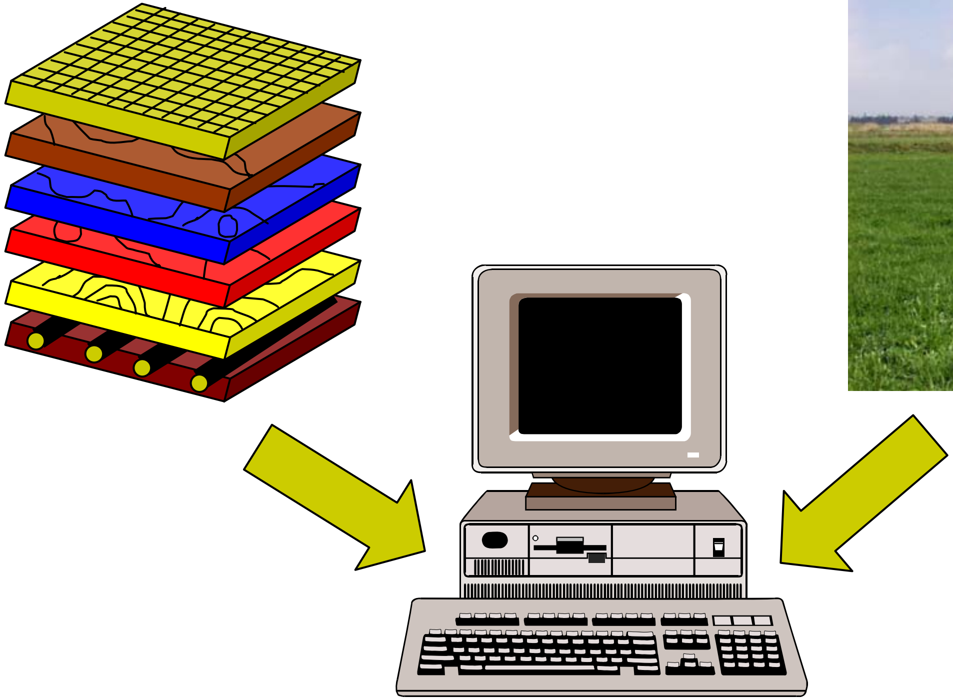
Simulation models to estimate N lost in irrigation return flows



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Introduction

- N inputs in irrigated areas depend upon the crops

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  In irrigated basins, models simulating N losses should include crop simulation models.

- Crop simulation models are made up of mathematical equations which calculate dynamically (f(time)) crop growth and development as well as changes in the environment (soil and water) where they grow.

Introduction

- Main difficulties in the use of models to estimate N losses at basin scale:

  - Limited number of crops that can be simulated.
  - Crop simulation has to be accurate (evapotranspiration, yield, N uptake).
  - Simulating N cycle involves different processes, some of which are biologically dependent.
  - Plot to basin scale integration:
    - Different processes can alter the N content in the soil water from the plot to the outflow point.
    - Simulation of groundwater.

Objectives

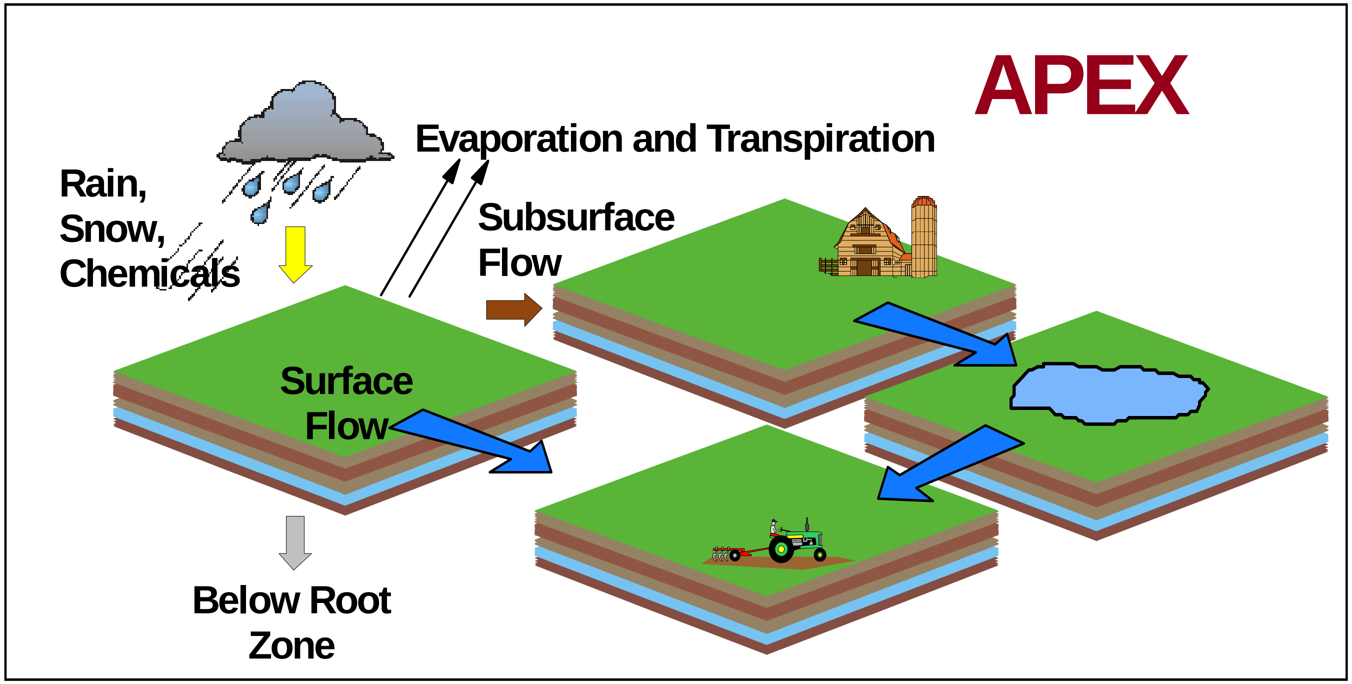
- Calibrate and validate a model that simulates N losses in irrigated basins.
- Study the effect of irrigation and fertilization improvements in reducing N losses in irrigated basins.

