Assessment of Nonpoint Pollution Instruments: the Case of the Spanish Agriculture

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ABSTRACT *Nonpoint pollution is characterized by imperfect knowledge of biophysical processes, stochastic components, and asymmetric information among agents. The design and implementation of measures to abate emissions is a difficult task, because of this lack of biophysical information and the strategic behavior of stakeholders. The development of the input intensive agriculture in Spain during the last century has created large discharges of nutrients and other harmful substances into water bodies, causing damages to aquatic ecosystems. In Spain and other European countries, the control of nonpoint pollution is a crucial step in achieving the 'good' ecological status of water bodies sought by the European Water Framework Directive. The empirical findings challenge the current approach to pollution policies and call for policy efforts focused on nurturing stakeholders' collective action and on supporting the necessary institutional setting.*

1. Introduction

Water resources are being subject to growing quantitative and qualitative pressures from urban, industrial, and agricultural uses. The increasing water extractions are especially worrying in arid and semiarid regions, where the huge overdraft of resources is destroying aquatic ecosystems and jeopardizing human activities. Water quality is also being seriously affected by point and nonpoint pollution loads, which make entire river tracts and aquifers useless. The case of pollution is the typical situation of a negative externality, which is defined as a public "bad" that results from "waste discharges" associated with the production of private goods (Cropper and Oates 1992). The task of water authorities is to assess these water scarcity and water quality problems, in order to develop policy strategies that improve water allocation and management. However, this requires the cooperation of stakeholders willing to internalize the damages and protect water resources

Agriculture generates significant pressures on water resources worldwide, and it has largely changed the natural environment for centuries. Agriculture produces goods and services, and provides a variety of environmental externalities both positive and negative. Traditional agriculture has supported during centuries the rural environment and its associated environmental services to society, for example controlling weather effects and pests, supporting biodiversity and providing shelter and recreational services. However, the intensive agriculture of recent decades has several drawbacks, such as emissions of nutrients and pesticides that degrade natural ecosystems. The runoff and leaching of pollutants, for instance nitrates, phosphorus, pesticides, or salts, degrade water resources and soils, the habitat of flora and fauna, and the services provided by ecosystems. The pollution emissions damage the aquatic ecosystems. Rivers, estuaries, lakes, and streams are being affected by the negative impacts on many types of aquatic biota, such as fish, vertebrates, invertebrates, flora, wetlands, and grasslands. The emissions from agriculture not only affect ecosystems, but also affect downstream human activities in farms, urban centers, and industries.

Another issue is water scarcity, with a large pressure from the development of irrigation. Especially worrying is the overexploitation of groundwater resources during recent decades. Groundwater resources are important sources of fresh water, storing 90 percent of freshwater in the Earth (Koundouri 2004). Groundwater resources are used for household, industrial, and agricultural uses, but the largest use is irrigation. When extractions are greater than recharge, the result is the depletion of the aquifers and desiccation of the surrounding areas. Most extractions of groundwater are out of the control of any public authority. This groundwater overdraft reduces the quantity and the quality of the water stored, with significant negative impacts on ecosystems depending on these water bodies.

The paper is organized as follows: section 2 presents the different instruments to control nonpoint pollution and the difficulties in their implementation. Section 3 analyzes the role of cooperation in nonpoint pollution control. In section 4 the Spanish case is explained with a brief description of the most important irrigation areas. Finally, the concluding section summarizes the main ideas and highlights the recommended policy actions.

2. The Control of Nonpoint Pollution

Pollution loads from agriculture into water bodies are characterized by being nonpoint emissions at the source. This type of pollution is linked to an important problem of information and knowledge, because of the impossibility of identifying the agent generating the emissions, the spatial location, and the amount of emission load at the source. This problem explains the difficulties in the design and implementation of policies to control nonpoint pollution. These issues are discussed in the nonpoint pollution literature and are presented by Shortle and Horan (2001), Tomasi et al. (1994), or Weersink et al. (1998).

