Open Workshop
ICT tools for innovating Groundwater Management in a changing world

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IDAEA. CID - CSIC

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Implementing Nitrates Directive: A FREEWAT-based simulation of Action Program reliability

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EIP Water Online Market Place
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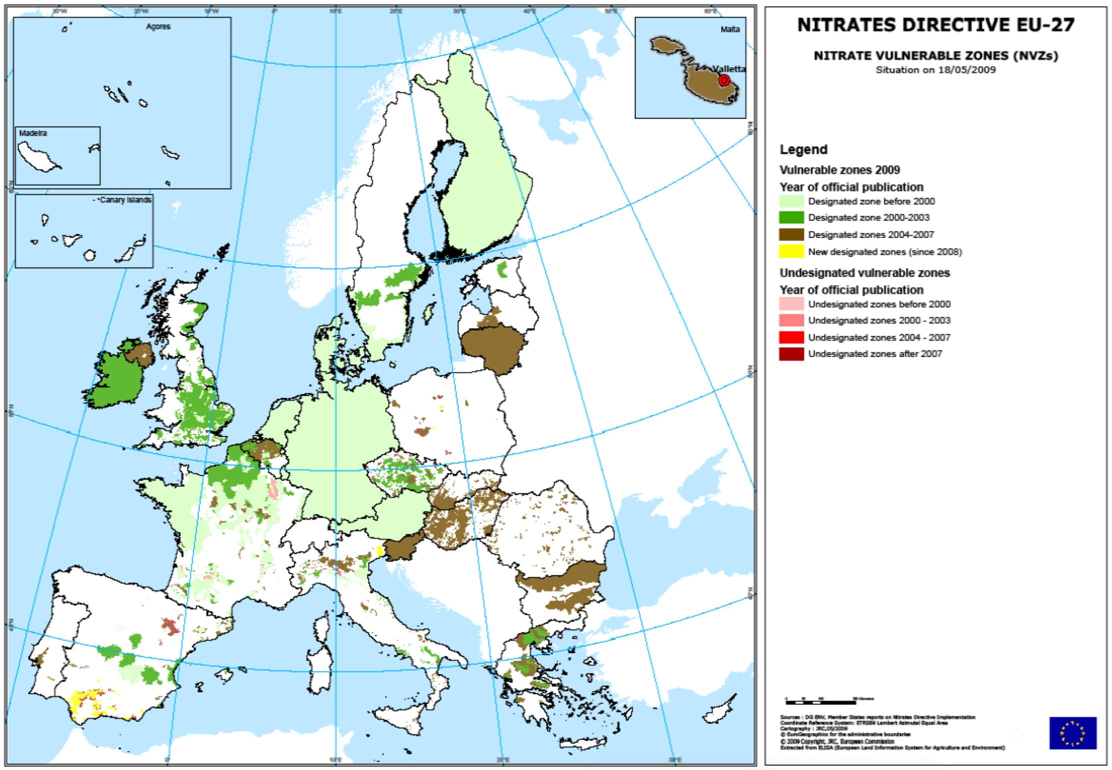
MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

Taken from: http://travessa-pirineus.blogspot.com.es/2014/08/dia-15-de-lospitalet-al-refugi-de-juclar.html

The EU Nitrates Directive (ND)

The EU Nitrates Directive (1991) aims to prevent nitrates from agricultural sources polluting ground and surface waters and to promote the use of good farming practices.



The ND forces member states to develop action programmes, aimed to prevent, monitor, minimize and ameliorate the nitrates pollution in water.

The member states have to monitor the water status, design Nitrate Vulnerable Zones (NVZs) and review the effectiveness of action programs, reporting to the EU Commission every 4 years.

The ND CoGAP and Action Programs

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Nitrates in infiltrated water can be due to fertilization and irrigation, as well as uncontrolled manure and adverse climatology.

Nitrate Vulnerable Zones are linked not only to intensive farming areas, but also to locations where soil types and hydrology boost nitrate leaching.

As a condition to receive the direct aids of the EU Common Agricultural Policy (CAP), farmers located in Nitrates Vulnerable Zones must follow the “Code of Good Agricultural Practices (CoGAP)” and the measures included in the Action Programs, as part of the CAP “cross-compliance”. The CoGAP and the Action Programs regulate fertilization, irrigation and manure control. All EU MS have developed CoGAP and Action Programs.

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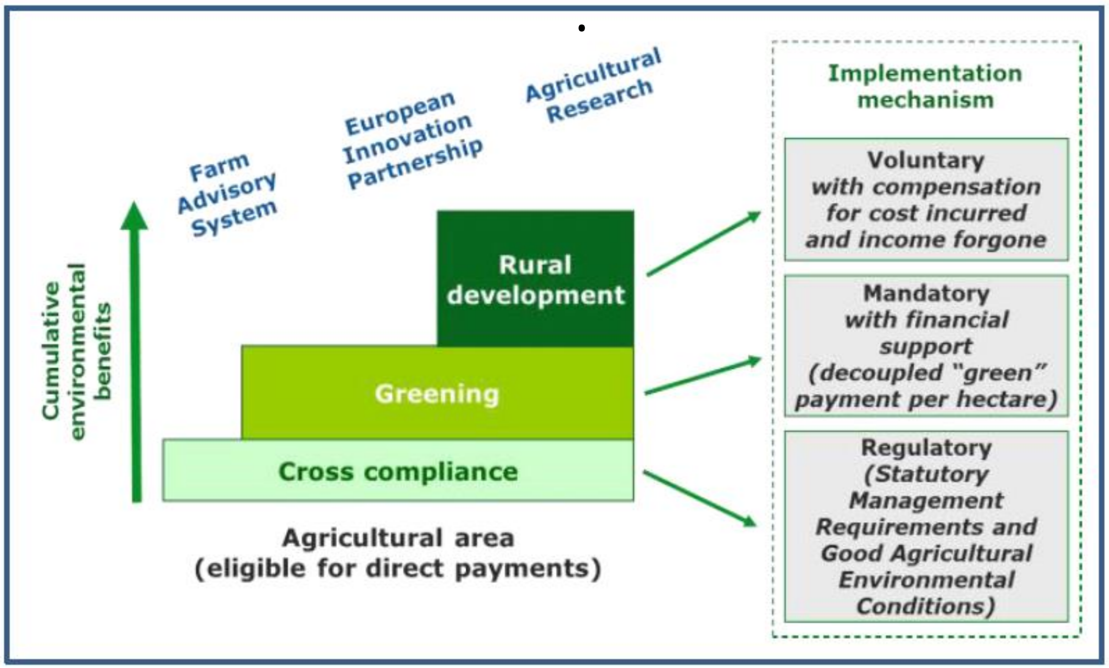
CAP Reform (2013) and WFD

