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Hydroeconomic modeling for assessing water scarcity and pollution abatement measures in the Ebro River Basin, Spain

What we do: Social Costs and Benefits of Pollution Abatement Policies at Basin Level

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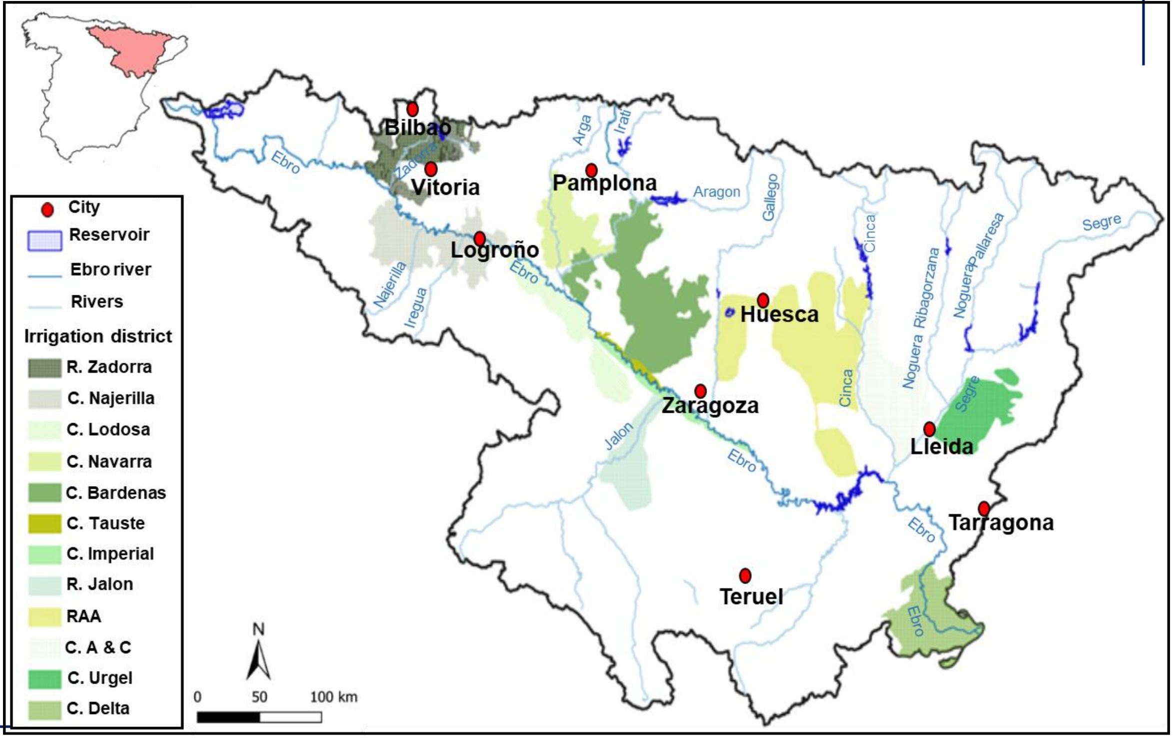
Introduction

