Water Quality

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Water Quality and Nonpoint Pollution: Comparative Global Analysis

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Water Quality

Since the industrial revolution, technological advances have triggered a massive increase in production, wealth, and population to levels that appear to be unsustainable. This extraordinary growth in human activities is pressuring natural resources and leading to extensive environmental damage, which in turn threaten the proper functioning of ecosystems and the well-being of many societies that rely on their services.

Current population is around 6,600 millions and income per capita is 8,000 US dollars, while predictions for 2050 are that 9,000 million inhabitants and 20,000 dollars per capita.

Water Quality

To face the degradation of water resources, some authors think that the only solution is to limit or reduce water extractions and pollution loads in order to contribute to more austere lifestyles required for ecosystem conservation.

Other authors are more optimistic and affirm that global public policies and market institutions will spur new technologies, able to augment income and wealth and reduce human impacts on water resources.

In any case, the efforts to achieve a sustainable use of water resources would be substantial.

Some examples of pressures

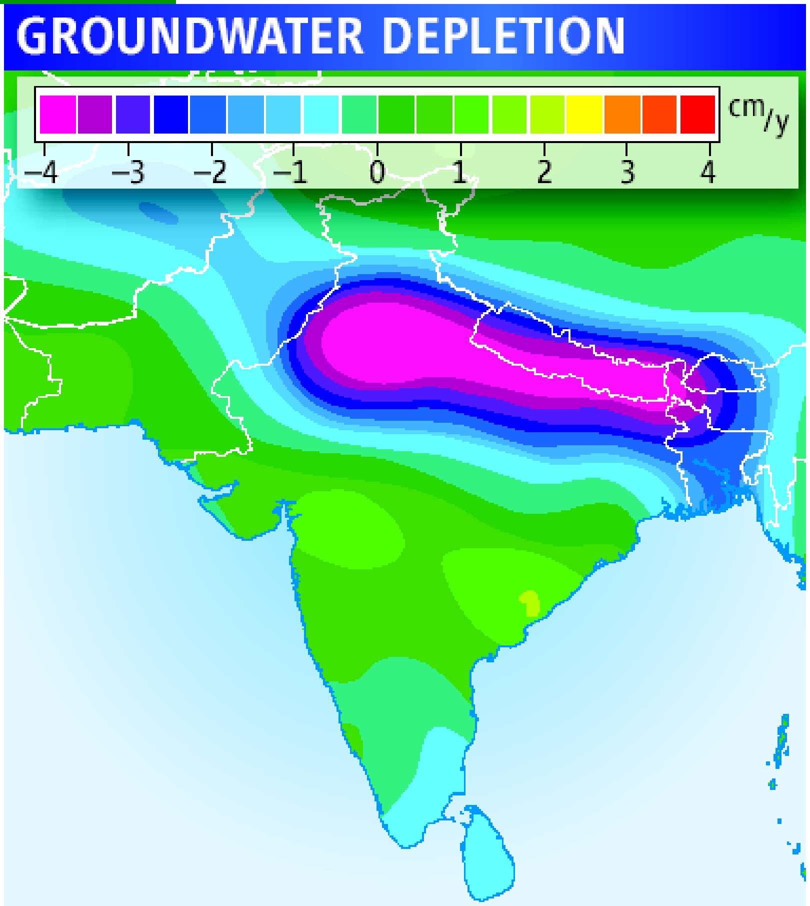
Antropogenic water extractions have climbed from 600 km^3 to 3,600 km^3 between 1900 and 2000, along with the growth of population from 1.7 to 6.0 billion

There are severe scarcity and quality problems in almost all the important rivers in arid and semiarid regions, such as in the Nile, Ganges, Indus, Yellow, Yangtze, Tigris, Euphrates, Amu and Syr Daria, Murray-Darling, Colorado and Rio Grande

Surface and subsurface resources in these river basins are being depleted and their quality degraded.

Water Quality

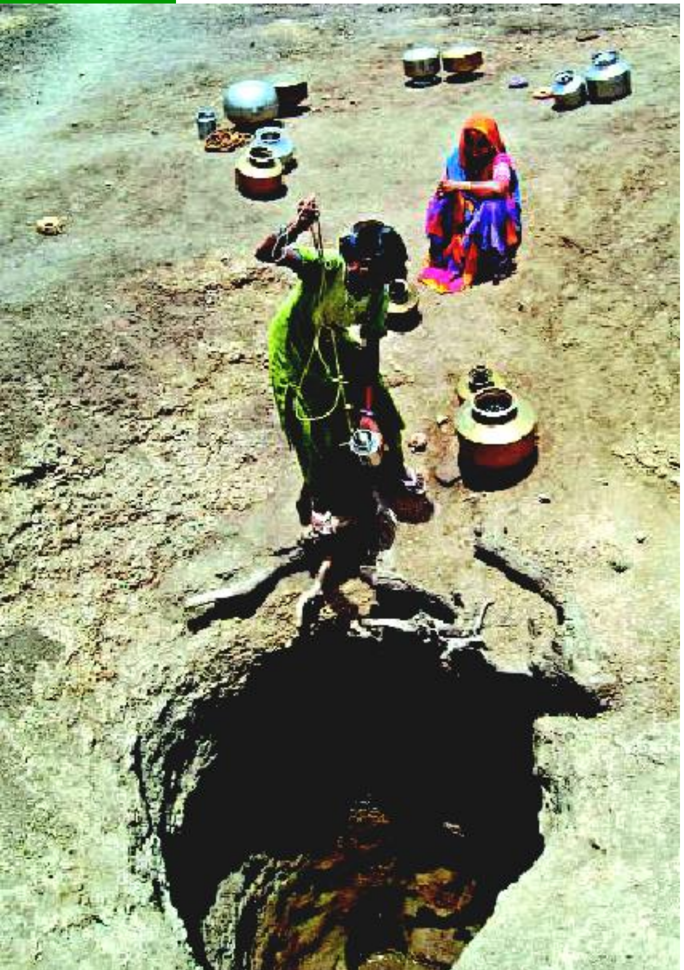
Examples of large aquifer systems being depleted are those of the Indus basin, the Ganges basin, the Northern China plain, and the North America high plains.



The region of the Indus, Ganges and Brahmaputra basins is the larger irrigated area in the world, and groundwater overdraft has been estimated at around 50 km^3 per year

Water Quality

Overdraft estimates by basin are 35 km^3 in the Ganges-Brahmaputra and 10 km^3 in the Indus basin.