Basins studied

- La Violada (Spain):
  - 4,013 ha
  - 2005-2008.
- Akarsu (Turkey):
  - 10,900 ha
  - 2006-2009.
- Sidi Rached (Algeria):
  - 10,971 ha
  - 2006-2009.

APEX Model (Agricultural Policy/ Environmental Extender)

(USDA-ARS)



- The basin is divided up into homogeneous subareas regarding climate, soil and management (crop, irrigation, fertilization).

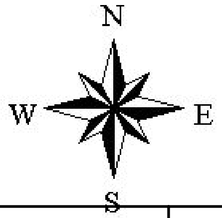
La Violada (Spain)

Hydrological years:
2005-2006, 2006-2007 and 2007-2008

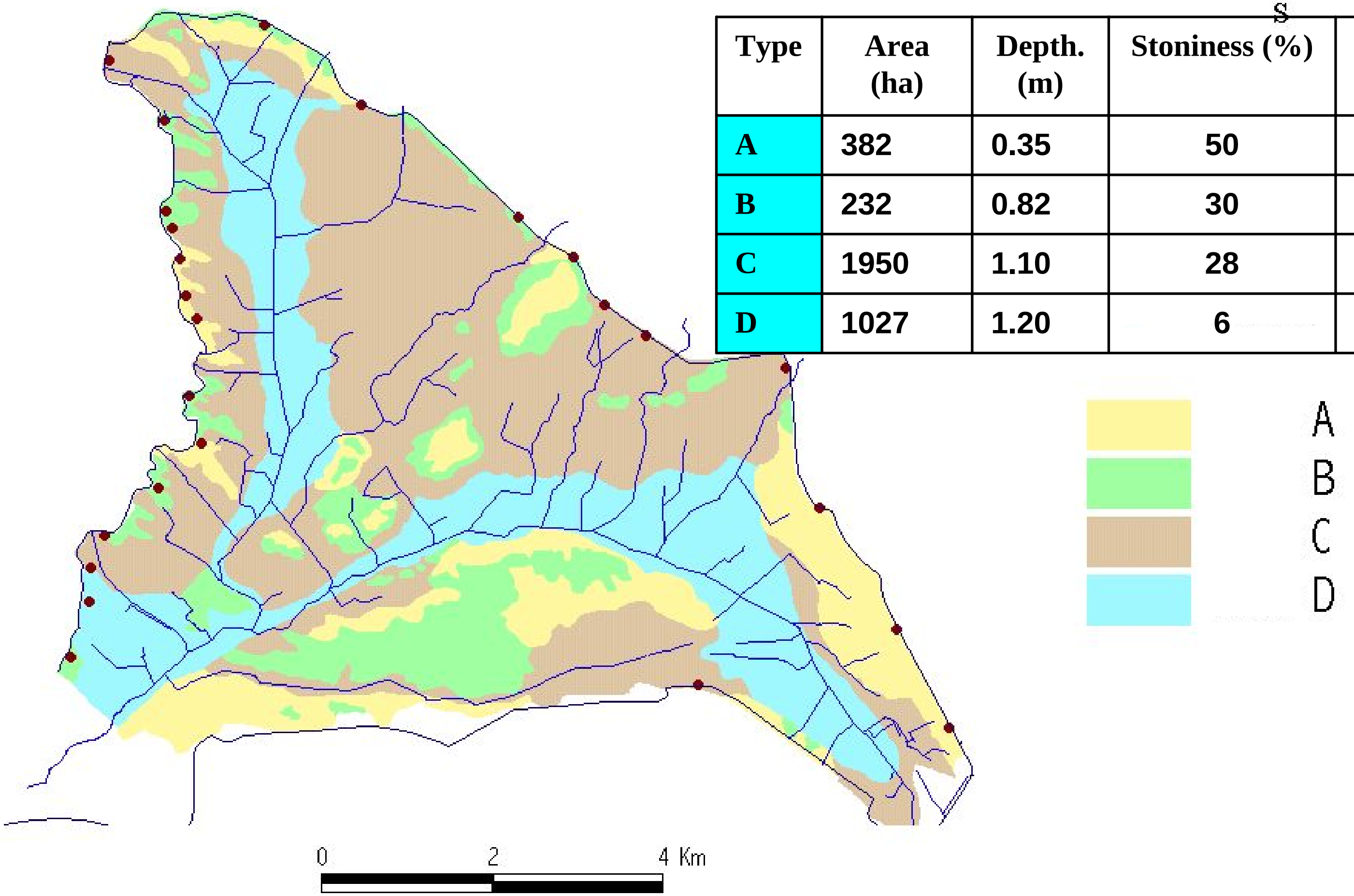
4013 ha

1 main outflow

Soil types



Type	Area (ha)	Depth. (m)	Stoniness (%)	CC (m/m)	PM (m/m)
A	382	0.35	50	0.070	0.042
B	232	0.82	30	0.144	0.056
C	1950	1.10	28	0.242	0.094
D	1027	1.20	6	0.308	0.189