CAP and WFD show important gaps, according to an audit report of the EU Court of Auditors.

The Court suggests to dedicate CAP budget to fund activities related to WFD and its goals.



Accordingly, the new CAP Reform (2013) strengths the cross-compliance, the Good Practices Codes and the environmental role of agriculture.

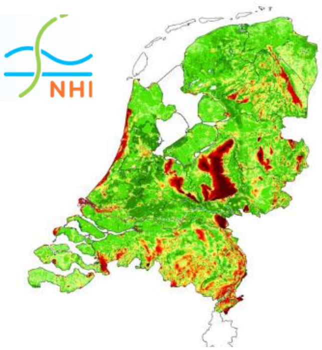
At least 30% of the Rural Development Funds (RDF) must be addressed to support environmental measures, including enhanced water protection*.

Furthermore, RDF will support "Pilot Demonstrations" through "Operational Groups", in the framework of EIP for agricultural productivity and sustainability*.

* REGULATION (EU) 1305/2013

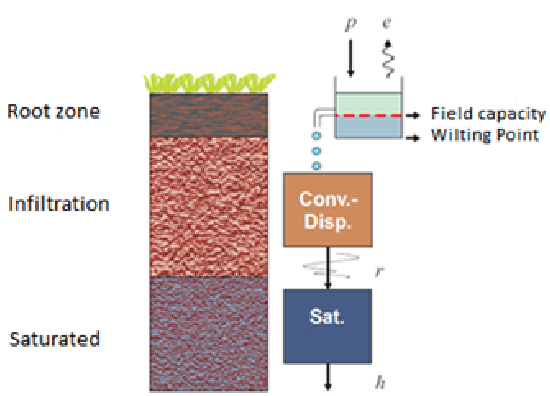
Simulating groundwater recharge from the soil unsaturated zone

Actually, it is very difficult to estimate the actual nitrate leaching due to a specific fertilizer and irrigation management in a land area. However, some computer-based models have been developed in the last years to simulate this process.



Unsaturated Zone (SWAP)

$$\frac{\partial}{\partial z}\left[K(\vartheta)\frac{\partial h}{\partial z}\right]=\frac{\partial \vartheta}{\partial t}$$

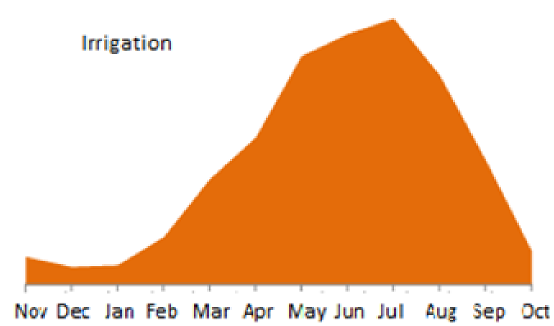


Discretization

- time: daily
- spatial: CAP plots
- 1D

Saturated Zone (MODFLOW)

$$\mathbf{q} = -\mathbf{K} \cdot \nabla(h(x, y, z))$$



Discretization

- time: monthly
- spatial: 100 m grids
- 3D

One of the most important applications of such modelling approach is the Netherlands Hydrologic Instrument (NHI), combining the SWAP model with Modflow.