In the India part of these basins, groundwater extractions per year are estimated at 280 km^3, with an overdraft amounting to 30 km^3.

The poorest farmers are threatened by this massive depletion of resources, because they have limited access to infrastructures such as electricity and crop distribution facilities, and to farm inputs, production technologies and

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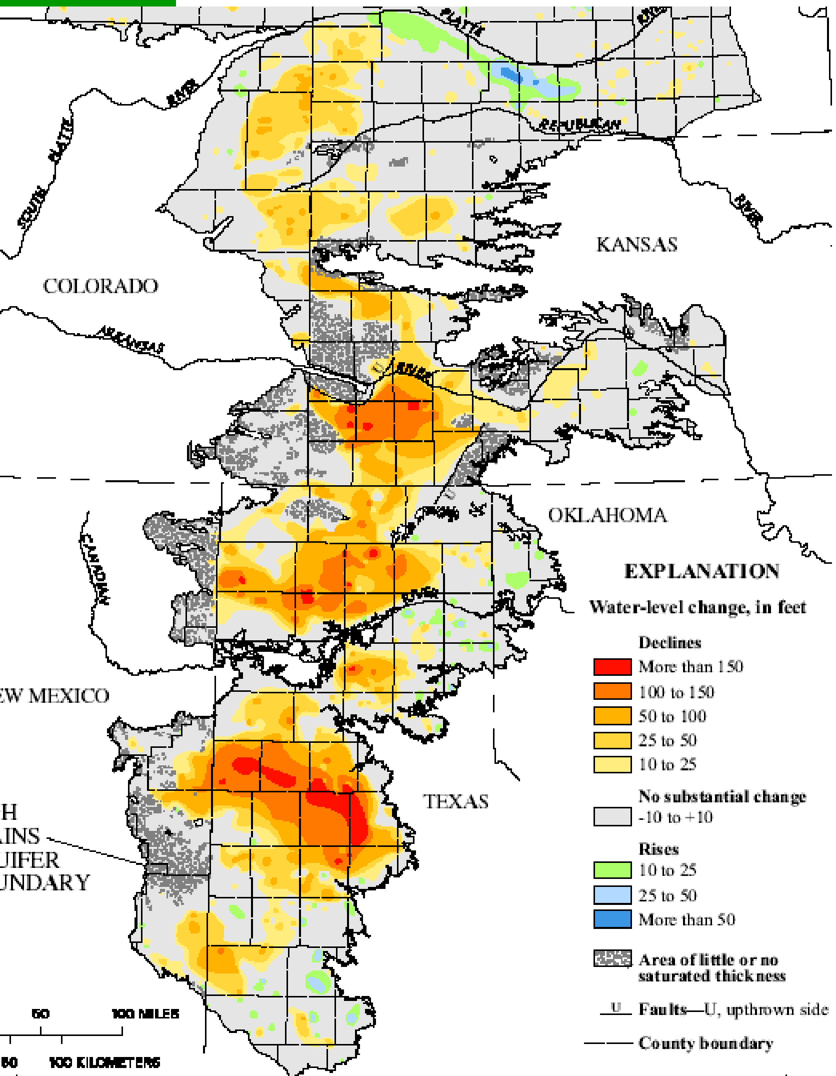
The Ogallala aquifer in the North America high plains: withdrawals 26 km³/year and 10 km³ overdraft.



The current storage amounts to 3,610 km³ and the accumulated depletion is estimated at 310 km³.

The main worries are pumping costs, dwindling surface flows, and impact on habitats.

The only measure taken so far is monitoring of water level changes, but no control measures to stabilize of reduce overdraft have been taken yet.

Water Quality

Gisser & Sanchez (1980) and other authors consider that welfare gains from policy interventions are negligible in aquifer management, when comparing with non regulation or "free-market" outcomes.

An essential element for the validity of this approach is the disregard of aquatic ecosystems, but when environmental externalities from overdraft are taken into account, this approach becomes untenable.

The policy issue is important, because of the severe scarcity and quality problems in the Indus and Ganges basins, the Northern China plain, the North America high plains and other regions, causing large scale degradation of aquatic ecosystems.

Water Quality

This "laissez faire" approach deserves revision, in order to demonstrate that policies and social interventions for sustainable water resources management not only make sense but are also very much needed.

Measures leading to sustainable water management require understanding the basic concepts of policy analysis, such as objectives, instruments (institutional, economic, command and control), optimum, target, cost-efficiency, private good, common pool good, cooperation among stakeholders, collective action.

Pollution control is unfeasible without these policy concepts, specially nonpoint pollution.

Water Quality

Water policies in irrigation can not work with economic instruments such as water prices and water markets.