Several policy measures have been proposed to internalize the social damages from nonpoint pollution emissions. These pollution measures are classified in three types of instruments: command & control, economic instruments, and institutional instruments (Table 1). The more common measures to abate agricultural pollution are regulations over inputs or practices, ambient pollution taxes, liability rules, and trading of pollution permits.

The complexity of biophysical processes and the heterogeneity of pollution functions among agents imply that first best policy measures are almost impossible to implement. The reason is that policy makers would need a huge amount of information and knowledge on agents' characteristics and biophysical processes. Additionally, the transaction costs involved in implementing control measures could be quite large. Therefore, the only option suggested for real world situations is to achieve a second best policy.[1] An important question that has to be considered is the issue of the enforcement and monitoring mechanisms, which are required for any pollution regulation. In the vast majority of studies, these transaction and administrative costs are not considered.

Several issues arise in the design of policies to control nonpoint pollution. These issues relate to the number of agents and their spatial location, the

Table 1. Classification of pollution control instruments.

Instrument	Type of instrument	Description
Command and control instruments		
Standards	Input control over quantity	Input use restriction
	Output control: quotas or prohibitions	Output production quantity restriction
	Emissions' limits	Regulation of the maximum quantity of emissions
Economic incentives or market-based instruments		
Tax/Subsidies	Charges on input or outputs	Input or output taxes per unit of product
	Subsidies for practice control	Subsidies for practices that reduce emissions
	Land retirement	Crop land retirement subsidy
	Performance bonds	Deposit paid, repayable on achieving

[1] A second best policy could be also infeasible because of the information available or the particular police sought. In this case, the regulator has to select third best or even fourth best policies.

		compliance
	Liability payments	Payments in compensation for damage
Markets	Input trading	Exchange of inputs' rights
	Emissions trading	Exchange of permits of emissions or emissions' rights
Institutional instruments		
Basin authority	Coordination of water resources by stakeholders	Planning and management by stakeholders at basin, watershed and district levels
Liability rules	Negligence laws and rules	Codification of rules of liability for environmental damage
Voluntary approaches	Non-compliance fees	Payments made by polluters for non-compliance with a limit of emissions
Development social responsibility	Education and social programmes	Energy conservation and environmental labelling Promotion citizenship
Facilitation bargaining	Cost of bargaining are reduced	Polluter information placed in public domain

Source: Adapted from Perman et al. (2003) and Shortle and Horan (2001).

production technologies and practices, the pollution transport and fate processes, and to risk and uncertainty. The strategic behavior of agents has to be taken into account because of the asymmetric information between the social planner and the agents, and the information problems such as moral hazard and adverse selection (Segerson 1988, Xepapadeas 1991 and 1992, Shortle and Dunn 1986).

The existence of multiple polluters distributed across space complicates the design and implementation of nonpoint pollution policies, since scientific knowledge and statistical information are quite scarce and costly. Another issue is the heterogeneity of agents displaying different production and pollution functions. This heterogeneity between agents implies different emission loads and pollution abatement costs. Heterogeneity also arises from the spatial distribution of biophysical features, where agents using the same technologies generate different emissions, just because of the location attributes. Stochastic elements represent imperfect information on the relationships involved in production and pollution functions, but also uncertainty in the pollution transport and fate processes. These issues explain why nonpoint pollution control is fraught with problems of moral hazard and asymmetric information.

Finally, an additional issue to consider is the transaction costs associated with monitoring and enforcement. The substantial differences in transaction costs among policies have to be considered when selecting the right policies for nonpoint pollution control.

Some authors consider that the best option to reduce pollution is that agents control voluntarily their level of emissions. However, voluntary schemes have been criticized in the literature for not achieving any significant pollution abatement. The alternative to voluntary schemes, but also to economic instruments, is institutional instruments where the public administration promotes the cooperation among farmers, leading to collective action in the protection of water resources. Collective action could be used to address problems such as uncertainty and insufficient information (Byström and Bromley 1998).