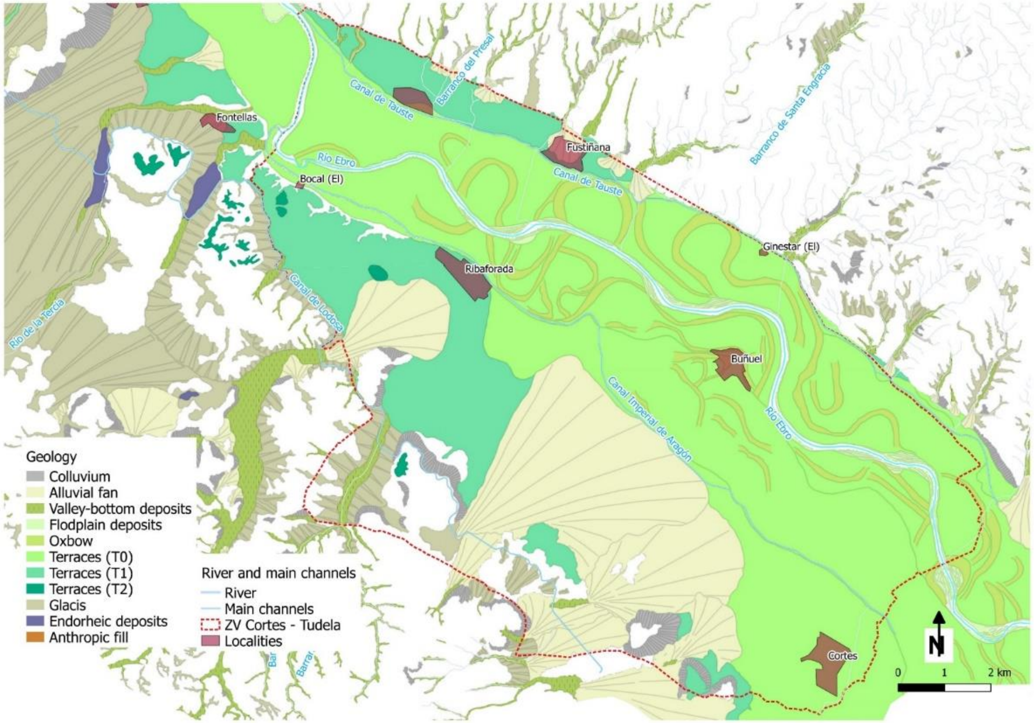
The FREEWAT case study

We aim to simulate nitrate pollution of waters in a Nitrate Vulnerable Zone (NVZ), due to agricultural practices. Furthermore, we aimed to evaluate the effects of potential measures simulating several “scenarios”, related to CoGAP and Action Program.

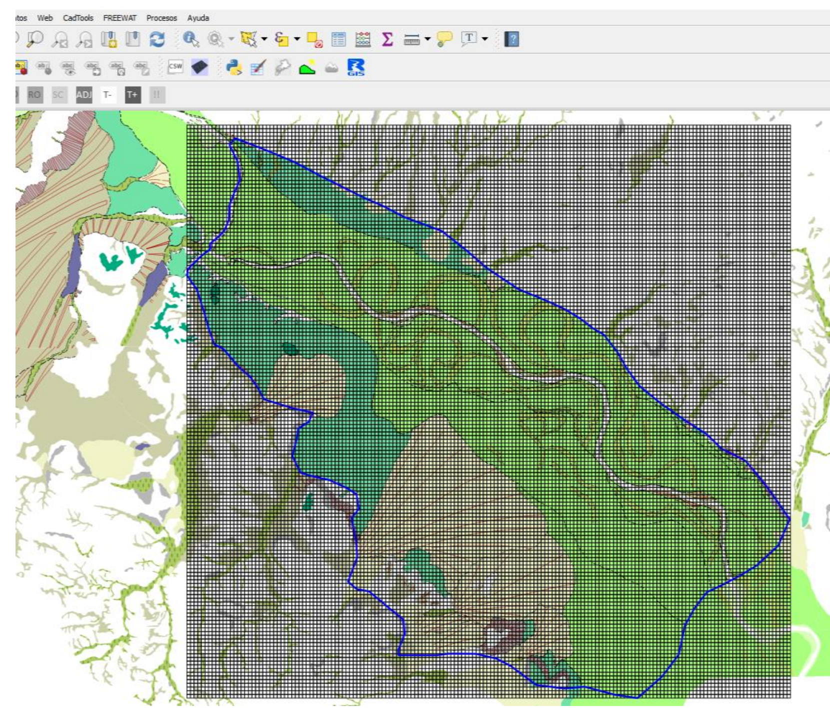
The case study was conducted in the Tudela-Cortes NVZ, in Navarra, Spain.
In order to mimic actual CAP data and diverse field conditions, we conducted a pre-processing using the model SWAP, estimating nitrate leaching from each farm.

The simulated baseline scenario is “business as usual”. Second scenario was total agriculture abandonment. Third was a fertilization reduction and the fourth assumed irrigation transformations, from flood to sprinkler, as well as an improvement of irrigation efficiency.