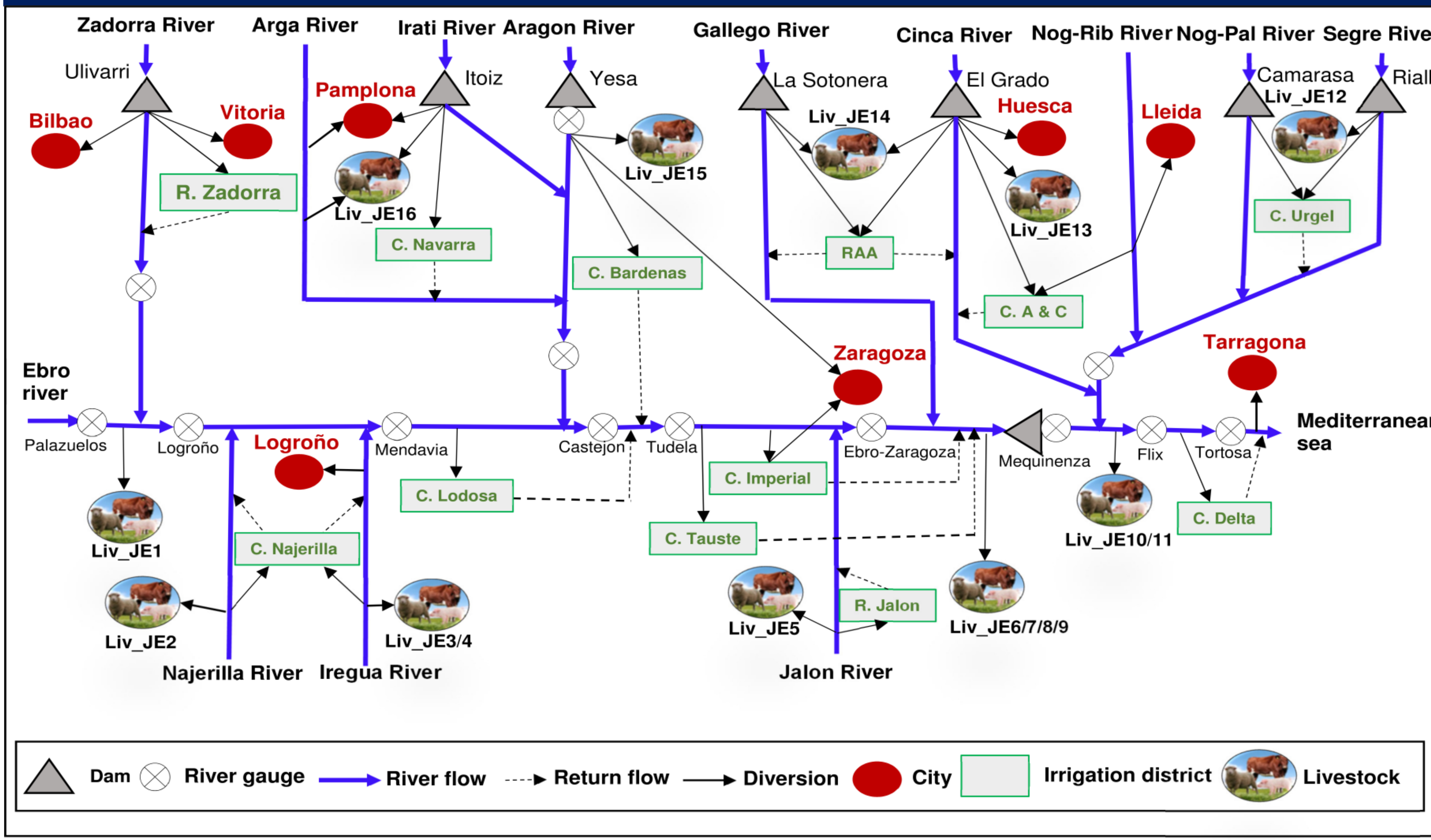
Climate change and agricultural nonpoint pollution are global problems that impact all regions and river basins in the world. There are severe water scarcity and quality degradation problems in Spanish basins which are under strong anthropic pressures.
This study analyzes the Ebro River Basin in northeastern Spain, which is under mounting scarcity pressures and water quality problems that require policy intervention for more sustainable management of water resources.

A hydro-economic model is developed to perform a detailed concurrent assessment of water allocation and pollution abatement solutions at river basin level.

The model assesses water allocation and agricultural nonpoint pollution into watercourses and atmosphere under different drought events and provides a series of mitigation and adaptation policies under normal climate and severe drought conditions in order to identify the effectiveness and robustness of policies.



Network of the Ebro Basin



The model includes the main water uses in the basin: irrigation, livestock, and urban uses.

Dryland crops are also included in the assessment of nonpoint pollution emissions.

Modeling Framework

The hydroeconomic model developed integrates hydrological, economic and environmental components. The interaction among components provides a better assessment of water allocation options among sectors and spatial locations, showing the specific impacts of droughts on the system.

Drought scenarios are used to understand future drought severity levels (moderate and severe) and the ensuing impacts of water scarcity and pollution on social benefits in the basin.