The economic analysis of point source pollution has been broadly dealt with in the literature and the typical control instruments are emission standards, emission permits, and Pigouvian taxes on emissions (Baumol and Oates 1988). The tools used in point source pollution are not suitable for nonpoint pollution. As explained previously, the analysis of nonpoint pollution is more sophisticated because the regulator lacks information about the source of pollution and the emissions loads. This situation favors the strategic behavior of agents, since the information is asymmetric and the polluting agent has more information than the agency regulating pollution. From a theoretical perspective, the seminal work dealing with nonpoint pollution includes the contributions of Griffin and Bromley (1982), Shortle and Dunn (1986), Segerson (1988), Xepapadeas (1991), and Byström and Bromley (1998).

The foundations for analyzing agricultural nonpoint pollution was developed using biophysical models that link production decisions with emission loads (Griffin and Bromley 1982). Pollution is made dependent on inputs and production practices, and then several control instruments can be considered such as taxes, subsidies and standards on polluting inputs and on emissions. A further refinement consists in introducing uncertainty from random natural processes and taking care of the imperfect information about biophysical processes (Shortle and Dunn 1986).

Since pollution at the source cannot be observed, an alternative is to design measures to control ambient pollution instead of trying to control pollution at the source (Segerson 1988). This type of control measure can be a tax or subsidy, depending on whether farmers pollute above (tax) or below (subsidy) an ambient pollution threshold. The tax or subsidy is calculated multiplying a tax rate by the difference between the observed pollution and a threshold fixed by the regulatory agency.

A large body of literature analyzes the best policy measures to reduce pollution emissions, with measures such as taxes and subsidies on inputs, on source pollution or on ambient pollution; and group fines or group lump-sum payments. The procedure followed in these studies is to develop a theoretical model, and then validate the results empirically by doing so-called "experimental economics". These models maximize social welfare, defined by the private profit of farmers' production activities minus the pollution environmental damages coming from these activities. The common feature of this literature is that pollution policies are tested using students in laboratory experiments (See Cochard et al. 2005, Spraggon 2002 and 2004, and Vossler et al. 2002).

There are two problems with this type of approach: the difficulty of abating nonpoint pollution by using pure economic instruments; and the validity of students' responses in representing the behavior and decisions of farmers, and other public and private stakeholders.

Most of the pollution policies consist on using economic instruments to compensate the private benefits of agents causing pollution damages, or using public funds in financing investments in pollution abatement technologies. But such policies seem ineffective in curtailing the large nonpoint pollution loads in river basins around the world. What might be useful is the cooperation of stakeholders managing the water resources. The economic argument supporting this collective action approach is that water resources are mostly common pool resources, requiring cooperation rather than just economic instruments that are harder to implement in the case of public goods (Albiac 2009).

Policies to control nonpoint pollution are not easy to design. Some authors such as Vitousek et al. (2009) mention the United States (US) and the European Union (EU) as examples of places that have reduced nutrient imbalances, yet pollution remains very high in their water bodies.

In the US, it seems that there is no improvement in nonpoint pollution loads over the last decade in the Mississippi basin. A large study completed by the National and Oceanic Atmospheric Administration (NOAA) in 2000 on hypoxia in the Northern Gulf of Mexico, has not spurred any significant reduction of nitrogen loads in the Mississippi basin (Environmental Protection Agency 2007). The major effort in the US to curb nonpoint pollution has been made in the Chesapeake Bay during the last 25 years, but results in there show only a moderate abatement. Reductions in nitrogen and phosphorus loads are still far from the sought thresholds. The implication is that the current voluntary measures in the Chesapeake Bay have to be supplemented with more strong regulatory measures (Linker et al. 2009).

In Europe, the policy efforts to curb pollution have been considerable but results appear disappointing. European regulations include the Urban Wastewater Treatment Directive and the Nitrates Directives, both of 1991, and the Water Framework Directive of 2000.