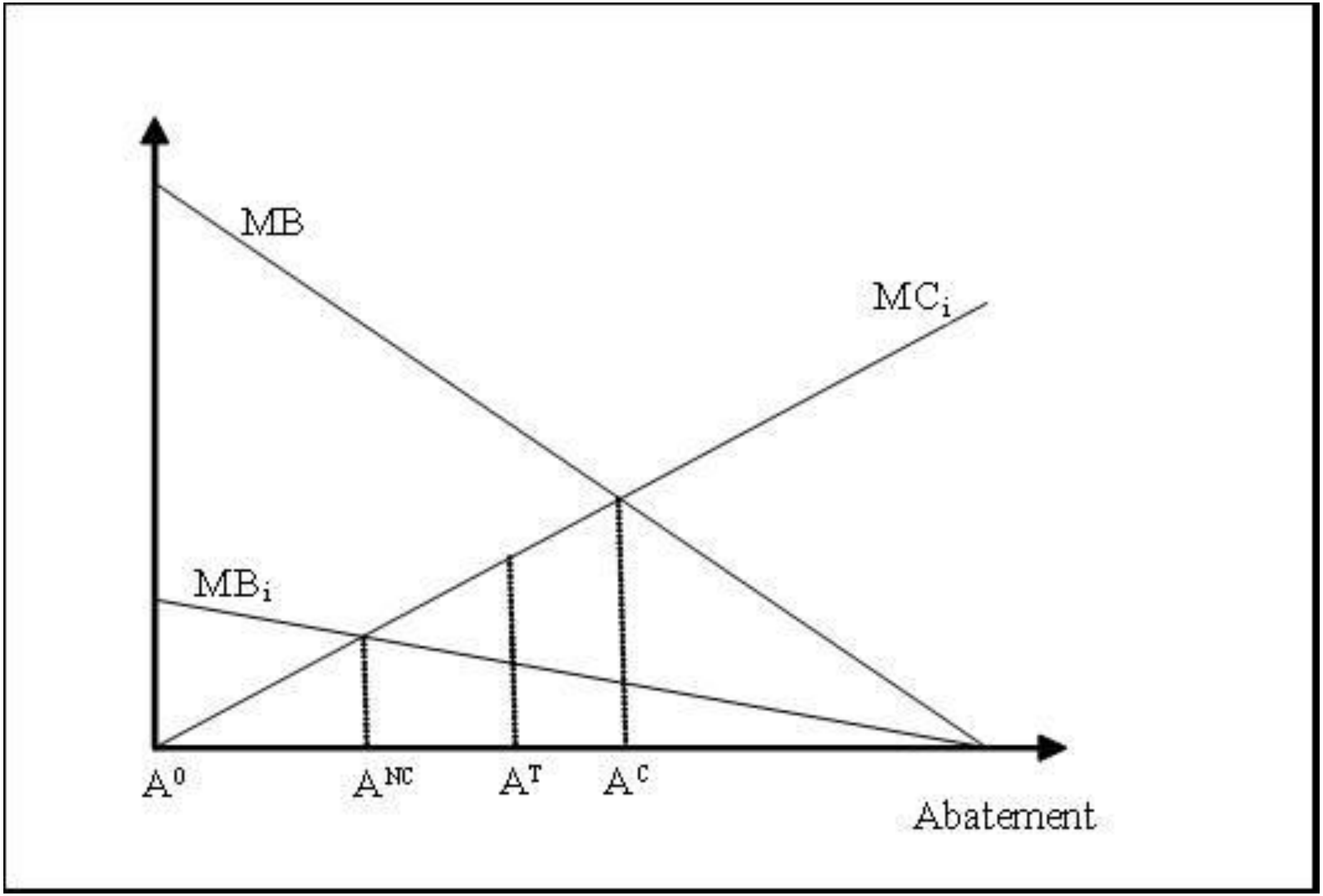
With common pool resources, there is a need to "give a helping hand to the invisible hand" through the mechanism design of Leonid Hurwicz (a student of Oskar Lange). Hurwicz discovered that the lack of information is the key problem in planning and also in markets, because of the lack of appropriate incentives.

Mechanism design is required in water management

Next figure shows the importance of these concepts.

Water Quality

Pollution abatement under non-cooperative and cooperative solutions



Water Quality

Water quality is an essential condition for having living rivers with healthy aquatic ecosystems. At present, pressures are growing rapidly in terms of expanding water extractions and quality degradation from pollution loads.

In high income countries, there have been large investments in water treatment facilities to control point pollution, which have stabilized or in some cases reduced the concentration of pollutants in rivers. Nonpoint pollution is much more difficult to tackle, because control measures are very difficult to design, implement and enforce.

Water Quality

In medium and low income countries, rivers and aquatic ecosystems are being degraded by the surge in point pollution loads from urban and industrial sources, and large tracts of water courses and large tracts of water courses become unsuitable for many water uses.

An example of flawed water quality measures is given by policy makers in China worrying about nonpoint pollution from agriculture, when in fact they should worry first on urban and industrial point pollution. Ongley et al. (2009) indicate that appropriate water policies in China require undertaking good studies and assessments on pollution loads from all sources in the whole country.

Water Quality

Policies to control nonpoint pollution are not so easy to design, and some authors (e.g. Vitousek et al. 2009) mention the US and the EU as examples of reductions in nutrient imbalances, in spite that pollution remains very high in their water media.

	Nutrient balances by region (kg ha $^{-1}$ year $^{-1}$)					
Inputs and outputs	Western Kenya		North China		Midwest U.S.A	
	N	P	N	P	N	P
Fertilizer	7	8	588	92	93	14
Biological N fixation					62	
Total agronomic inputs	7	8	588	92	155	14
Removal in grain and/or beans	23	4	361	39	145	23
Removal in other harvested products	36	3				
Total agronomic outputs	59	7	361	39	145	23
Agronomic inputs minus harvest removals	-52	+1	+227	+53	+10	−9

Water Quality

This article reinforces the flawed approach to water quality in China, giving the impression that nonpoint pollution is developed countries has been reduced substantially. This claim seems dubious.

In the US, it seems that there is no improvement in nonpoint pollution loads over the last decade. The large study completed by NOAA in 2000 on hypoxia in the Northern Gulf of Mexico, has not spurred any significant reduction of nitrogen loads in the Mississippi basin

(See the figure below from EPA 2007).

