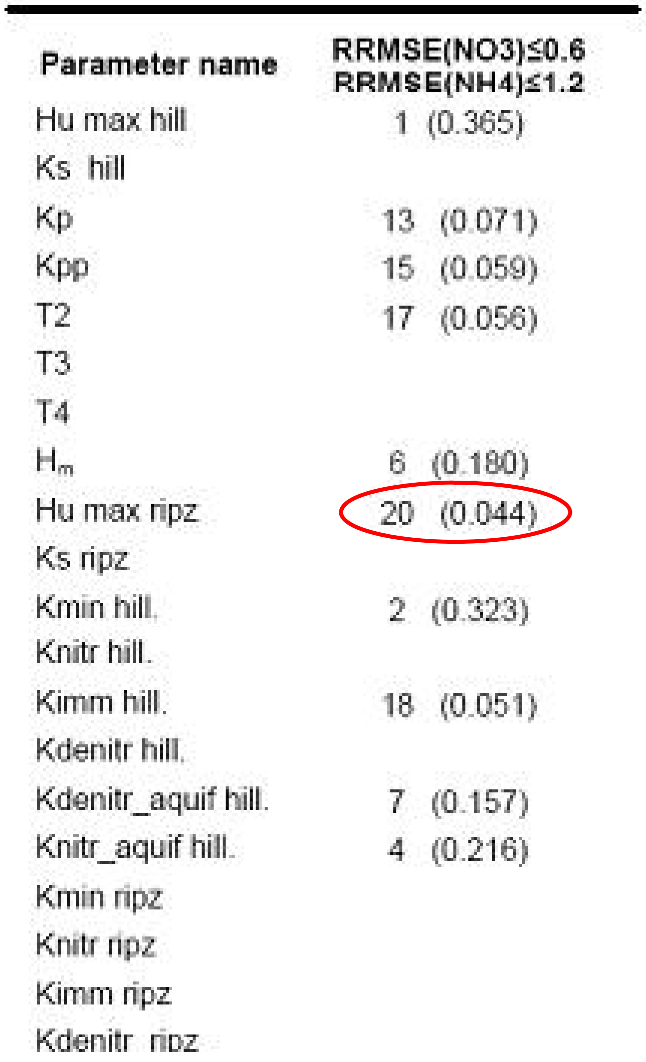
	LU4-R-N model		
Parameter name	**RRMSE(Q)≤0.5**	**E_{tot}(Q)≥0.77**	**E^*_{123}(Q)≥1.5**
Hu max hill	1 (0.744)	1 (0.736)	1 (0.497)
Ks hill	3 (0.219)	3 (0.187)	4 (0.209)
Kp	4 (0.149)	4 (0.140)	3 (0.299)
Kpp	6 (0.069)	6 (0.050)	6 (0.056)
T2	5 (0.146)	5 (0.129)	5 (0.162)
T3	7 (0.041)	7 (0.049)	7 (0.037)
T4	n. i.	n. i.	n. i.
H_m	2 (0.407)	2 (0.324)	2 (0.419)
Hu max ripz	n. i.	n. i.	n. i. 5 (0.053)
Ks ripz	n. i.	n. i.	n. i.

p-value ≤ 0.005; Models parameters significant at 99.95% (0.034) level or greater (Single objective approach)

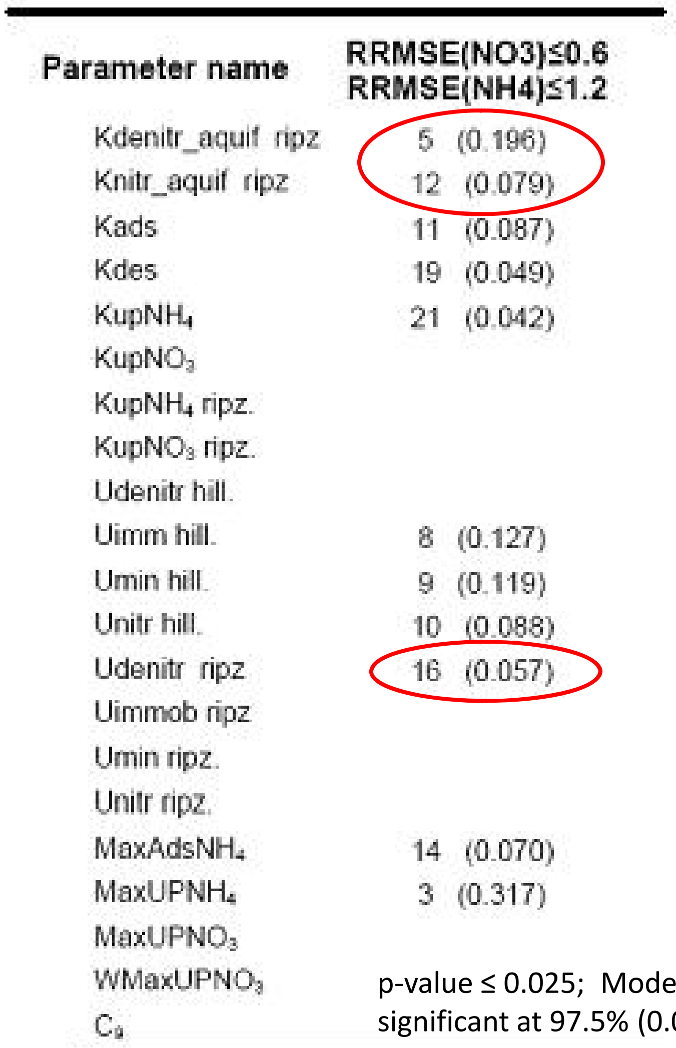
❑ The **riparian zone** seems to exert its influence over a **very specific hydrograph characteristic** that is catchment drying-up and wetting-up