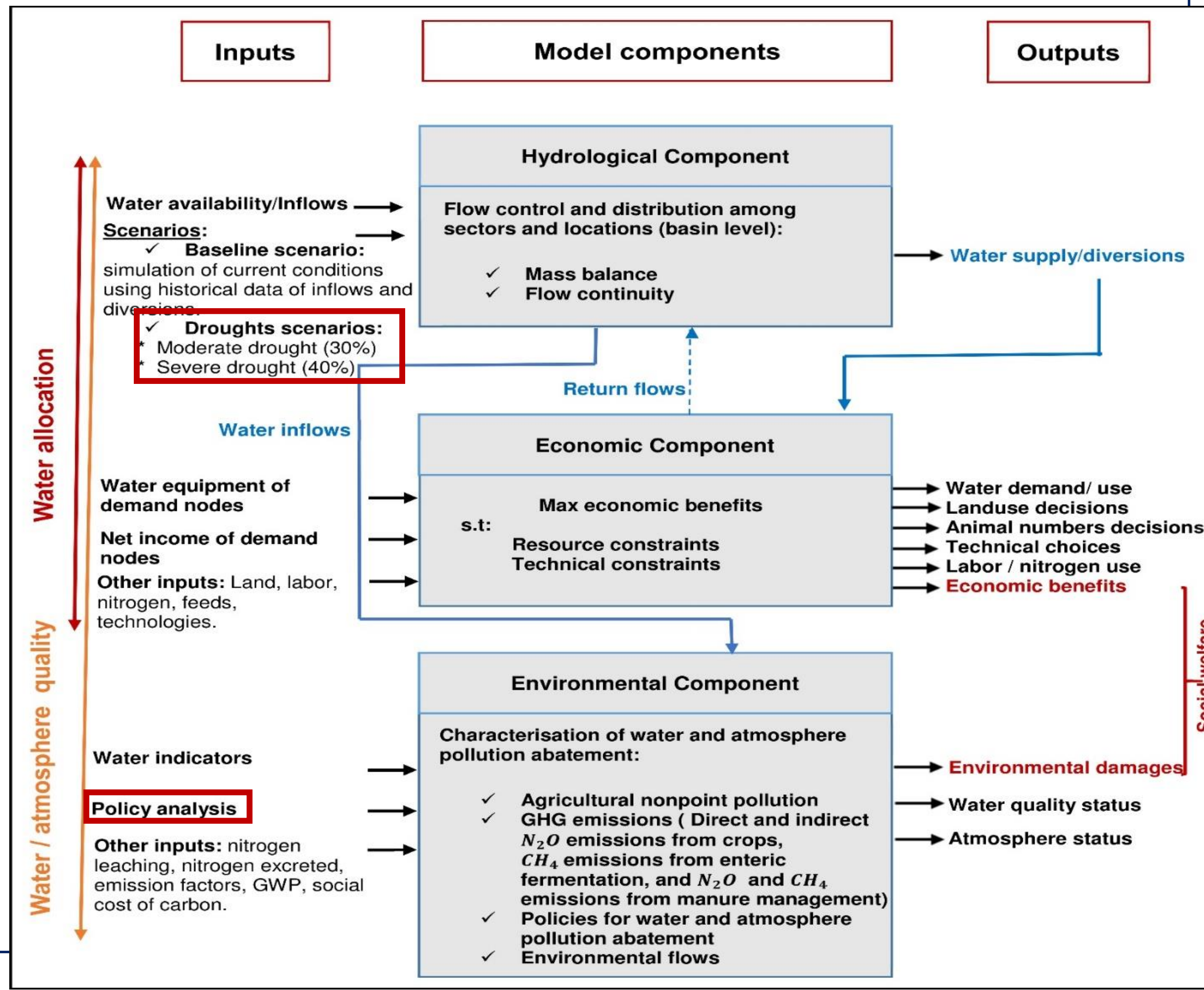
The selected policies are

P1: Optimization of nitrogen fertilization;

P2: Substitution of synthetic fertilization by organic fertilization;