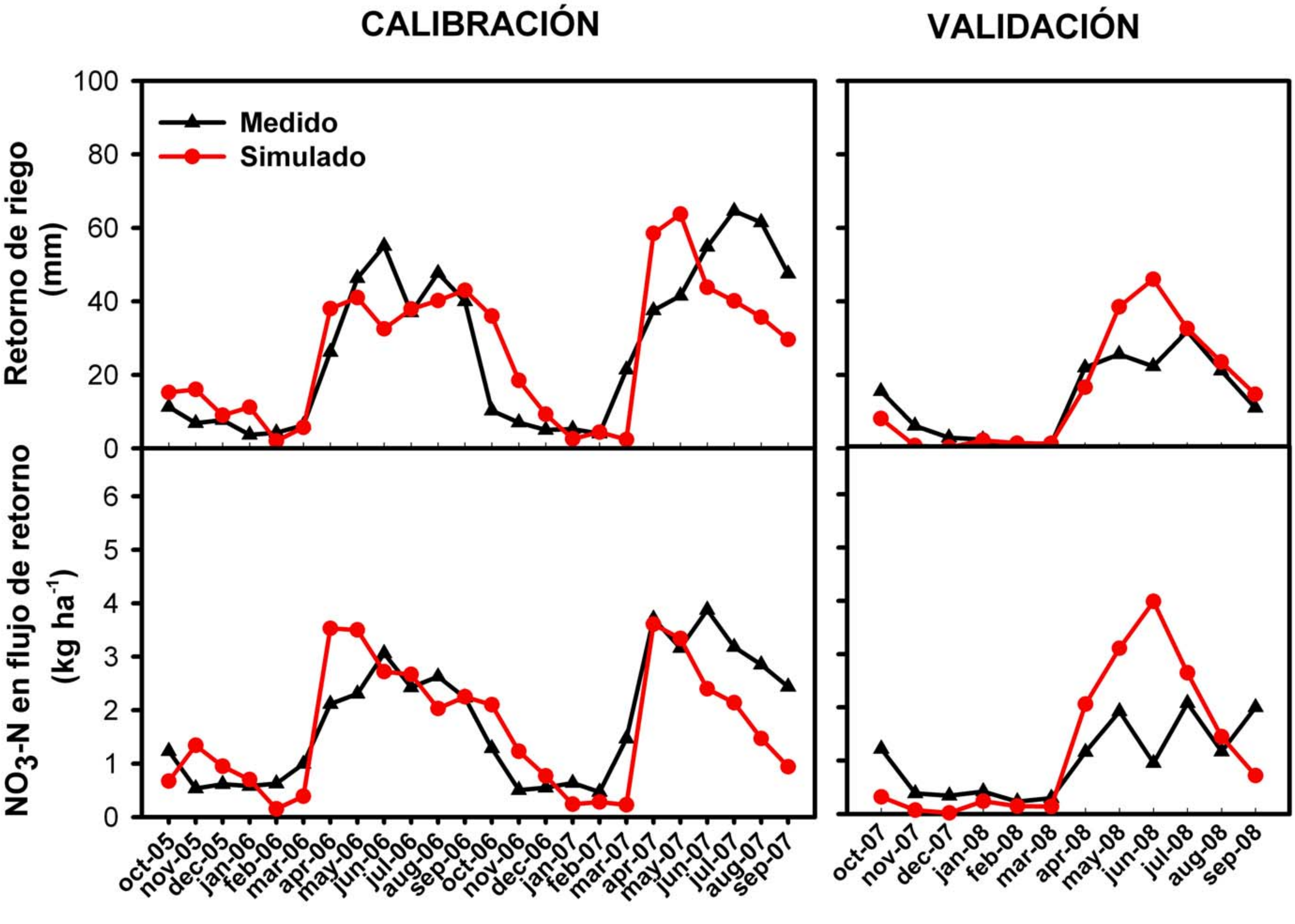


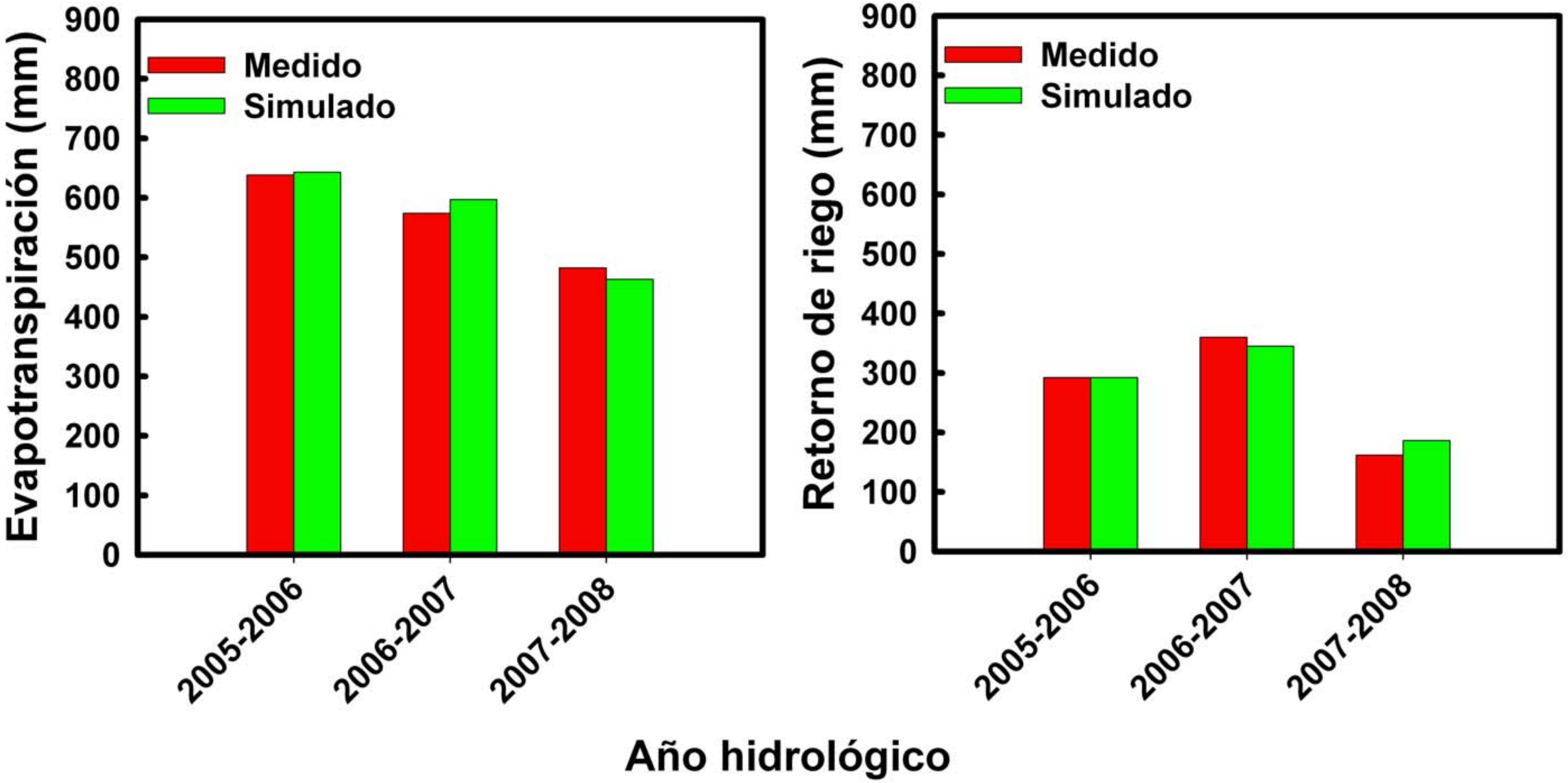
- Evolution of crops in La Violada

Crop	Surface area (ha)		
	2006	2007	2008
Alfalfa	1820	1517	935
Rice	37	11	0
Barley	1153	1622	789
Sunflower	57	19	39
Maize	329	270	78
Raygras	92	92	121
Wheat	149	149	135
Horticultural c.	37	37	0
No crop	251	207	1859