LU4-R-N model nitrate influential parameters

Sensitivity ranking



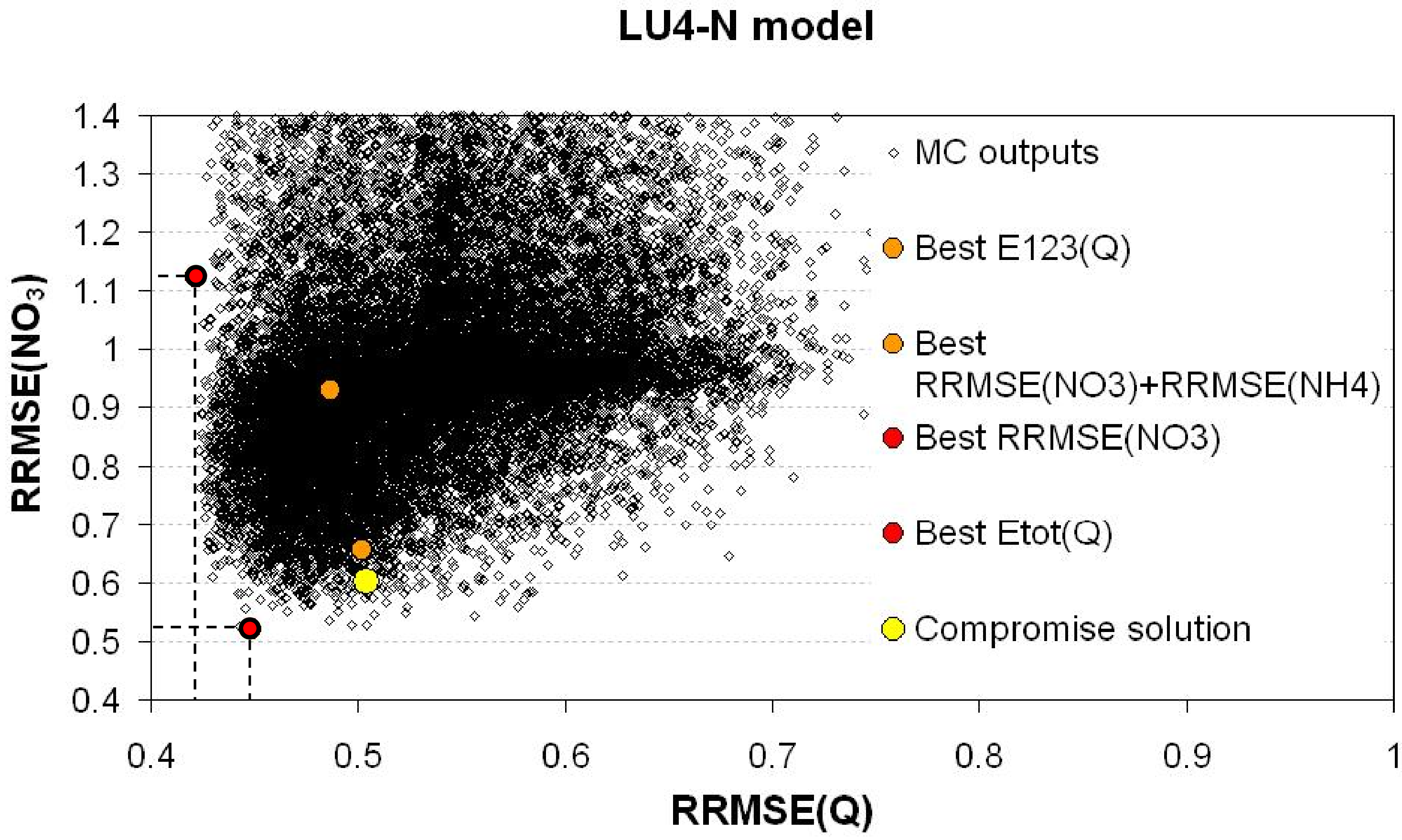
Parameter name	RRMSE(NO3)≤0.6 RRMSE(NH4)≤1.2
Hu max hill	1 (0.365)
Ks hill	
Kp	13 (0.071)
Kpp	15 (0.059)
T2	17 (0.056)
T3	
T4	
H_m	6 (0.180)
Hu max ripz	20 (0.044)
Ks ripz	
Kmin hill.	2 (0.323)
Knitr hill.	
Kimm hill.	18 (0.051)
Kdenitr hill.	
Kdenitr_aquif hill.	7 (0.157)
Knitr_aquif hill.	4 (0.216)
Kmin ripz	
Knitr ripz	
Kimm ripz	
Kdenitr ripz	