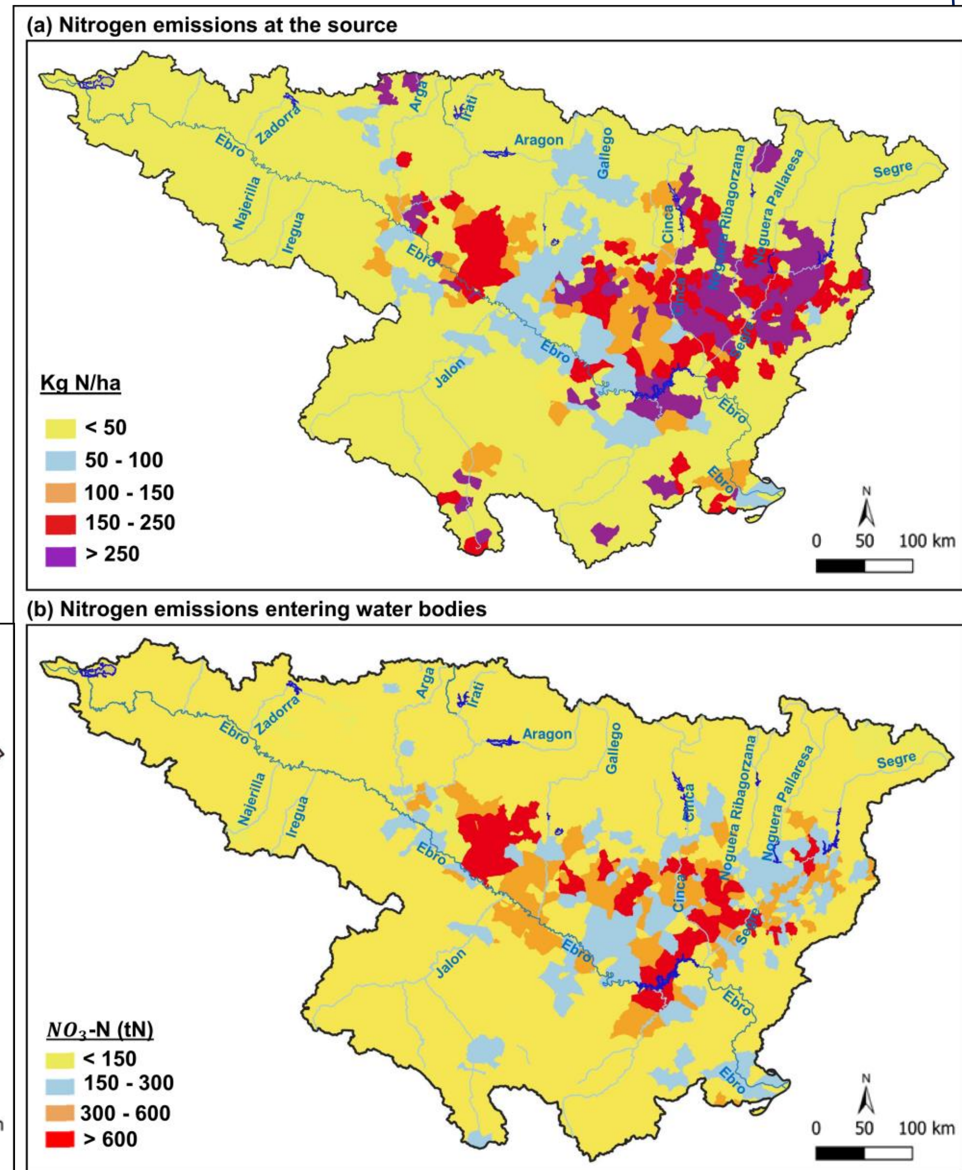
P3: Irrigation modernization;

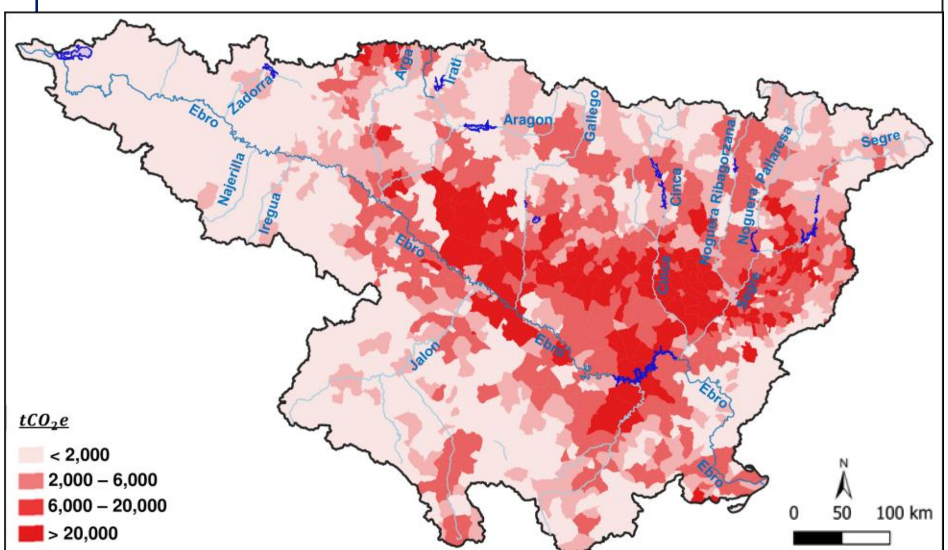
P4: Manure treatment plants



Agricultural nonpoint pollution in the Ebro basin

GHG emissions and nitrogen emissions are concentered in the areas with the large irrigated cropland and swine herds.