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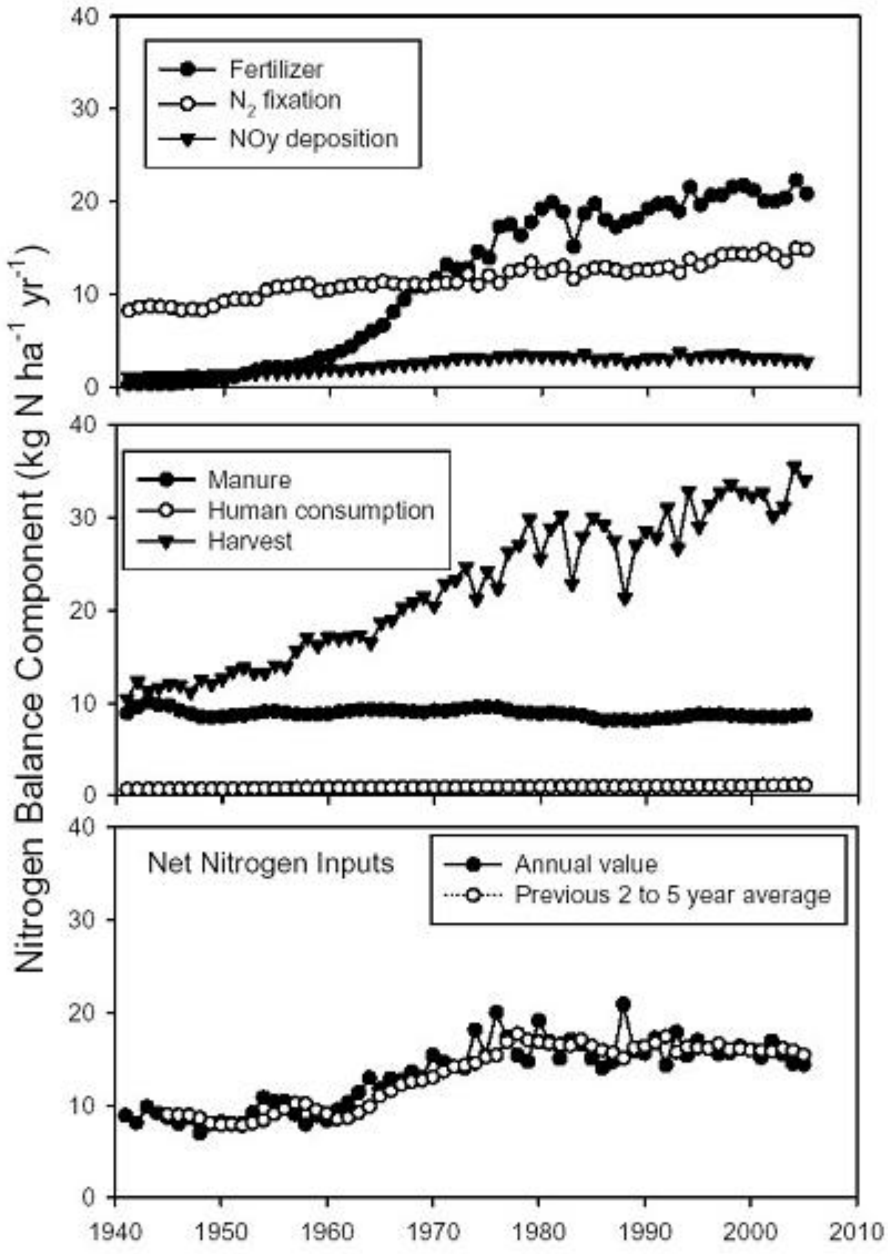
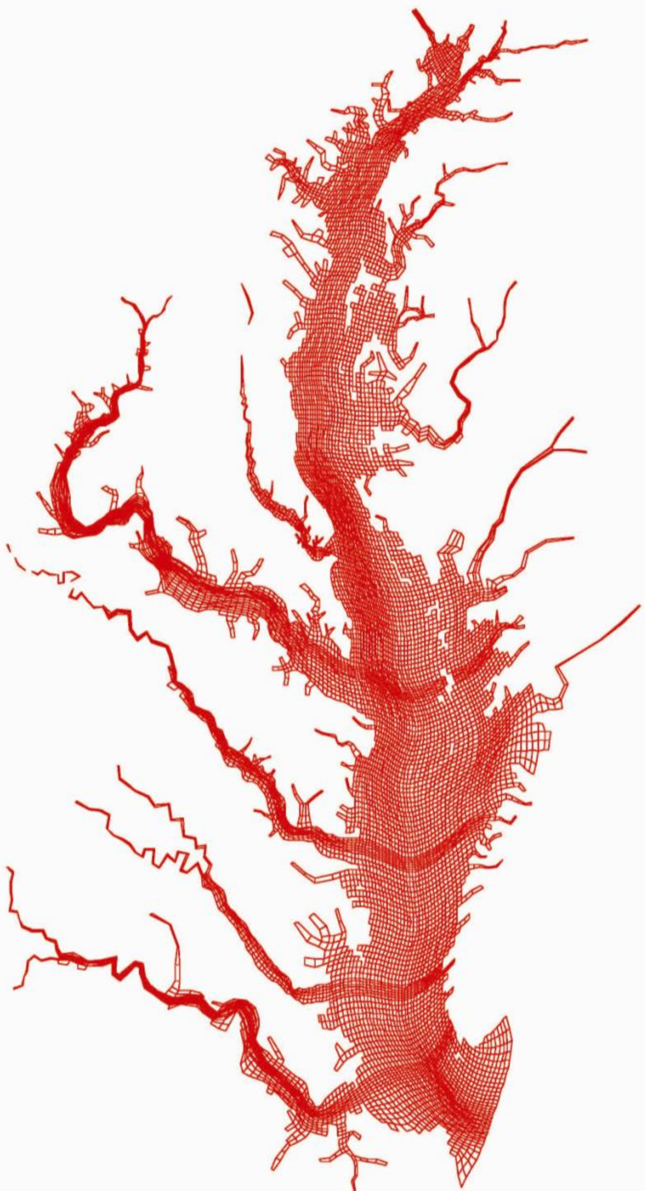


Water Quality

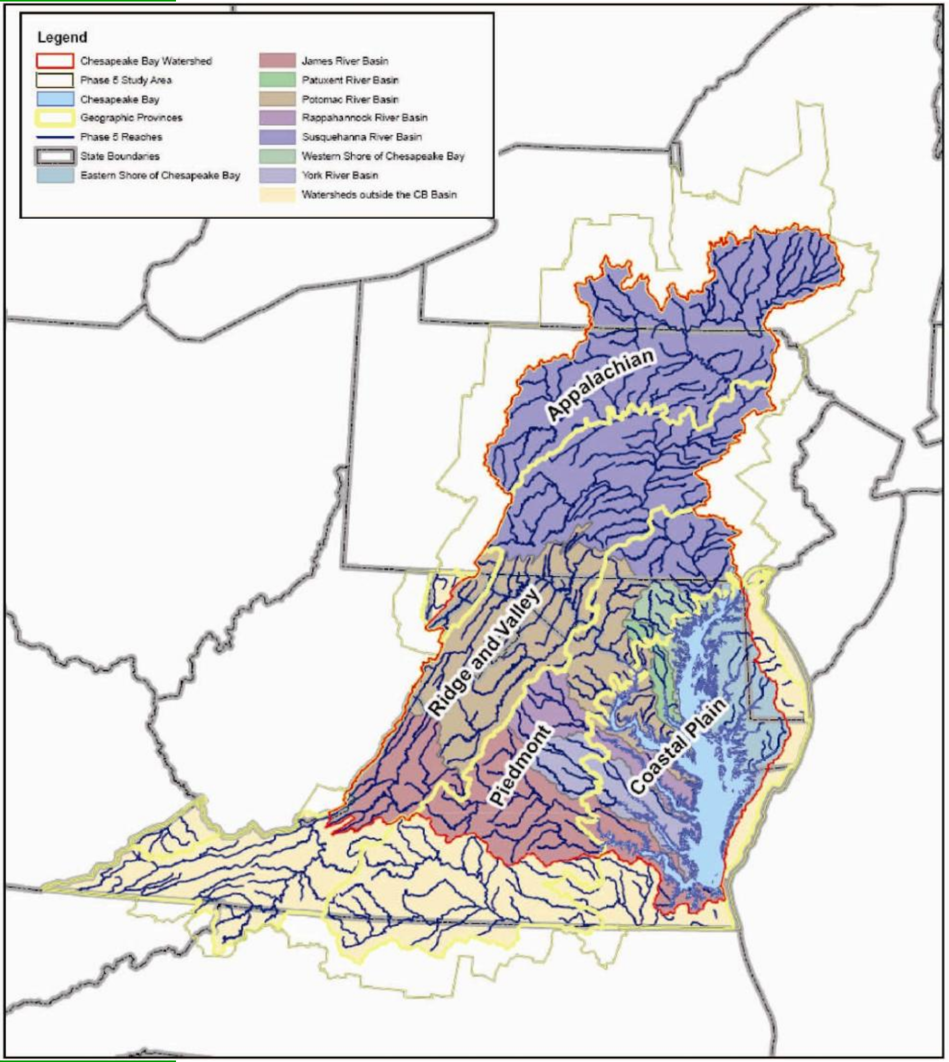


The major effort in the US to curb nonpoint pollution has been made in the Chesapeake Bay, but results there show only moderate reductions.