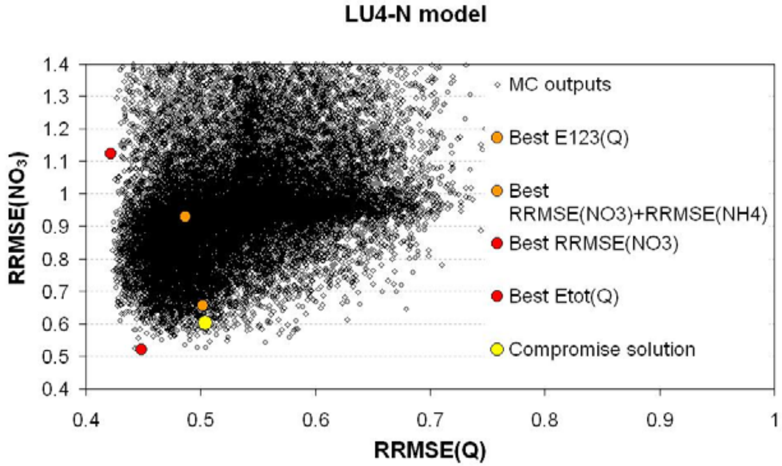
Parameter name	RRMSE(NO3)≤0.6 RRMSE(NH4)≤1.2
Kdenitr_aquif ripz	5 (0.196)
Knitr_aquif ripz	12 (0.079)
Kads	11 (0.087)
Kdes	19 (0.049)
$KupNH_4$	21 (0.042)
$KupNO_3$	
$KupNH_4$ ripz.	
$KupNO_3$ ripz.	
Udenitr hill.	
Uimm hill.	8 (0.127)
Umin hill.	9 (0.119)
Unitr hill.	10 (0.088)
Udenitr ripz	16 (0.057)
Uimmob ripz	
Umin ripz.	
Unitr ripz.	
$MaxAdsNH_4$	14 (0.070)
$MaxUPNH_4$	3 (0.317)
$MaxUPNO_3$	
$WMaxUPNO_3$	
C_a	

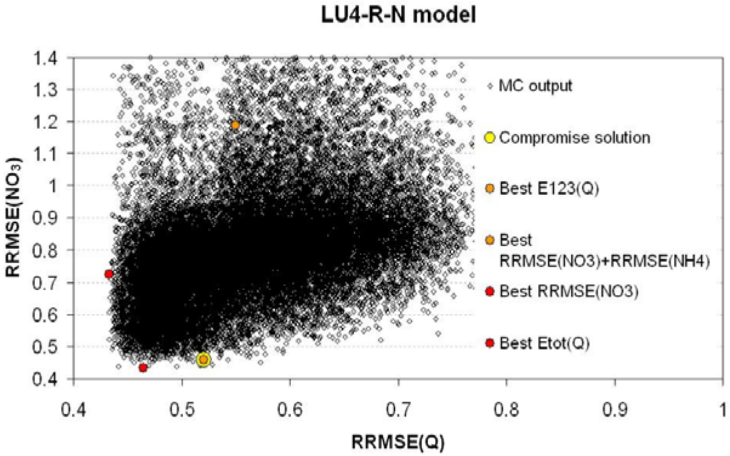
p-value ≤ 0.025; Models parameters significant at 97.5% (0.041) level or greater