Results

Results of drought scenarios

Climate conditions	Normal flow	Moderate drought	Severe drought
Land (1,000 ha)			
Irrigated land	557	362	315
Dryland	1,194	1,194	1,194
Livestock (LSU)	2,769	2,769	2,769
Water use (Mm^3)	3,874	2,825	2,475
Streamflow at the river mouth (Mm^3)	**9,272**	**6,366**	**5,406**
Nitrogen emissions (1000 tNO_3-N)			
At the source	236	227	225
Entering water bodies	94	91	90
Nitrate concentration (mg/l NO_3^-)			
Ebro River mouth	**11.3**	**15.8**	**18.4**
GHG emissions ($MtCO_2e$)	7.15	6.97	6,93
Private benefits (M€)	3,784	3,650	3,586
Environmental damages (M€)	409	397	394
Social benefits (M€)	3,375	3,253	3,192

The results show in general that drought conditions reduce crops with low profitability and high water requirements, and the cropland acreage under less efficient irrigation technologies.

Results highlight the tradeoff between nitrate concentrations and water availability. Nitrate concentrations increase under drought conditions, as the dilution processes worsen driven by water scarcity.

Results

Results of mitigation and adaptation policies under normal flow and drought conditions

	Normal flow					Severe drought				
Policies	**Without policies**	**P1**	**P2**	**P3**	**P4**	**Without policies**	**P1**	**P2**	**P3**	**P4**
Land (1,000 ha)										
Irrigated land	557	584	584	566	557	315	330	347	328	315
Dryland	1,194	1,194	1,194	1,194	1,194	1194	1,194	1,194	1,194	1,194
Livestock (LSU)										
Animals	2,769	2,769	2,769	2,769	2,769	2,769	2,769	2,769	2,769	2,769
Water use (Mm^3)	**3,874**	**4,031**	**4,031**	**3,549**	**3,874**	**2,475**	**2,566**	**2,564**	**2,280**	**2,475**
Agriculture	3,552	3,709	3,709	3,227	3,552	2,176	2,244	2242	1,958	2,176
Urban	322	322	322	322	322	322	322	322	322	322
Streamflow at the river mouth	9,272	9,160	9,160	9,290	9,272	5,406	5,341	5,342	5,416	5,406
Nitrogen emissions (1000 tNO_3-N)										
At the source	236	229	160	234	115	225	220	189	224	105
Entering water bodies	94	91	66	93	46	89	87	73	89	42
NO_3^- concentration (mg/l NO_3^-)										
Ebro River mouth	11.3	11.0	7.7	11.1	5.5	18.4	18.2	15.7	18.3	8.6
GHG emissions ($MtCO_2e$)	7.15	6.96	6.85	7.11	6.65	6.93	6.79	6.81	6.92	6.43
Private benefits (M€)										
Agriculture	1,925	1,970	1,937	1,937	1,642	1,727	1,764	1,772	1,761	1,444
Urban	1,859	1,859	1,859	1,859	1,859	1,859	1,859	1,859	1,859	1,859
Total	**3.784**	**3,829**	**3,796**	**3,796**	**3.501**	**3,586**	**3,623**	**3,623**	**3,620**	**3,303**
Env. damag. (M€)	409	397	300	406	326	394	386	312	393	312
Social benefits (M€)	3,375	3,432	3,531	3,390	3,175	3,192	3,237	3,311	3,277	2,292

The results reveal the tradeoffs and synergies between the economic and environmental effects of these abatement policies.

Droughts could limit the effectiveness of abatement policies in curbing nonpoint emissions and improving water and air quality compared with normal weather. However, these policies still have significant economic and environmental positive effects compared to drought conditions without policies.

Conclusions

This study shed light on a number of <u>important topics</u>, including nitrogen water contamination and GHG emissions, the synergies and tradeoffs between environmental and economic objectives under various policies, and the potential tradeoffs among water quantity and water quality.

↳ **The capabilities of integrated hydroeconomic modeling to address challenging research questions involved in the sustainable management of water resources:**

Social Costs and Benefits of Pollution Abatement at Basin Level

The analysis of abatement policies could support decision makers and contribute to the ongoing policy discussion for designing basin wide sustainable water management policies.