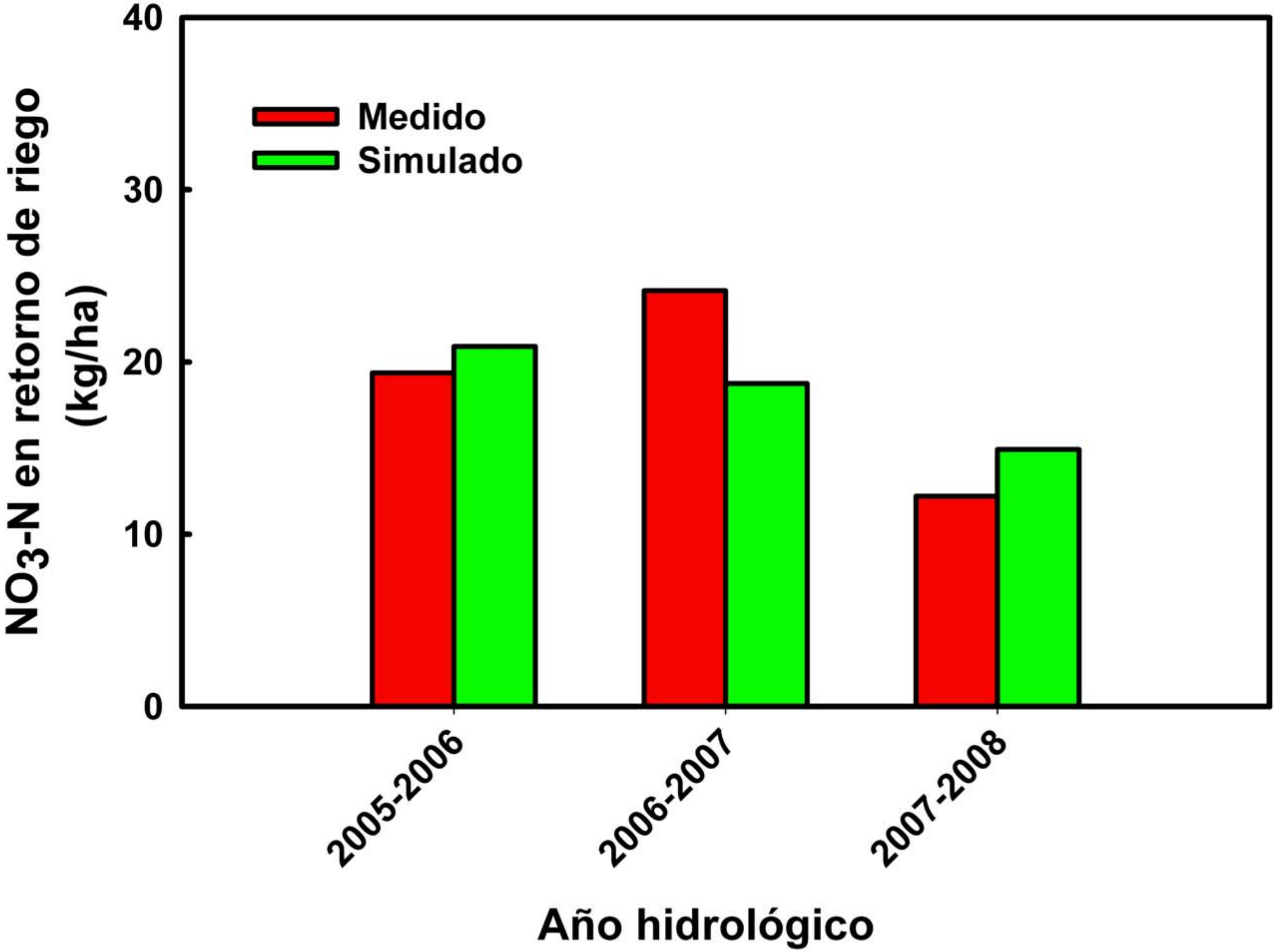
- Simulation methodology:
  - Only general information available about the crops:
    - One single N fertilization for each crop is considered.
    - Surface irrigation: irrigation applied to each crop depends on the soil.
  - Subareas defined for the soil type (irrigation) – crop type combinations.
  - The real location of subareas is not considered.

CALIBRATION - VALIDATION


CALIBRACIÓN
VALIDACIÓN
Medido
Simulado
Retorno de riego (mm)
NO_3-N en flujo de retorno (kg ha^{-1})
0
20
40
60
80
100
0
1
2
3
4
5
6
oct-05
nov-05
dec-05
jan-06
feb-06
mar-06
apr-06
may-06
jun-06
jul-06
aug-06
sep-06
oct-06
nov-06
dec-06
jan-07
feb-07
mar-07
apr-07
may-07
jun-07
jul-07
aug-07
sep-07
oct-07
nov-07
dec-07
jan-08
feb-08
mar-08
apr-08
may-08
jun-08
jul-08
aug-08
sep-08