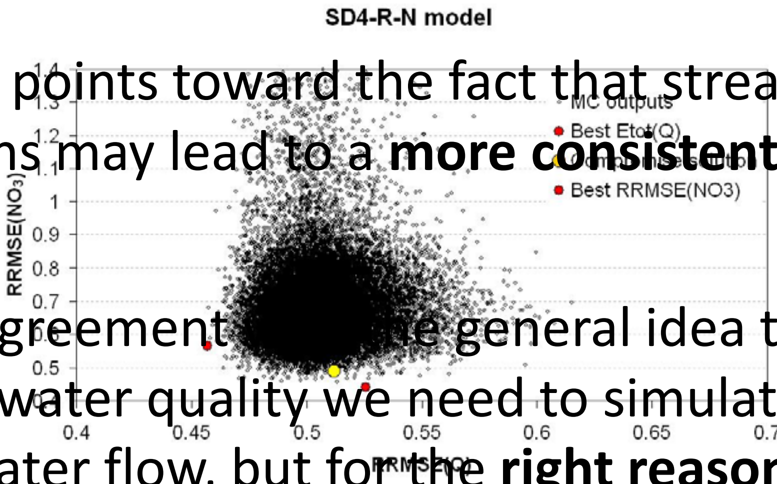
Relationships between RRMSE(NO_3) and RRMSE(Q)



Relationships between RRMSE(NO_3) and RRMSE(Q)





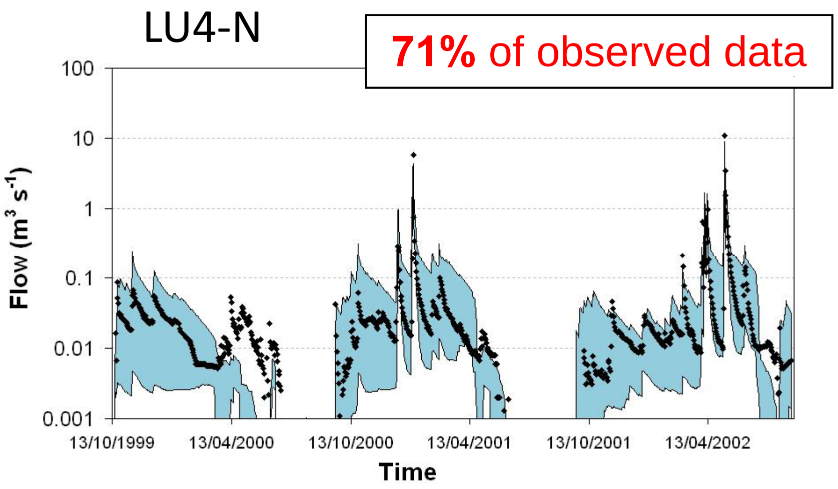


- ❑ This result points toward the fact that stream data concentrations may lead to a **more consistent hydrological simulation**
- ❑ This is in agreement with the general idea that to simulate properly the water quality we need to simulate well the catchment water flow, but for the **right reason**

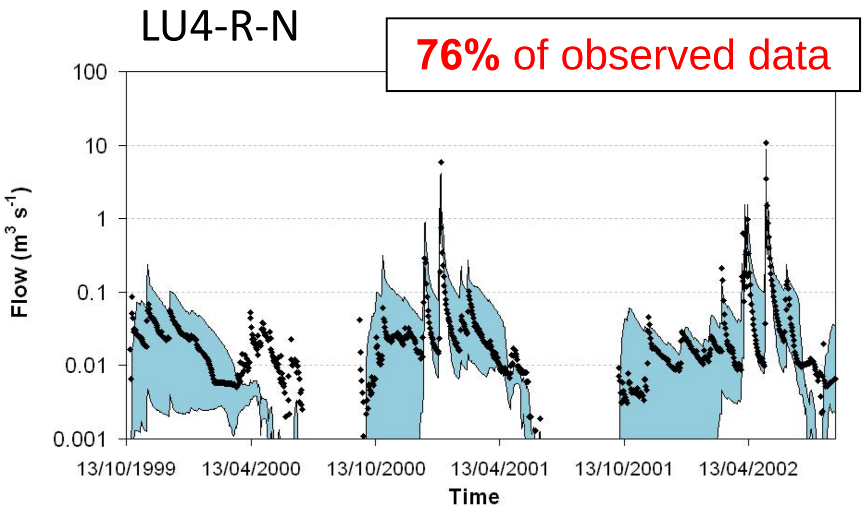
Behavioural runs

	LU4-N	**LU4-R-N**	**SD4-R-N**
Discharge			
RRMSE			
E_{tot}			
E^{*}_{123}			
Nitrate			
RRMSE			
Discharge & Nitrate	----	59	127