From 1985 to 2007, the nitrogen loads have fallen from 153,000 to 119,000 t and the phosphorus loads from 12,300 to 8,300 t

These are still far from the sought thresholds of 79,000 t of nitrogen and 5,800 t of phosphorus (Linker et al. 2009).

Water Quality



The implication is that the current voluntary measures have to be supplemented with more strong regulatory measures (Linker et al. 2009).

Water Quality

In Europe, results appear disappointing after the considerable efforts to curb pollution. European regulations include the Urban Wastewater Directive, the Nitrates Directive, both of 1991, and the Water Framework Directive of 2000.

The huge investments of the Wastewater Directive (1991-2005), with investments around of 150 billion euros in EU15 and around 12 billion euros in Spain, should have reduced urban pollution.

Water Quality

Water quality in selected European rivers

Country	Watershed	BOD (mg O_2/l)	Nitrates (mg N/l)	Phosphorus (mg P/l)	Lead (µg/l)	Cadmium (µg/l)	Chromium (µg/l)	Copper (µg/l)
Norway	Skienselva	2.0*	0.2	0.01	0.2	0.02	0.11	0.62
Sweden	Dalalven		0.1	0.02	0.5*	0.02	0.37*	1.48
Denmark	Gudena	1.9	1.3	0.09				
UK	Thames	3.4	6.6	0.66	2.9	0.10	1.17	6.63*
Netherlands	Maas	2.5	3.6	0.21	2.8	0.15	1.77	3.77
Belgium	Escaut	3.6	4.7	0.66	12.0	0.67	9.93	10.10
Germany	Rhein	3.0	2.5	0.14	3.0	0.20	2.55	6.22
	Elbe	6.9	3.0	0.17	2.2	0.18	1.20	4.36
	Weser	2.8	3.7	0.14	4.5*	0.20	2.03*	3.56
France	Loire	3.2	3.1	0.21		0.40*		
	Seine	3.1*	5.6	0.63*	22.1*	2.18*	24.67*	15.03*
Spain	Guadalquivir	4.2*	6.1*	0.95*	10.2*	1.87*		5.73*
	Ebro	1.9	2.2	0.09	7.5	0.23*	0.92*	1.61*
	Guadiana	1.6	1.8	0.69*		3.39		
Portugal	Tejo	2.3	1.0	0.20	11.0	3.00	22.33*	2.10
Italy	Po	1.3	2.5	0.25				
Greece	Strimonas		1.8	0.14		0.64*		
Turkey	Porsuk	1.4	1.5	0.06	12.2	6.50	7.50	5.67

Nutrient problems: Thames, Guadalquivir, Seine
Heavy metals: Seine, Tejo, Guadalquivir, Porsuk

Related to tertiary treatment
(Northern countries)

Water Quality

But the European data (EEA 2009) for the last 15 years on nitrate concentration indicate a slight reduction in rivers and a 50% increase in aquifers.

The data from OECD (2008) confirm this poor quality improvement, with most major European rivers showing no abatement of nutrients or even a worsening in some rivers (Table 1 above). These data show this poor behavior which hampers the recovery of water quality in the last thirty years.

Water Quality

The Biochemical Oxygen Demand (BOD) has improved in most European countries except in Belgium (Escaut), UK (Thames) and Netherlands (Maas). The improvement in BOD took place in Germany and Denmark in the beginning of 1990's, and in France, Spain and Italy in the beginning of 2000's.

The worst water quality results are for nitrates, with most countries showing no improvement in the last thirty years, and rivers such as Loire, Guadalquivir and Strimonas increasing nitrate loads in the beginning of the 2000's. Only Germany and Norway reduce nitrate loads during the late 1990's. Phosphorus pollution loads show no improvement in the majority of rivers.

Water Framework Directive

The emphasis of the Water Framework Directive on water pricing in order to achieve efficient water use and promote conservation and protection, follows the Dublin declaration of 1992, but it is a flawed approach.

The problem of this “economic good” approach assumed by the WFD and by many environmental decision makers in Europe is that, the price mechanism can work only where water is a private good (rivalry in consumption and exclusion) which is traded in markets.

Water Quality

Domestic and industrial uses have characteristics of a private good, but irrigation is different because it is an impure public good which has environmental externalities. Water pricing could modify consumption where markets exist, such as in urban networks for domestic and industrial demand, but not in agricultural or environmental uses.

Furthermore, water markets are not internalizing environmental externalities, as seems to be the case in California and Australia. Protection and conservation of water resources, when they are common pool resources, requires the cooperation by agents to achieve collective action.

Water Quality

The lack of basic information and knowledge on biophysical processes favors the strategic behavior by countries, basins and stakeholders in the whole implementation process of the Water Directive.

The description of the basic measures and supplementary measures in the Water Framework Directive does not make much sense. The writing of measures which are listed by the WFD does not take into account the state of knowledge in policy analysis from the field of environmental economics.

Water Quality

The Directive does not consider either the concepts of private good, public good and externality, and therefore ignores that different types of measures are needed for the different kind of problems in water resources.

The conceptual and empirical misunderstanding in the policy analysis of the Directive is such, that there is a large confusion among many environmental decision makers in Europe.

In order to elaborate reasonable measures, it is essential to clarify the conceptual methodology of policy analysis, and determine the requirements regarding water statistics and scientific knowledge on biophysical processes for the design of measures.

Water Quality

Even when all biophysical knowledge is available, the management of quantity and quality aspects of surface and subsurface water is a complex task, because of the public good characteristics of water and their environmental externalities. The design of measures must take into account the strategic behavior of stakeholders, creating incentives able to encourage cooperation among stakeholders in order to achieve resource conservation through collective action.