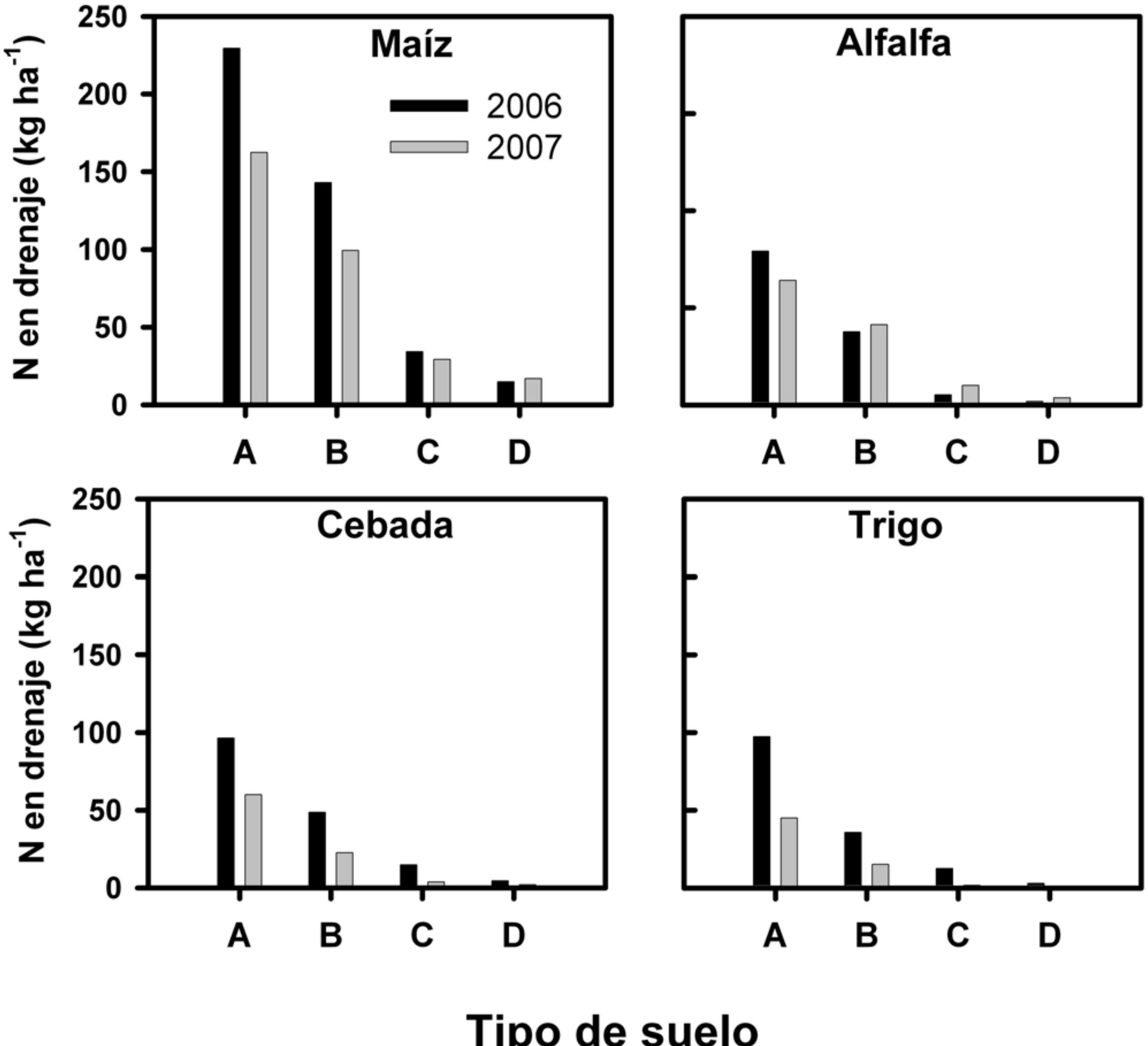


Evapotranspiración (mm)
900
800
700
600
500
400
300
200
100
0
Medido
Simulado
2005-2006
2006-2007
2007-2008
Retorno de riego (mm)
Año hidrológico



40
30
20
10
0
Medido