The huge investments of the Wastewater Directive with investments above 100 billion €, should have reduced pollution in the European water bodies. However, the European data for the past 15 years on nitrate concentration indicate only a slight reduction in rivers and a large increase in aquifers (European Environmental Agency 2009). The data from the Organization for Economic Cooperation and Development (OECD 2008) also found that most major European rivers show no abatement of nitrates, and some have even grown worse.

The Nitrates Directive of 1991 also sought to reduce pollution. It was based initially on information and voluntary compliance, and more recently farmers have been required to keep a nitrogen balance book. Uncomplying farmers drawn by chance are being penalized in their Common Agricultural Policy payments. The Nitrates Directive applies to cultivation over aquifers declared officially polluted. But the Directive ignores the cultivation over whole basins and very polluting crops that are not receiving subsidies such as greenhouses. The achievements of this Directive are quite questionable (Albiac 2009).

The Water Framework Directive of 2000 relies heavily on economic instruments to achieve the sustainable management of water resources. Water pricing and "full recovery costs" are advanced as the key policy measures. But these water based instruments to abate pollution do not seem to be good enough to curb nitrate pollution since the pollution driver is fertilizer and not water.

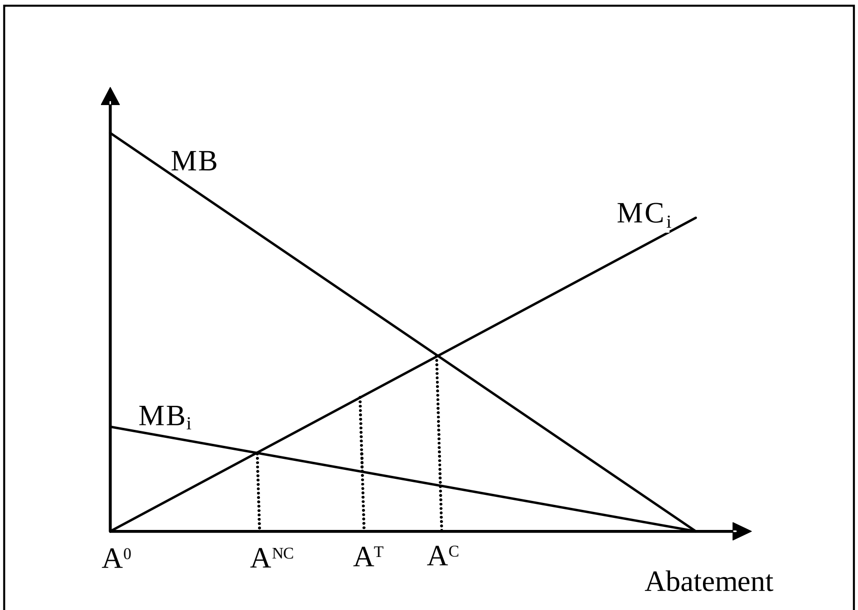
3. Nonpoint pollution control is beyond economic instruments

The economic theory argument explaining the difficulties of previous pollution abatement policies is the following: nonpoint pollution is a common pool "resource" (or public bad), where economic instruments such as taxes and subsidies are likely to fail. Nonpoint pollution policies cannot be just based on pure economic instruments, following the "polluter pays" principle. Pollution abatement measures such as pollution taxes or markets for emission permits are very good for point pollution, but break down with nonpoint pollution.

The key policy issue is that an institutional setting is required to induce farmers' cooperation. Pollution abatement is impossible without farmers' involvement and active support to spur the needed collective action.

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 resource, public good, cooperation among stakeholders, and collective action. The control of nonpoint pollution is unfeasible without these policy concepts, because of the public good aspects of nonpoint pollution. Pollution abatement becomes quite challenging since there are incentives to free riding.

Figure 1. Pollution abatement under non-cooperative and cooperative solutions.



Source: Perman el al. (2003).