Example: the Eastern La Mancha aquifer with collective action in place and Western La Mancha aquifer with complete failure (and plan to pour in 5 billion euros)

Both aspects, biophysical knowledge and collective action, are unlikely to be achieved by 2015 which is the deadline for the good ecological status of water resources.

Water Quality

What we do in Spain:

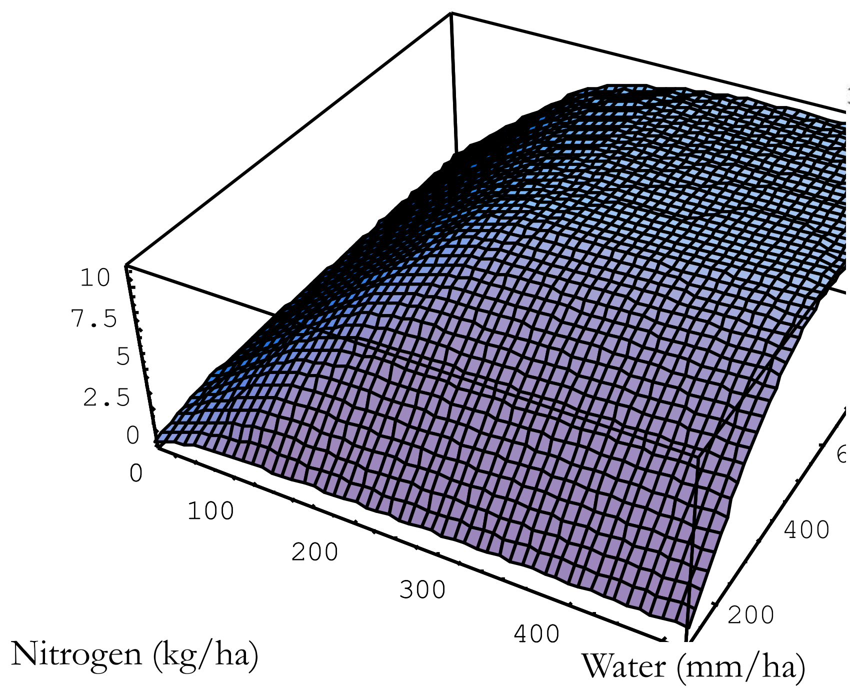
- Irrigation modernization which abates substantially nonpoint pollution and may save water

- Investments in tertiary treatment, protection of water sources and storm tanks (Water Quality National Plan 20 billion euro in Spain 2007-2015), which will diminish further urban and industrial point pollution.

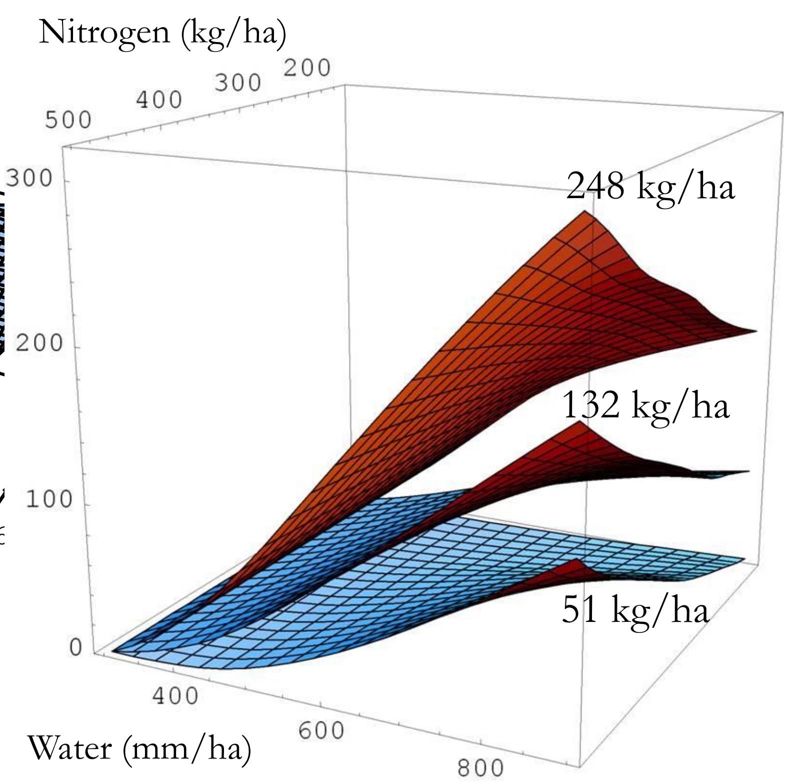
Together with these two measures, cooperation from stakeholders is needed in basins to reduce both nonpoint pollution and excessive water extractions, especially where they produce large damages because of the high value of aquatic ecosystems. Following the example of the Eastern La Mancha aquifer. It is doable.