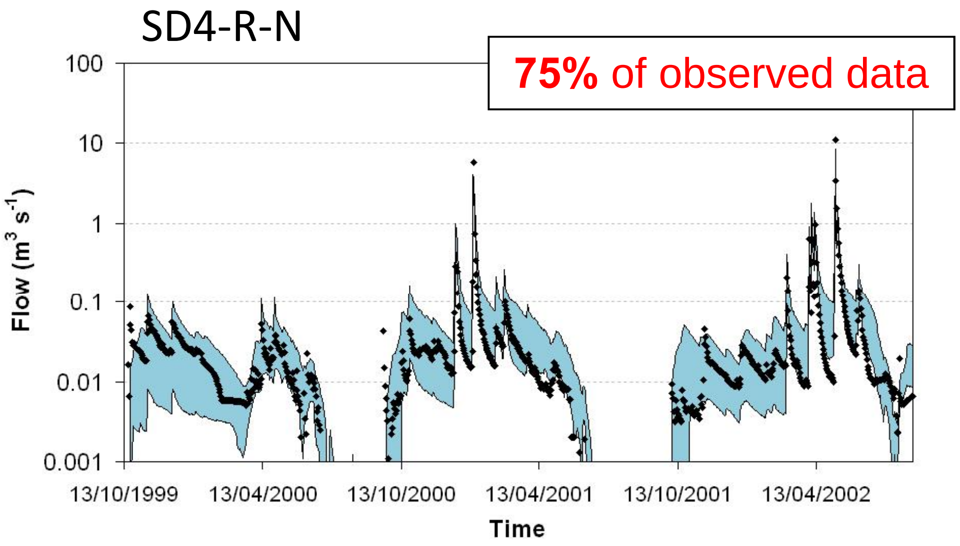
Discharge – 5% and 95% GLUE bounds (E_{tot})


LU4-N

71% of observed data


LU4-R-N

76% of observed data

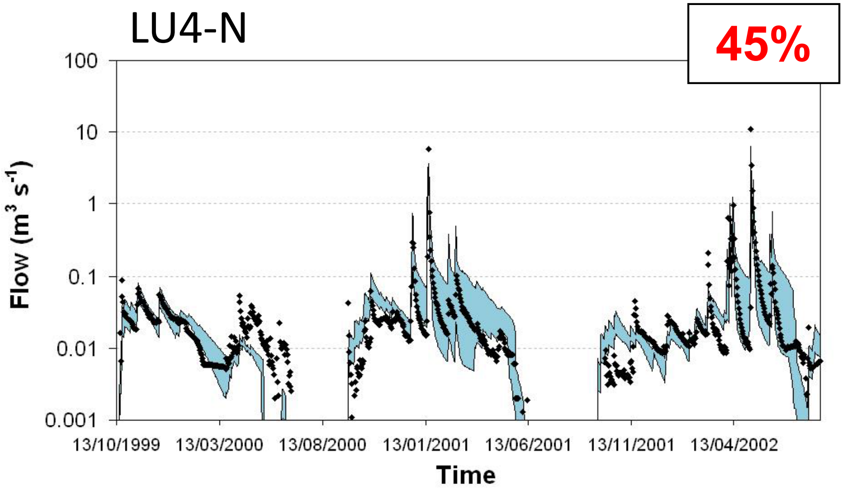

SD4-R-N

75% of observed data

Discharge – 5% and 95% GLUE bounds (E^{*}_{123})