Hydrogeology and conceptual model

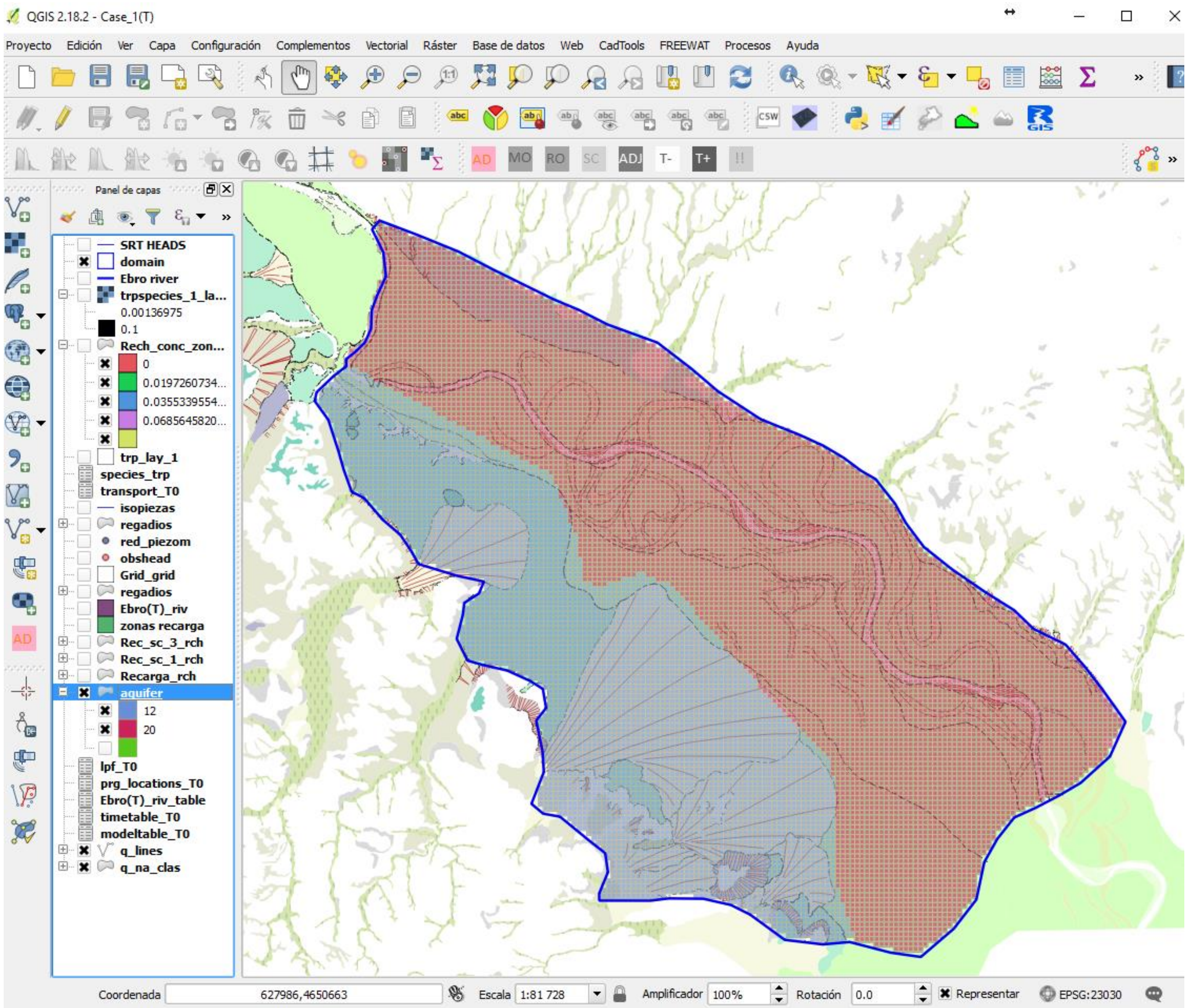


The conceptual model includes aquifer delimitation and geometry, spatial discretization, hydrodynamic parameters, boundary conditions and extractions. The aquifer boundaries are closed at north and south. The SE is considered an open border, with an underground alluvial flow downstream.



The model has 25885 cells, of which 12470 are active cells. Up to 48 stress periods have been defined (one for each month of simulation).

Hydrodynamic parameters



Hydrodynamic parameter data are available at 10 control points.

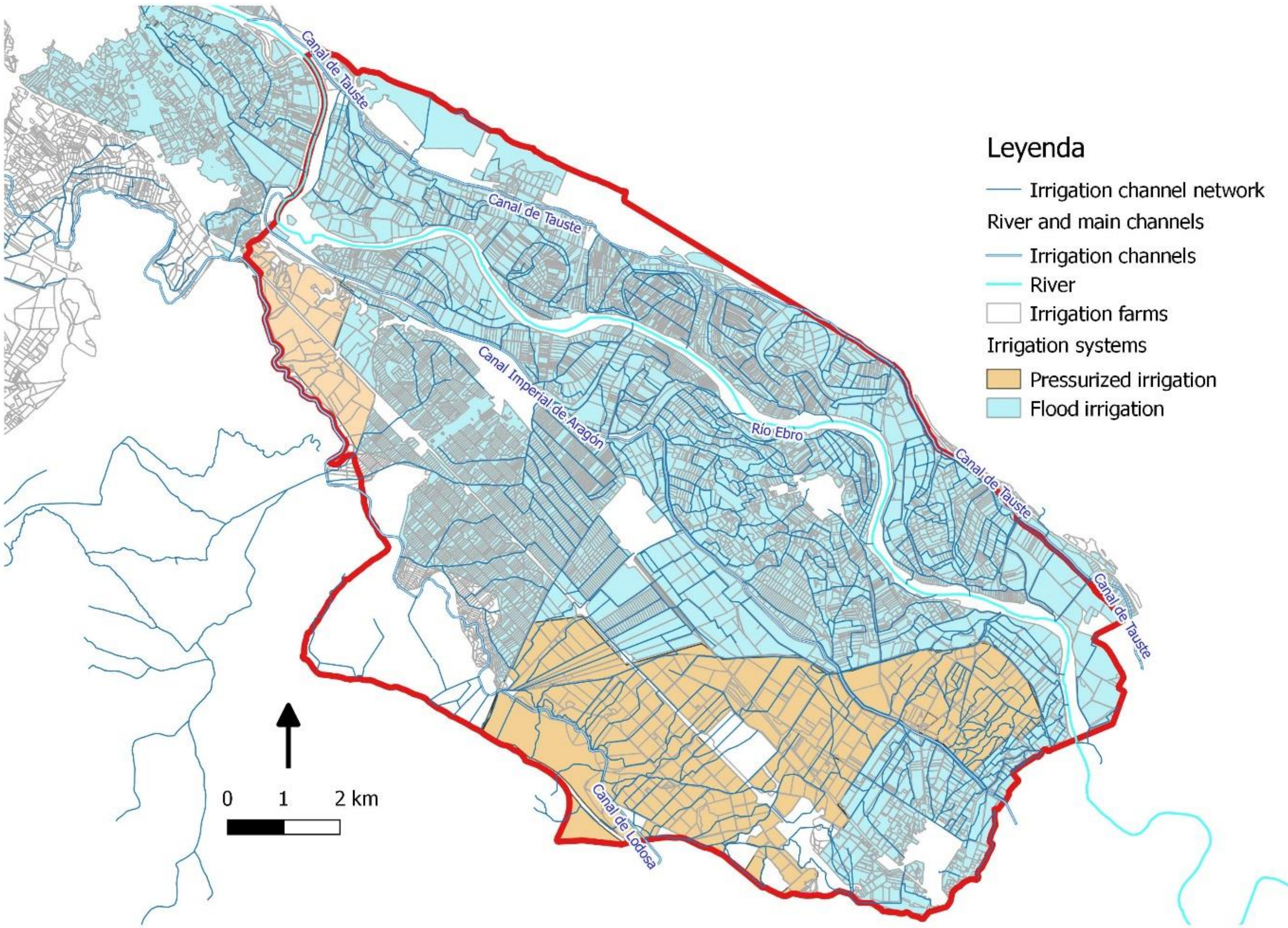
Two clearly differentiated terraces were identified. Permeability and specific yield properties have been attributed to each terrace, based on the information available in pumping tests

Land uses

More than 70 different crops are cultivated in the NVZ area. Fertilization and irrigation management depend on the crop and on the particular farmer conditions.