Simulado
NO3-N en retorno de riego (kg/ha)
2005-2006
2006-2007
2007-2008
Año hidrológico

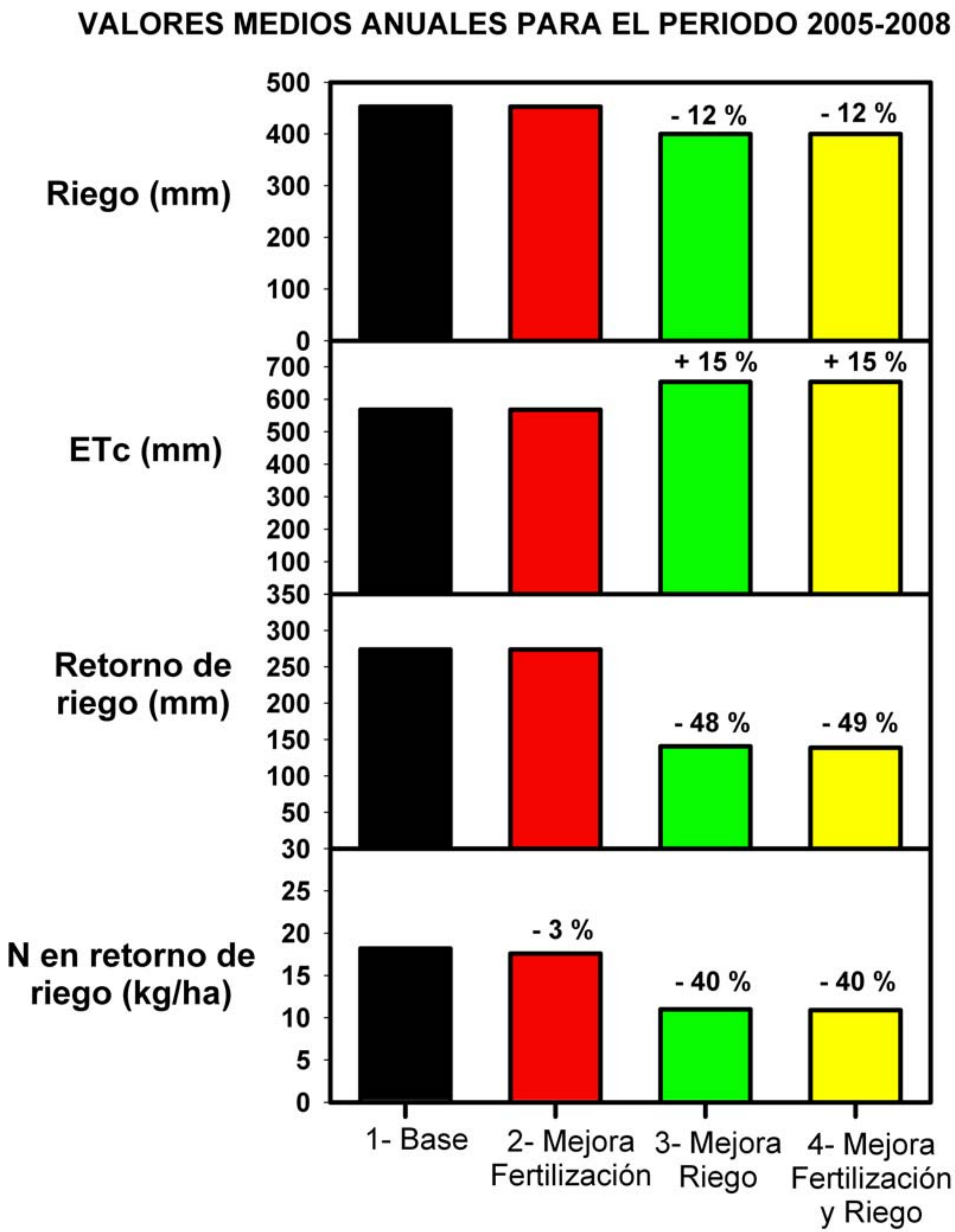
Simulation of Nitrogen lost in drainage water according to crop and soil