Water Quality

Corn production function

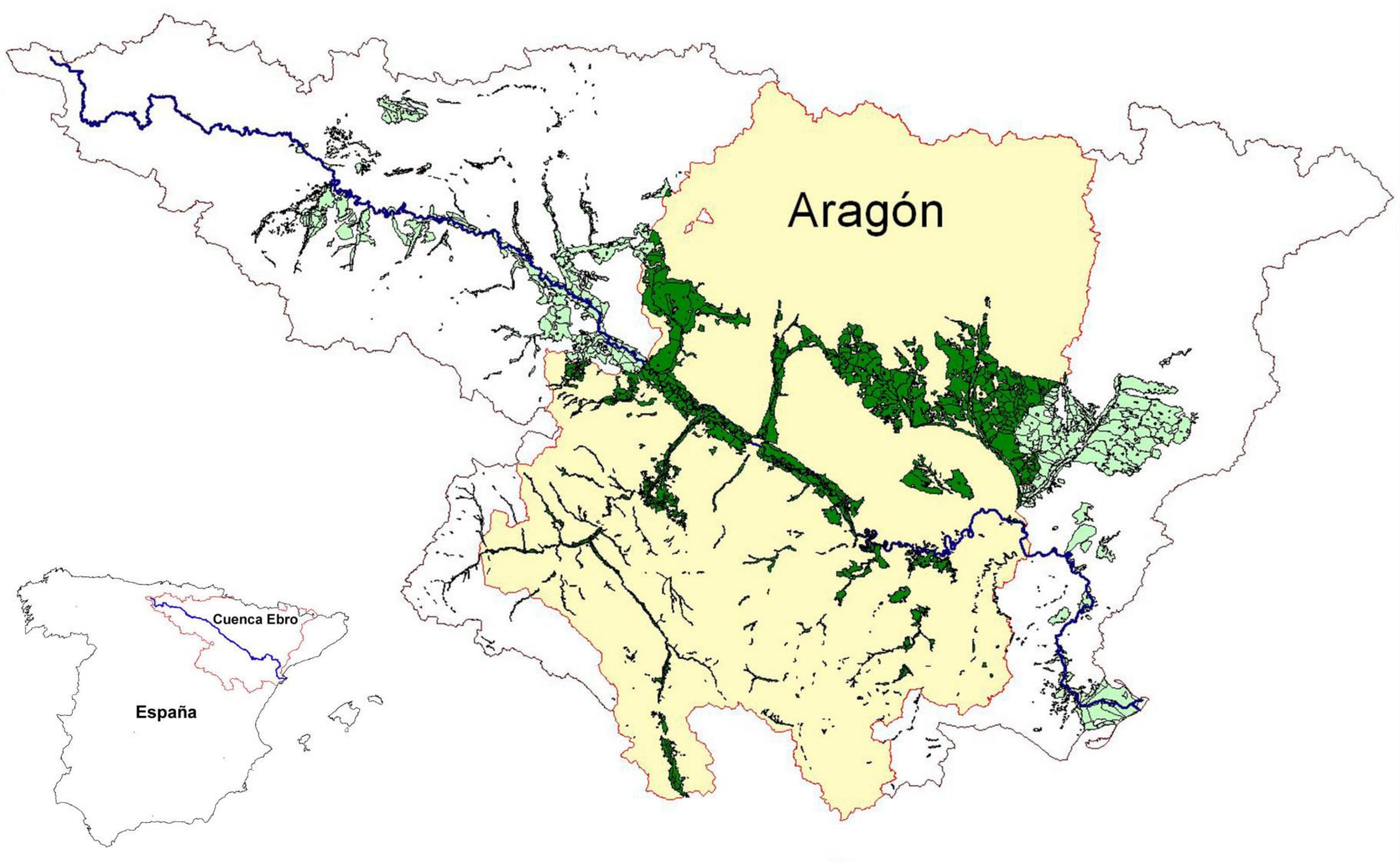


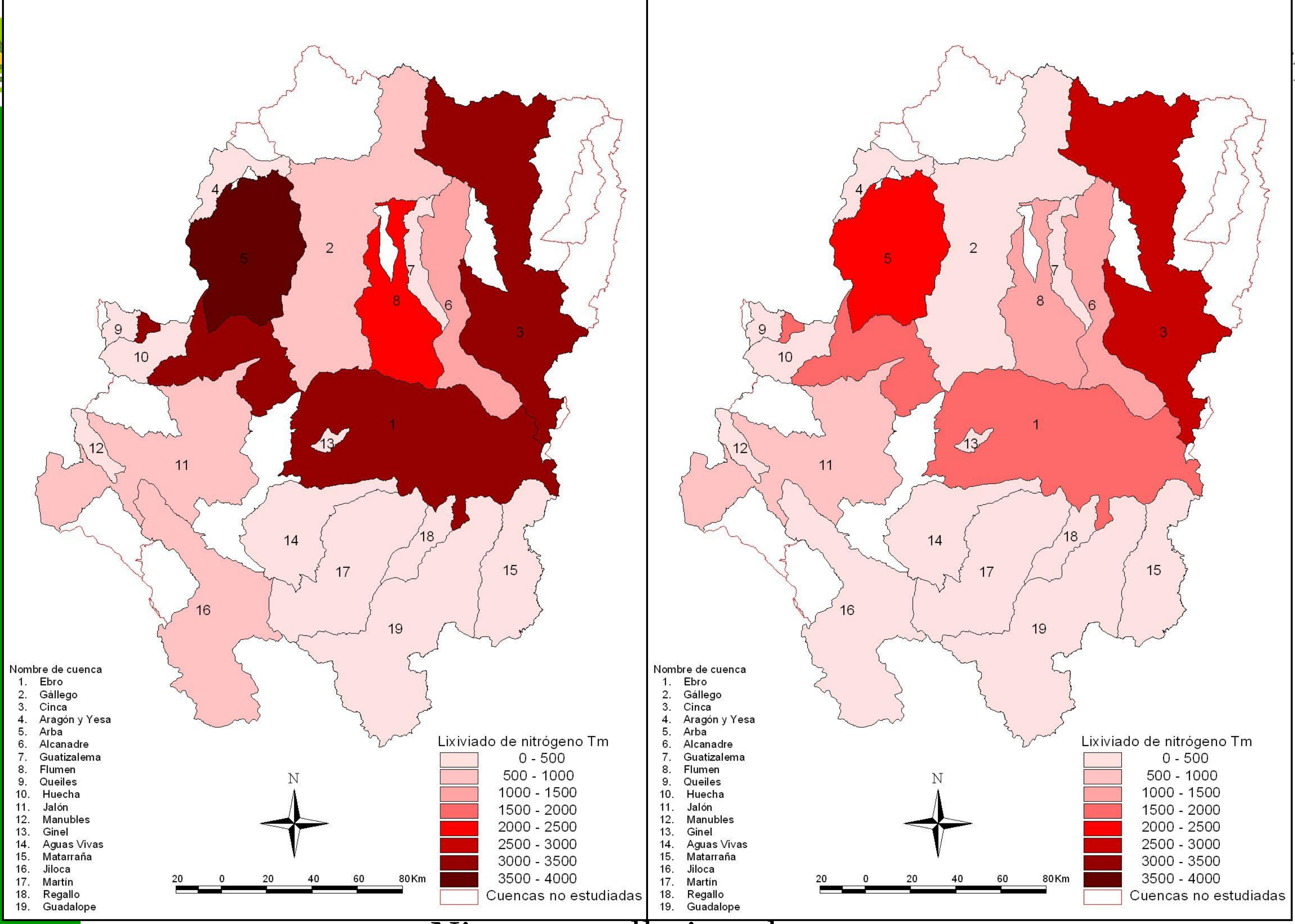
Corn pollution function



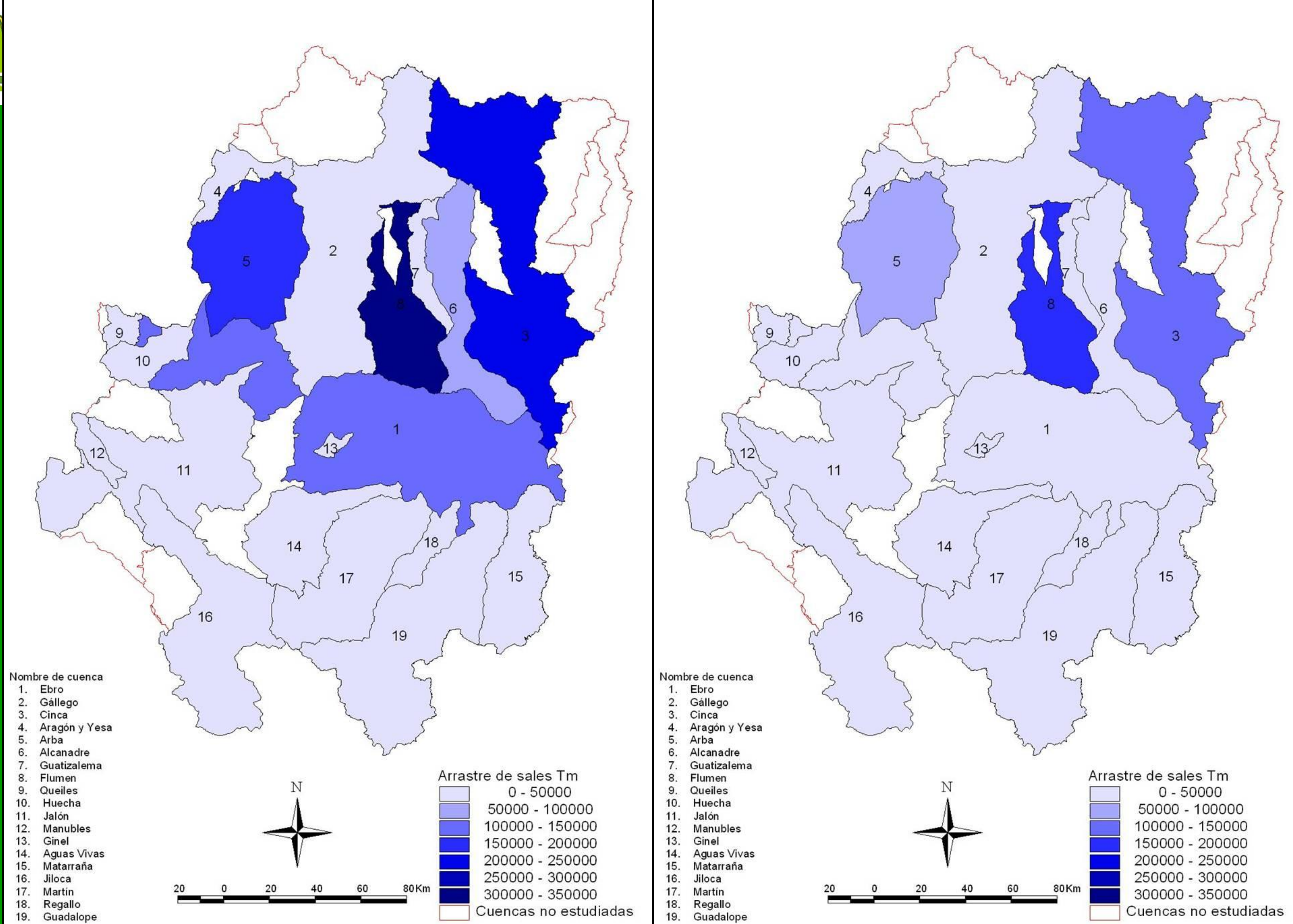
Water Quality

Nitrogen and salinity pollution from the 400.000 ha of irrigation in the middle Ebro basin.





Nitrogen pollution abatement
from irrigation modernization (-40%)



Salinity abatement from irrigation modernization (-50%)

Conclusions

Water quality is an essential condition for having living rivers with healthy aquatic ecosystems. At present, pressures are growing rapidly in terms of expanding water extractions and quality degradation from pollution loads.

Policies and social interventions for sustainable water resources management not only make sense, but are also very much needed.

Water Quality

In high income countries, large investments in water treatment facilities have stabilized or in some cases reduced pollutants in rivers. Nonpoint pollution is much more difficult to tackle, because control measures are very difficult to design, implement and enforce.

In medium and low income countries, rivers and aquatic ecosystems are being degraded by point pollution from urban and industrial sources, and large tracts of water courses are heavily degraded.

Water Quality

In Europe, regulation has facilitated large investments in water treatment plants and technological innovations in industries and households, reducing the emissions of some pollutants although abatement is not general.

Pollution by nutrients and heavy metals remains high in many watersheds of the more important river basins in Europe.

The efforts on urban and industrial point source emissions should continue, and effective control on nonpoint source pollution is needed such as abatement of nutrients and pesticides from agriculture.

Water Quality

The case of Spain shows that the implementation of the Water Framework Directive is not an easy task. Both the former Spanish Ministry of Environment and the European Commission Environment Directorate advocate water pricing in irrigation and using the Common Agricultural Policy (CAP) to penalize farmers.