Small-size farms mean a significant percent of total irrigation and fertilization.

Water uses



Irrigation is performed through a dense network of canals and ditches that cover the entire area.

Pumping water from wells is irrelevant.

Most of the irrigation systems are low efficiency surface, generally in very small farms (less than 1 ha).

Sprinkler irrigation can be found in some areas, with plans to enlarge this area in the future.

Head simulation and Model calibration

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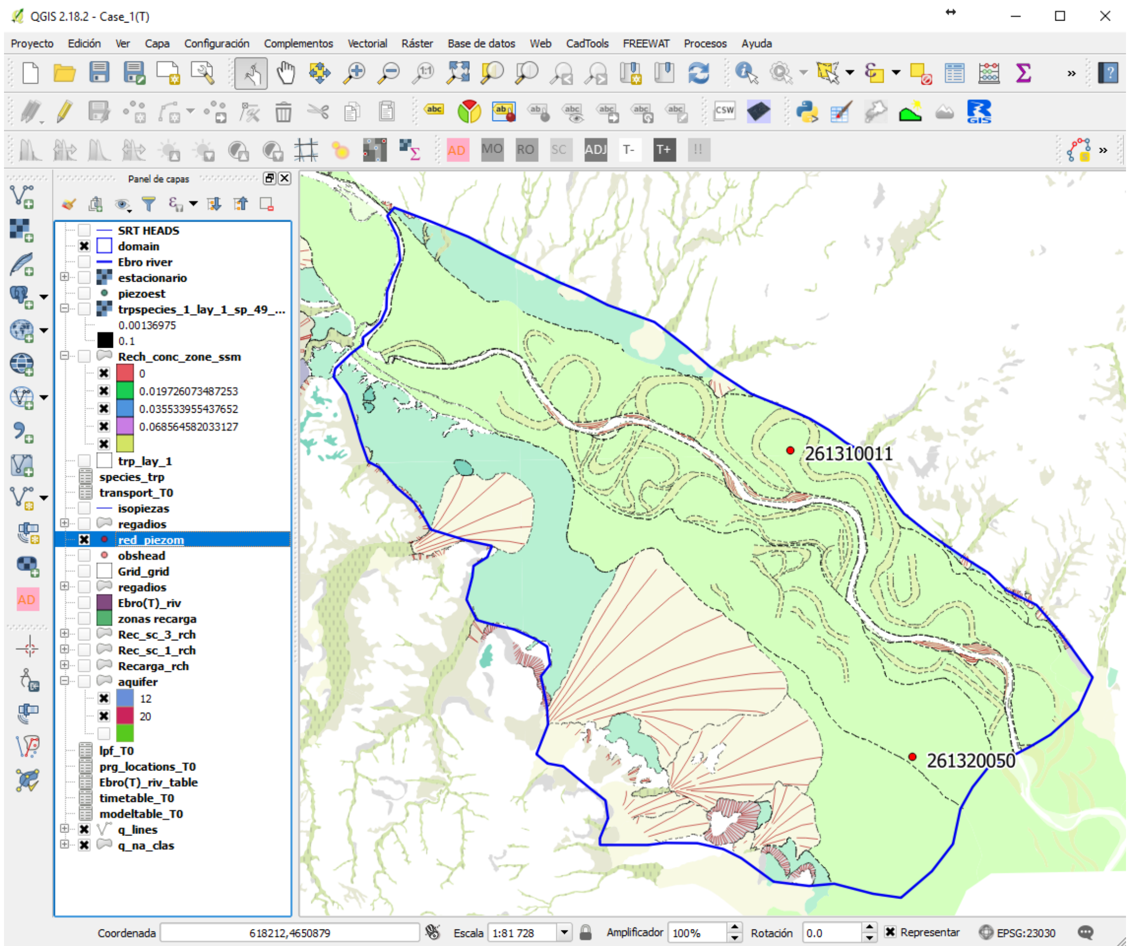
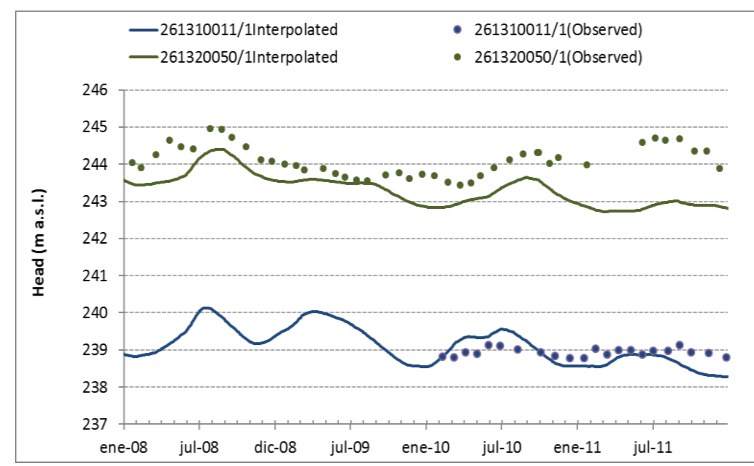
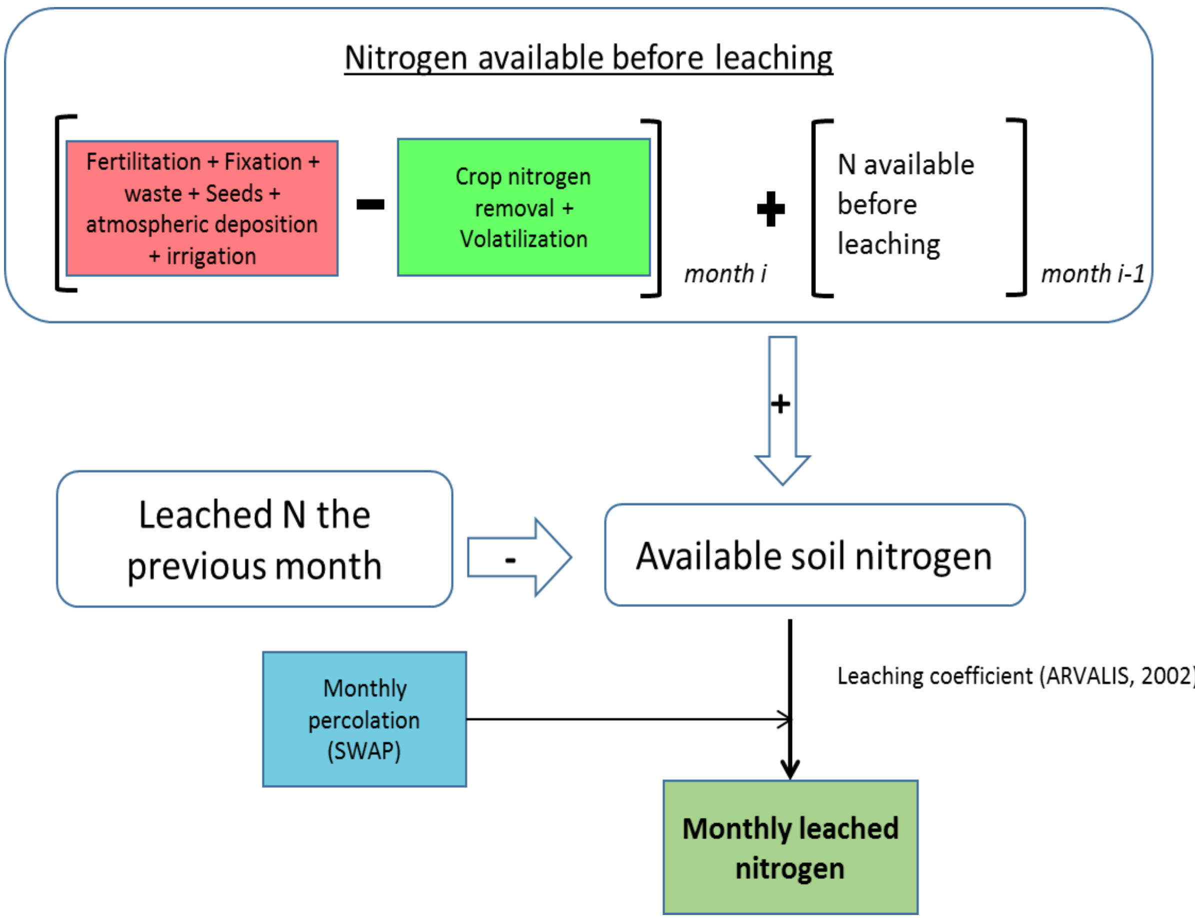