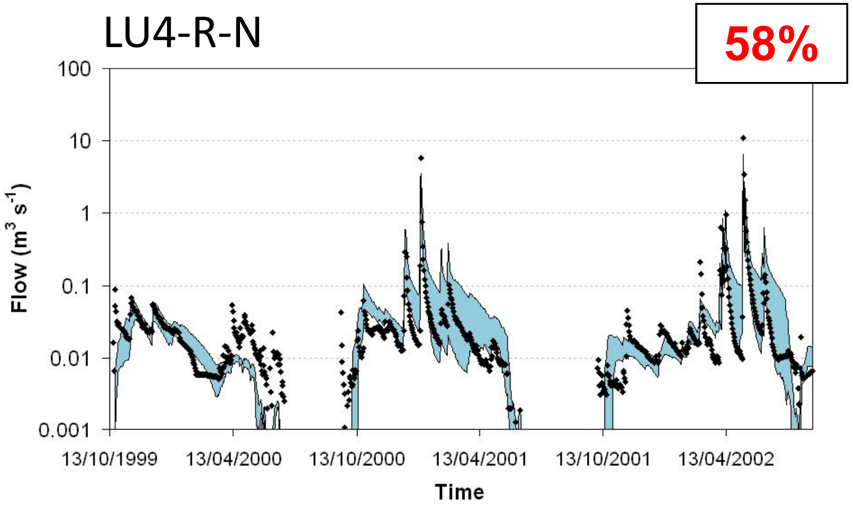
LU4-N

45%



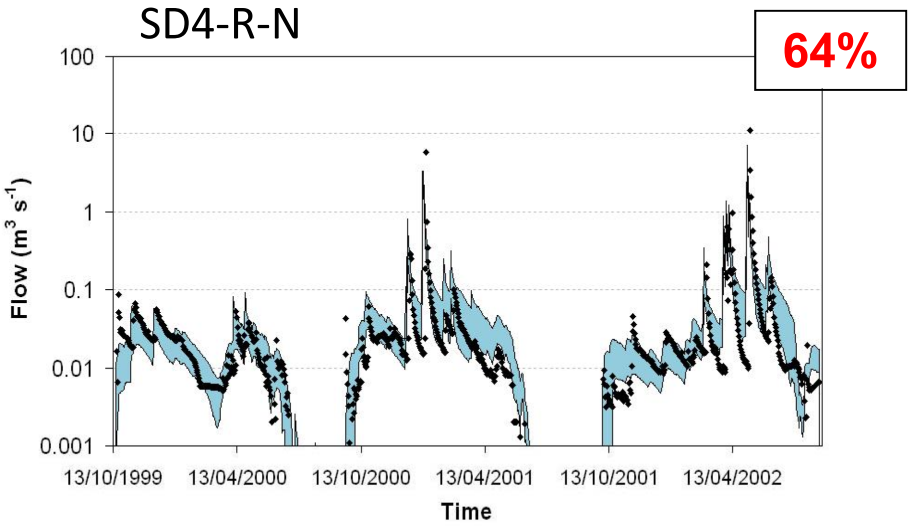
LU4-R-N

58%

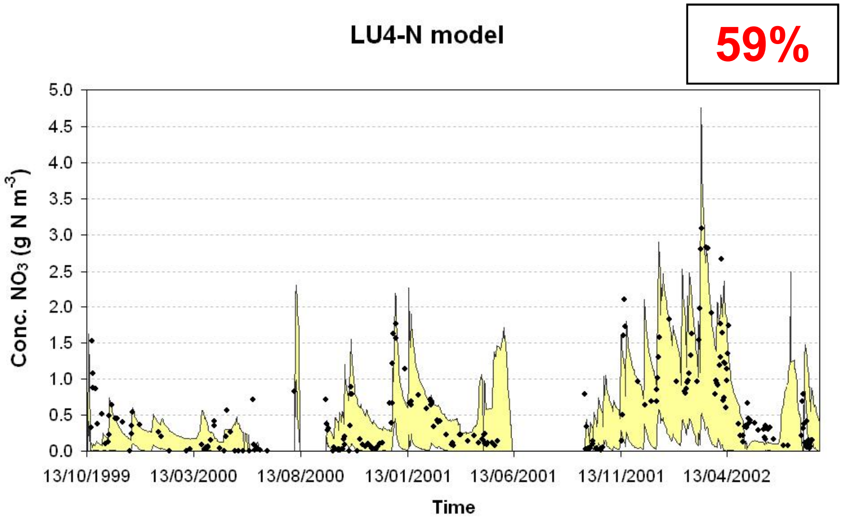


SD4-R-N

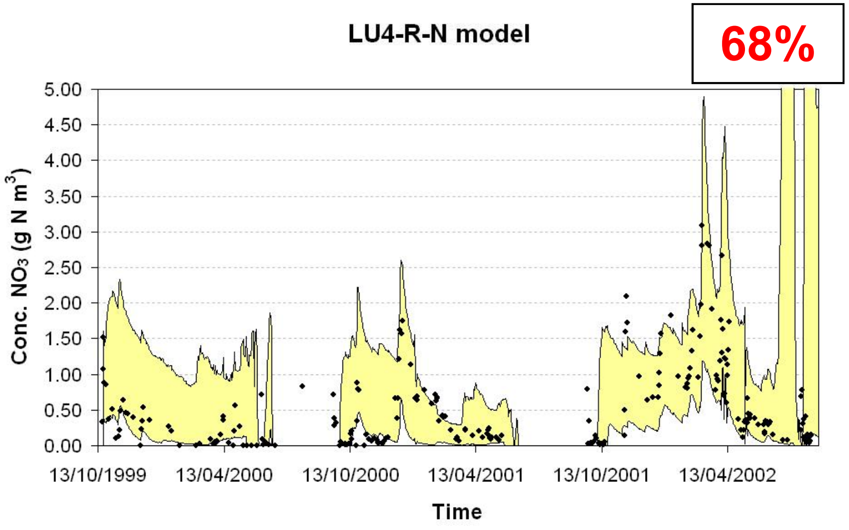
64%



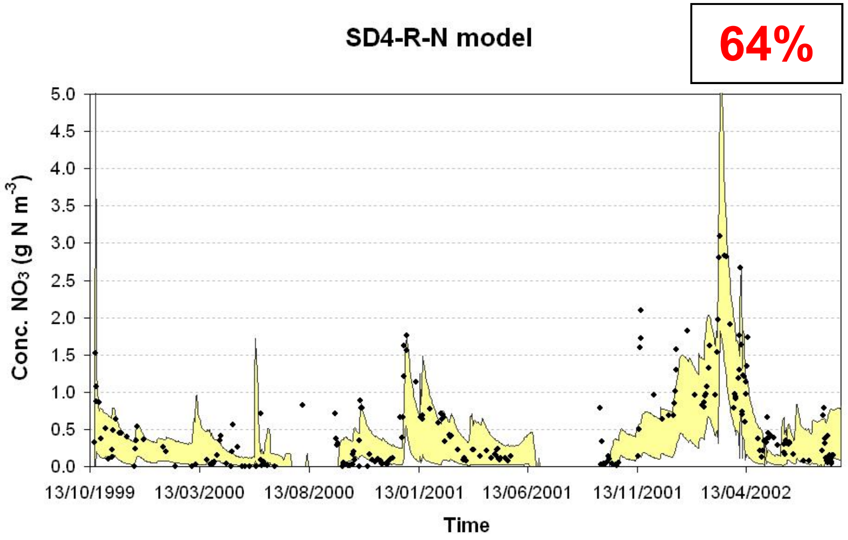
Nitrate – 5% and 95% GLUE bounds


LU4-N model

59%


LU4-R-N model

68%


SD4-R-N model

64%

Conclusions

Conclusions (Hydrology)

☐ The hydrological modelling led to a perceptual model that involves **four different hydrological responses**: overland flow; interflow; quick base flow and slow base flow

☐ The results obtained suggested that **water flow paths** were essentially **different during wet and dry conditions**

☐ Also highlighted the importance of considering the **spatial variability** for the **evapotranspiration process**, since in Mediterranean ecosystems it is generally one of the most important factors of catchments water balance

Conclusions (Hydrology)

❑ Several mechanisms were taken into account to explain the catchment non linear behaviour:

- ➢ The permanent saturated zone ‘**switching behaviour**’
- ➢ Water from the **permanent saturated zone** is lost by **transpiration** rather than lateral flow
- ➢ The formation of a **perched water table** at the interface between the soil and the upper part of the weathered bedrock layer
- ➢ The **non-linear recharge to the permanent saturated zone** that can occur only when the catchment recovers a **certain saturation degree**