Research projects funded by the European Commission and some other studies recommend also these flawed policy options:

WFD meets CAP (www.ecologic.de/modules.php?name=News&file=article&sid =1369), Aquamoney (www.aquamoney.org), AquaStress (www.aquastress.net), WADI (www.uco.es/investiga/grupos/wadi), POPA-CTDA (www.popa-ctda.net) and POLAGWAT (http://susproc.jrc.es/docs/waterdocs/FinalRep150802.pdf).

Water Quality

The investments in advanced irrigation technologies in Spain are much more interesting than the WFD approach. These new technologies facilitate the private and public control over water quantity and quality, and their potential depends on the right coordination and collaboration between farmers, their water user associations and water authorities.

Knowledge on the underlying biophysical processes is critical for water management, specially for managing aquifers and controlling nonpoint source pollution, and this requires the availability of basic facts on aquifer and pollution characteristics and dynamics at local watershed scale.

Water Quality

To control pollution, information is needed on emission loads, pollutants transport and fate processes, and ambient pollution in water courses. Also, the lack of economic valuation of damage costs to aquatic ecosystem from aquifer overdraft and nonpoint source pollution, precludes the assessment of the benefits of policy measures.

Even when all biophysical knowledge is available, management is quite challenging because of the public good characteristics of water and the associated environmental externalities. The design of measures must take into account the strategic behavior of stakeholders. Both aspects, biophysical knowledge and collective action, are unlikely to be in place in any European (or non European) country by 2015, when the “good ecological status” objective of the WFD is supposed to be attained.