There are two piezometric control points in this area, both in lower terrace.

The adjustment can be considered good: mean square error is low, 1.3%, and the correlation coefficient is 0.99. Both indicators of a good fit



Simulating nitrogen leaching



The estimations of leaching nitrogen from the unsaturated zone came from SWAP simulations of each-farm water percolation and nitrogen balance taking into account fertilization management and leaching coefficient.

Monthly leached nitrogen (mg/l)
$$\frac{\sum_1^n lix_{i,m}}{\sum_1^n S_i} \cdot 100/Inf_m$$

n – number of parcels in the recharge area

Si – surface of parcel i (ha)

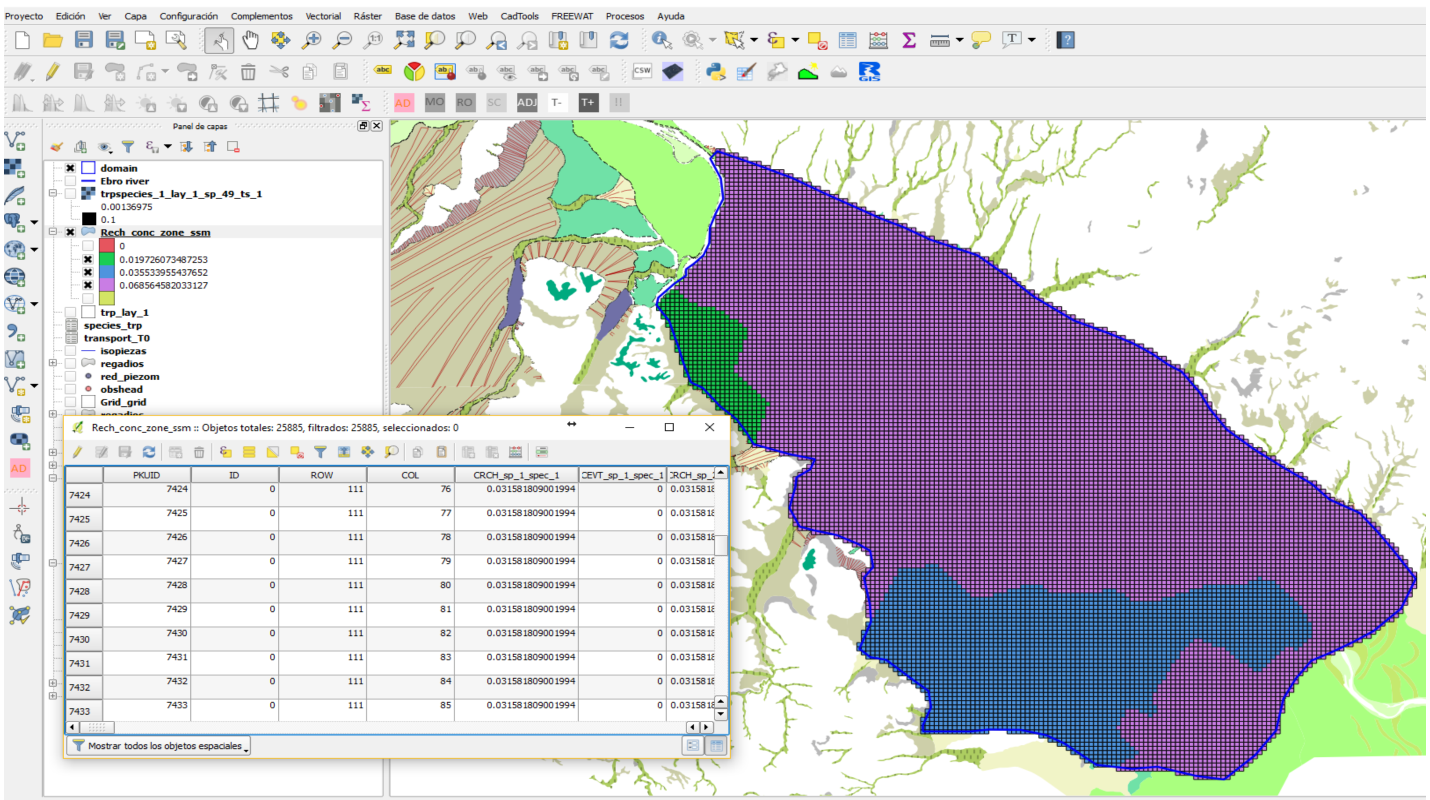
lxi – N leached (kg) in parcel i, month m

Infm – recharge (mm) month m

Nitrate leaching input in FREEWAT

The tables implemented in FREEWAT, with water recharge and nitrogen leaching simulated with SWAP for the four considered scenarios are:

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Recharge	Recarga_rch	Rec_sc_1_rch	Recarga_rch	Rec_sc_3_rch
Leaching	Rech_conc_zone_ssm	Rech_conc_zone1_ssm	Rech_conc_zone2_ssm	Rech_conc_zone2_ssm



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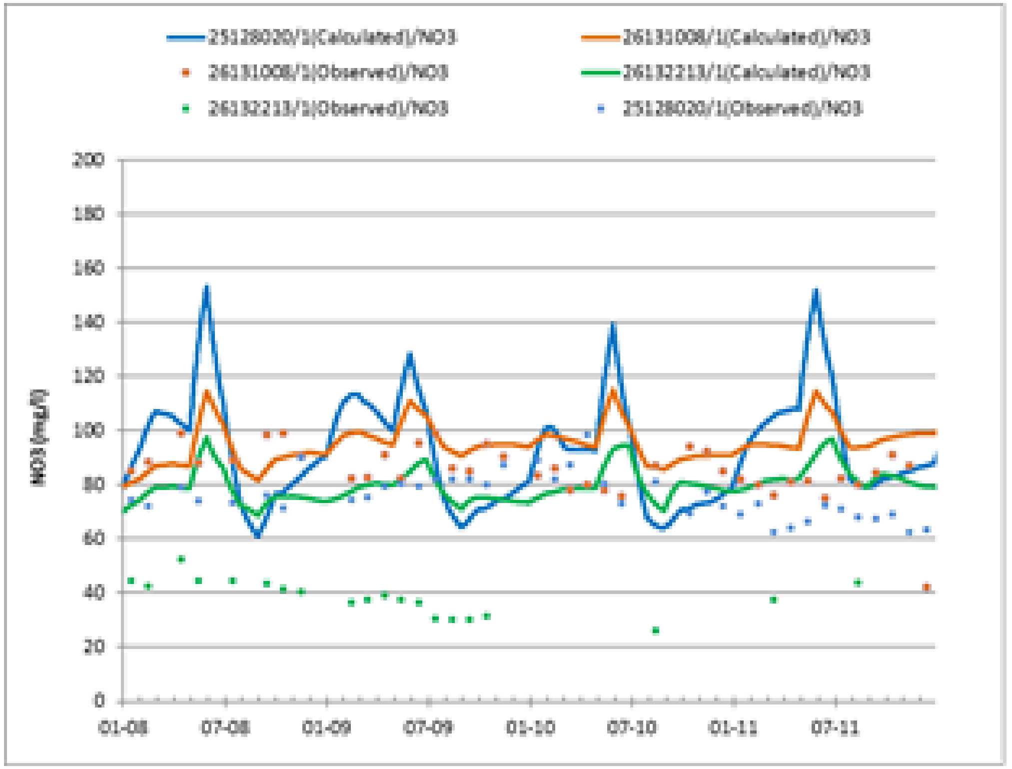
United Nations Educational, Scientific and Cultural Organization
International Hydrological Programme

Calibrating and validating

A sensitivity analysis of the effects of the nitrate leaching coefficient on nitrate leaching results was conducted. Results were compared with the actual measurements of nitrogen exported, according to calculations conducted by Government of Navarra.