Can irrigation and fertilization improvements reduce N losses in La Violada?

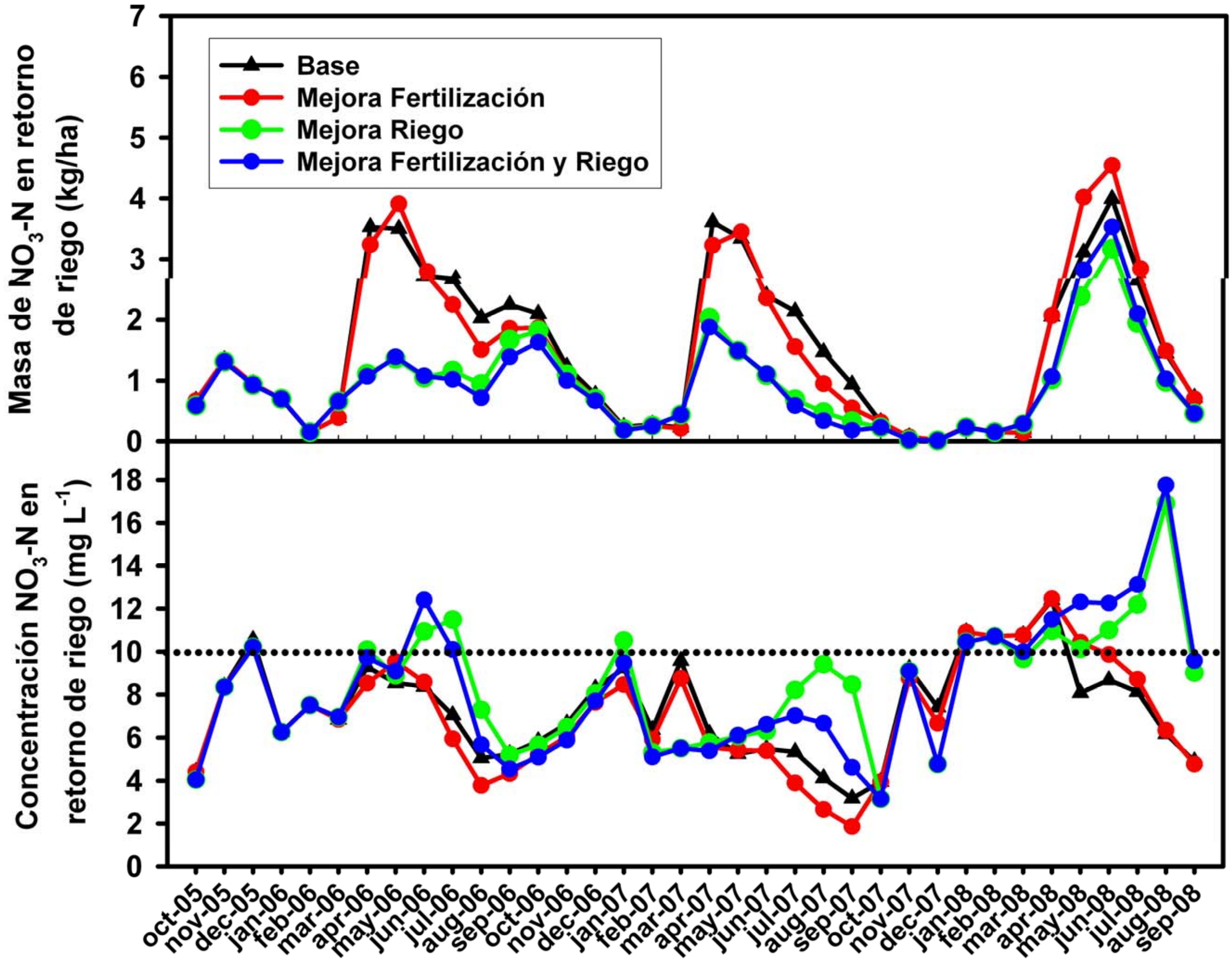
- **Simulation scenarios:**
  - **1- Base-line: irrigation and N fertilization as applied by farmers.**
  - **2- Improved N Fertilization:**
    - **Dose “reduction” (maize and alfalfa).**
    - **Increase in partitioning (maize and winter cereal).**
  - **3- Improved irrigation:**
    - **Sprinkler irrigation: independent from soil type.**
    - **Application of 1-2 irrigations per week according to crop requeriments.**
  - **4- Improved N Fertilization and Irrigation.**