The general situation regarding nonpoint pollution in many countries is the absence of any authority or policy. As indicated in the previous section, even the few existing policies in the European Union and the United States are limited, with policy instruments and enforcement mechanisms that seem largely inadequate. The current lack of cooperation in pollution abatement is driven by the structure of incentives, which may lead to the well-known tragedy of the commons and the free riding of polluters (Hardin 1968).

The lack of cooperation results in the Nash equilibrium of the game, while full cooperation would maximize social welfare. Figure 1 illustrates these outcomes from cooperation in pollution abatement (A), using marginal benefit and marginal cost functions of abatement. For each polluter i, MB_i are marginal benefits and MC_i are marginal costs from pollution abatement, while $MB=\sum MB_i$ are total marginal benefits from abatement. Under A^0, there is no effort on pollution abatement. The non-cooperative solution A^{NC} is the Nash equilibrium where polluters equalize individual marginal benefits MB_i with individual marginal costs MC_i. The abatement in the full cooperative solution A^C maximizes welfare, and applies the condition for efficient provision of public goods $MB=\sum MB_i=MC_i$.

The specification of the marginal benefit function requires knowledge on biophysical processes and pollution damages to ecosystems. When this information is not available, the optimum level of abatement A^C is not known. In such a case the alternative is to establish a "reasonable" abatement threshold

A^T, where cooperation implies minimizing total abatement costs across polluters to reach the threshold.

What is the policy message from these game theory outcomes? The European Water Framework Directive relies on economic instruments in application of the "polluter pays" principle. Using economic instruments, such as an emission tax on every individual polluter, the result achieved is the non-cooperative solution. Under this solution A^{NC}, the marginal benefit of abatement is just the tax applied to every farmer $MB_i(A^{NC})$ and the farmer responds by incurring in marginal cost of abatement equal to the tax $MC_i(A^{NC})$.

However, the suitable policy measure should be applied over the set of polluters to achieve cooperation A^C, instead of applying economic instruments to individual polluters that result in non-cooperation A^{NC}. This type of sustainable management calls for control mechanisms designed to induce collective action among stakeholders. The approach to follows is governing the commons by the stakeholders' involvement in the management of nonpoint pollution (Ostrom 2010). Therefore, pollution abatement efforts would be more effective if focused on nurturing collective action and providing the right institutional setting to support it.

4. Nonpoint Pollution Policies in Spain

The analysis of water quality and water scarcity problems is an important topic in Spain because of the pervasive degradation of river basins in recent decades. This topic is politically relevant for the different economic sectors, groups of stakeholders, and public decision makers at state and federal levels. Another reason is the large negative effects that climate change is likely to have on water resources in Spain, aggravating further the current water scarcity and quality degradation problems.

Water policies should be integrated in the climate change strategies and plans, especially in adaptation measures. Reasonable policies should induce stakeholders' cooperation through institutions, in order to achieve the required collective action in protecting the resources and adapting to climate change. Cooperation is a key element in order to improve the allocation of water resources to human uses and the environment. But it is also a key tool in order to improve water quality by abating nonpoint and point pollution emissions.

The responses and adaptation to water scarcity and water quality degradation in Spain during the last twenty years have been shaped by the national water policies and also by the European Water Framework Directive. The main water policies have been the National Hydrological Plan proposal of 1993, the National Hydrological Plan of 2001 modified with the AGUA Project of 2004, the National Irrigation Plan of 2002, the Upper Guadiana Plan of 2008, and the First and Second Sanitation Plans of 1995 and 2008. The European Water Framework Directive was enacted in Spanish legislation in 2003. The Directive does not address water scarcity which is the main issue in Spain, but rather deals with the water quality of water bodies and the attainment of their good ecological status.