- ➢ **Riparian pumping** effect: the **riparian zone vegetation** may induce a **reverse flux** from the stream to the riparian zone

Conclusions (Inorganic Nitrogen)

❑The results suggested that soil nitrogen processes were highly influenced by the **rain episodes** and that **soil microbial processes** occurred in '**pulses**' stimulated by soil moisture after rain

❑ The **riparian zone** was highlighted as a **key element** to simulate catchment nitrate behaviour:

- ➢ It can act as a source as well as a sink for nitrate
- ➢ The mineralisation/nitrification mechanism is essentially different from the rest of the catchment

Conclusions (Inorganic Nitrogen)

❑ The models reproduce **higher mineralisation** rates **after the summer drought** period which can be related with the well known ‘**Birch effect**’ (Birch, 1959, 1960 and 1964)

❑ The results highlighted the **nitrification and denitrification** in the **unsaturated weathered granite**, below the soil organic horizon, **as important processes** as suggested by Legout et al., 2005

❑ Further work is needed to improve the simulation of stream ammonium concentration

Conclusions (GSA and GLUE)

❑ All the **threshold mechanisms** included in the models were highlighted as very **influential**, suggesting that any simplification of the conceptual scheme adopted should not be recommended

❑ It was highlighted the **relevance** of the choice of the **objective function** adopted for the analysis