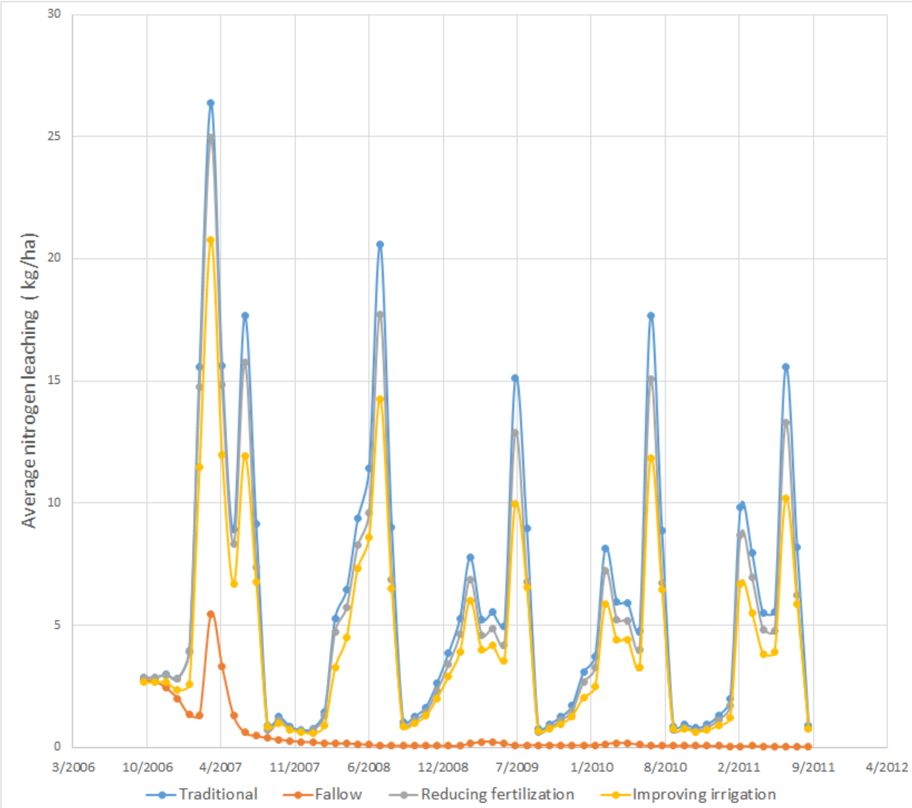
Balance area	Balance N Ebro (kg N/ha)	Simulation SWAP (Kg N/ha) Leaching coefficient				
		0,3	0,6	0,75	0,8	0,97
Alluvial Arga Aragón	76	57,12	82,77	91,96	94,75	103,41
Alluvial Ebro Castejón - Cortes	100	59,84	85,75	94,92	97,79	107,58
Alluvial Viana - Castejón	43	26,52	39,55	44,56	46,13	51,21



Simulation results were compared with nitrogen content measurements in the control network.
A reasonable agreement is reached between the mean values observed and those obtained by the model.

Results are similar to those obtained previously.
The approach can be considered valid, although it needs to be improved.

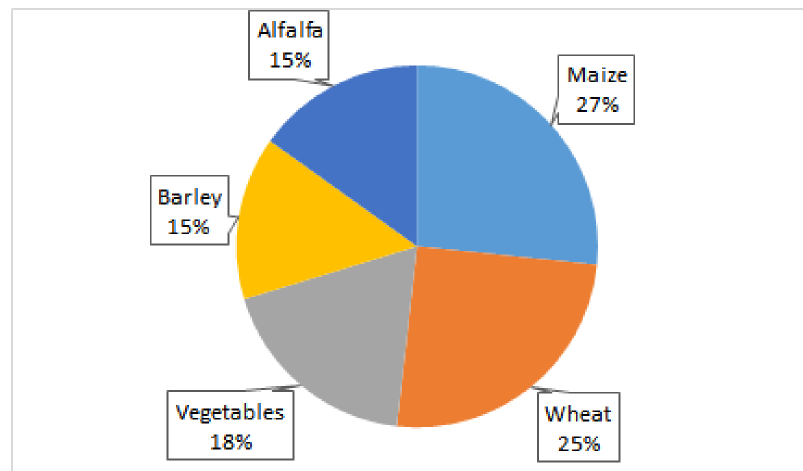
Simulated scenarios



Fallow is the only effective way to avoid nitrogen leaching. However, there is still some nitrogen remaining and leaching risks might be important due to rain and runoff.

Improving irrigation efficiency and reducing water tables seems to be the most effective way to diminish nitrogen leaching.

Weather variability is an important (and uncontrolled) source of nitrate leaching.



Maize and Winter cereals are the most important contributors to the leached nitrogen. Vegetables contributes with 18% of the total leached nitrogen, although they mean less than 10% of the cropped area.

Differences between scenario 1 (fallow) and traditional practices (scenario 0)

Future business-oriented actions

- **EIP-AGRI** "Improving irrigation systems in North Aragon": Saving water, energy and fertilizers while reducing nitrogen leaching. Meeting CAP cross-compliance. Funded agro-environmental measures. (EIP-SPAIN, EIP-EU).
- **Tailoring ND Implementation**: Adapted evaluations of Action Programs. Extending FREEWAT (SWAP, DSSAT, SWAT). Improving nitrogen leaching simulation (LIFE, INTERREG).
- **Climate impact assessments**: Combining climate scenarios, weather generators and FREEWAT models to provide evaluations of Climate-Change impacts in new WFD Hydrological plans, as well as in the required Environmental Impact Assessment of any new EU-funded large project*. (www.climarisk.com)
- **Capacity building**: Tailored courses of FREEWAT as an open-source platform linking water models with spatial analysis tools. (www.water-models.com)

* Council Directive 2014/52/EU