	Applied N (kg/ha)			
	2005-2006	**2006-2007**	**2007-2008**	**Fertilization improvement**
Alfalfa	78	99	40	**0**
Barley	111	108	78	**135**
Maize	302	324	267	**250**
Pepper	188	188		**150**
Raygras	98	202	92	**170**
Sunflower	71	71	32	**90**
Wheat	111	108	78	**135**


VALORES MEDIOS ANUALES PARA EL PERIODO 2005-2008
Riego (mm)
ETc (mm)
Retorno de riego (mm)
N en retorno de riego (kg/ha)
- 12 %
- 12 %
+ 15 %
+ 15 %
- 48 %
- 49 %
- 3 %
- 40 %
- 40 %
1- Base
2- Mejora Fertilización
3- Mejora Riego
4- Mejora Fertilización y Riego

	Annual loss of N (kg/ha)				
Scenario	**Alfalfa**	**Barley**	**Maize**	**Sunflower**	**Wheat**
1-Base-line	**16**	**16**	**67**	**27**	**15**
2- Improved Fertilization	**8**	**22**	**60**	**31**	**19**
3- Improved irrigation	**7**	**10**	**30**	**12**	**9**
4- Improved Fertilization and Irrigation	**3**	**13**	**27**	**13**	**11**

	Mean annual yield (t/ha)				
Scenario	Alfalfa	Barley	Maize	Sunflower	Wheat
1-Base-line	12.2	5.8	12.3	3.3	6.6
2-Improved Fertilization	12.2	5.9	12.3	3.4	6.8
3- Improved Irrigation	14.5	6.4	14.2	4.2	7.7
4- Improved Fertilization and Irrigation	14.5	6.4	14.2	4.6	7.9



Base
Mejora Fertilización
Mejora Riego
Mejora Fertilización y Riego
Masa de NO3-N en retorno de riego (kg/ha)
Concentración NO3-N en retorno de riego (mg L-1)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14
16
18
oct-05
nov-05
dec-05
jan-06
feb-06
mar-06
apr-06
may-06
jun-06
jul-06
aug-06
sep-06
oct-06
nov-06
dec-06
jan-07
feb-07
mar-07
apr-07
may-07
jun-07
jul-07
aug-07
sep-07
oct-07
nov-07
dec-07
jan-08
feb-08
mar-08
apr-08
may-08
jun-08
jul-08
aug-08
sep-08

	Mean annual concentration of NO_3-N in return water (mg/L)		
Scenario	**2005-2006**	**2006-2007**	**2007-2008**
1-Base-line	**7.16**	**5.44**	**8.02**
2-Improved Fertilization	**6.77**	**4.79**	**8.92**
3- Improved Irrigation	**7.59**	**6.36**	**10.59**
4- Improved Fertilization and Irrigation	**7.32**	**5.88**	**11.73**

CONCLUSIONS

- **The APEX model has been calibrated and validated for La Violada basin.**
  - **The model simulated adequately mean annual values, the largest differences being between mean and simulation values in monthly data.**
  - **Discrepancy between mean and simulation values was less than 4% for evapotranspiration.**
  - **Regarding irrigation returns, discrepancy was less than 15%.**
  - **N loss was overestimated in the validation by 25%, although in absolute terms discrepancy was less than 3 kg/ha.**

- **The analysis of different scenarios indicates that:**
  - **Improvements in N fertilization will only reduce N lost in irrigation returns by 3%.**
  - **Improvements in irrigation (switch to sprinkler irrigation) may decrease N losses by 40%, due to a 49% reduction in return flows.**
  - **Improvements in irrigation and fertilization may have helped to use 12% less irrigation water and increase evapotranspiration by 15%, resulting in increased yield of alfalfa (+18%), barley (+9%), maize (+15%), sunflower (+30%) and wheat (15%).**

- **Although irrigation and N fertilization improvements may reduce by 40% N mass exported to irrigation returns, NO_3-N concentration will increase.**

- **In the study period (2005-2008) the 10 mg/L NO_3-N threshold was only exceeded during 4 months under the base-line scenario. However, when improving irrigation the threshold was exceeded for 11 months.**

- **European environmental regulations concerning nitrate pollution of waters generally refer to maximum allowable concentrations. However, it is the exported N mass per surface unit what should be taken into account to assess the polluting effect of irrigated areas on rivers (as is the case in the US).**