  ➢ For example for the **riparian zone** rainfall-runoff model parameters

Conclusions (GSA and GLUE)

- ☐ For the **discharge**, the number of **behavioural runs decreases with model complexity** and the **GLUE bands get narrower**, suggesting less model sensitivity to parameter variations, hence increased model robustness

- ☐ For **nitrate**, the number of **behavioural runs increases with model complexity**, while the **GLUE bands get narrower**
  - ➢ For the **LU4-R-N model** this can be explained by the larger number of parameters (due to the inclusion of the riparian zone), hence larger model's degrees of freedom
  - ➢ For the **SD4-R-N model**, it has been attributed to a better hydrological simulation, which made the inclusion of the riparian zone more effective

Conclusions (GSA and GLUE)

❑ Several **hydrological parameters** were regarded as **influential on nitrate** simulation. Moreover, near-optimum parameter sets for nitrate, generally provided acceptable simulations for the discharge

- ➢ A **simultaneous calibration strategy** represents the best solution for this study case, as found by McIntyre (2005)

❑ When **hydrology and water quality** were **modelled simultaneously** the number of equally good parameter sets decreased dramatically

- ➢ **Transfer of information**: Concentrations data may help to constrain rainfall-runoff models parameters
- ➢ It also demonstrates that a good conceptual representation of the catchment represented by a model, reduces the equifinality problem through a better understanding of the system

General conclusion and main contribution

The hydrological and water quality modelling of **Mediterranean systems** is a **complex challenge**, but it was shown that it could be better addressed by an **appropriate hydrological and biogeochemical conceptualization** of these systems

Future research lines

☐ Improve the **understanding** of the storage, transport and transformation of **ammonium**

- ➢ Collecting more data

☐ **Testing** the developed models in **other Mediterranean catchments** to understand the relevance of the important mechanisms highlighted in this work

- ➢ **SCARCE** Project, WP PROCESS: It will assess the effects of global changes in streams and rivers, and will evaluate effects of disturbances on nutrient cycling and metabolism of Mediterranean stream and rivers

☐ Uncertainty analysis of model's predictive capabilities

Thank you for your attention!

UNIVERSIDAD POLITECNICA DE VALENCIA

University of Reading

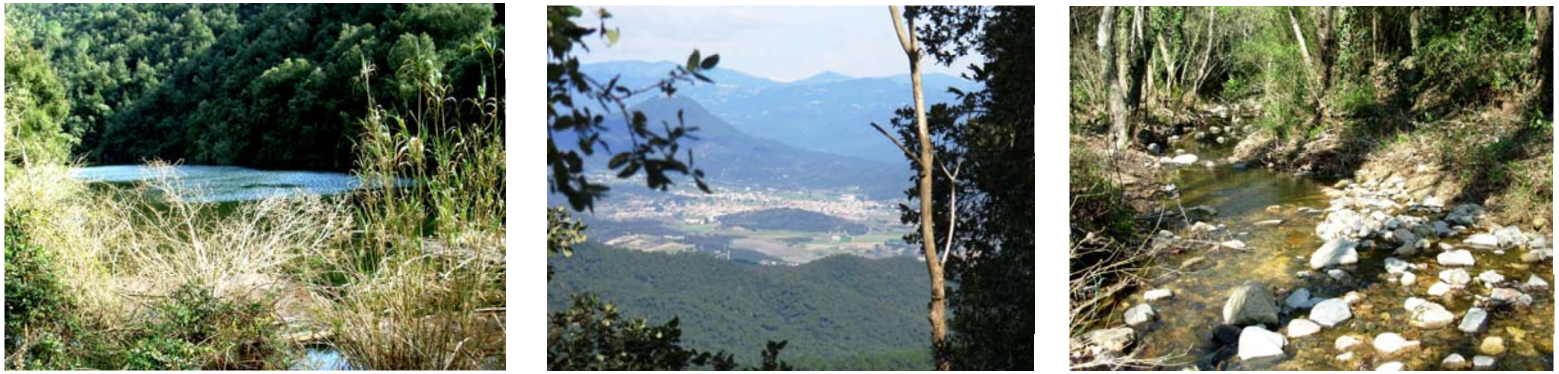
Doctorado en
Ingeniería del Agua
y Medioambiental

Progressive development of a hydrologic and inorganic nitrogen conceptual model to improve the understanding of small Mediterranean catchments behaviour

Chiara Medici

Supervisor: Prof. Félix Francés

Co-Supervisors: Dr Andrew J. Wade and Dr Miguel Martín



Valencia, 2nd of July 2010