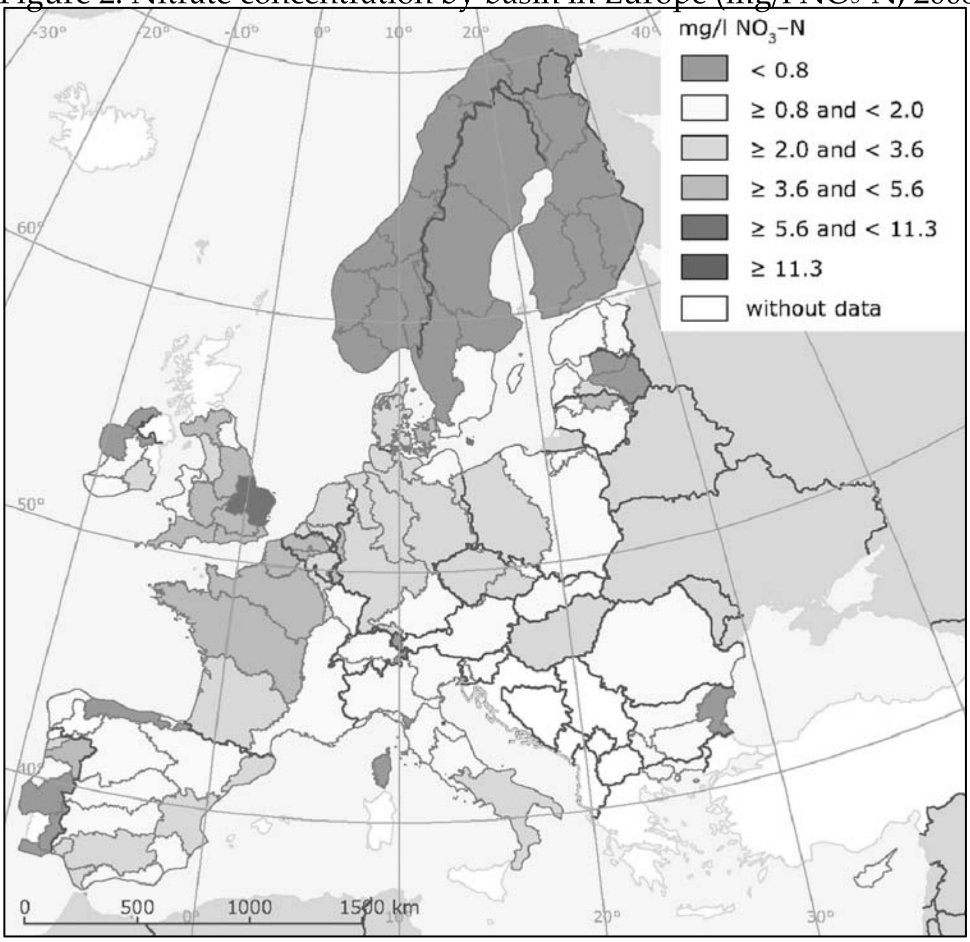
Large-scale aquifer depletion in southern and eastern Spain led to the proposal of considerable water interbasin transfers in both National Hydrological Plans of 1993 and 2001. These large interbasin transfers were met by the opposition of political parties, groups of interest, and donating territories. Finally, the large interbasin water transfers have been abandoned and substituted by the so called AGUA project. This project involves large investments in desalination plants to supply the Spanish southeastern coastal fringe with an additional volume of 600 Mm^3 per year.

The investments of water policy planning in Spain are considerable with the main policies summing up almost 50 billion Euros: 19 billion Euros for the

National Hydrological Plan, 6 billion for the National Irrigation Plan, 3 billion for the Upper Guadiana Plan, and 20 billion for the Second Sanitation Plan. The National Irrigation Plan and the Second Sanitation Plan seem well designed to improve water quality by reducing pollution loads. But other policies embodied in the Upper Guadiana Plan and the AGUA project of the National Hydrological Plan, seem poorly designed or even misguided.

Regarding water quality, it is important to evaluate the quality parameters of Spanish rivers in the European context (Figures 2 and 3). The quality parameters of the main Spanish and European rivers show modest or no improvement despite

Figure 2. Nitrate concentration by basin in Europe (mg/l NO_3-N, 2008).

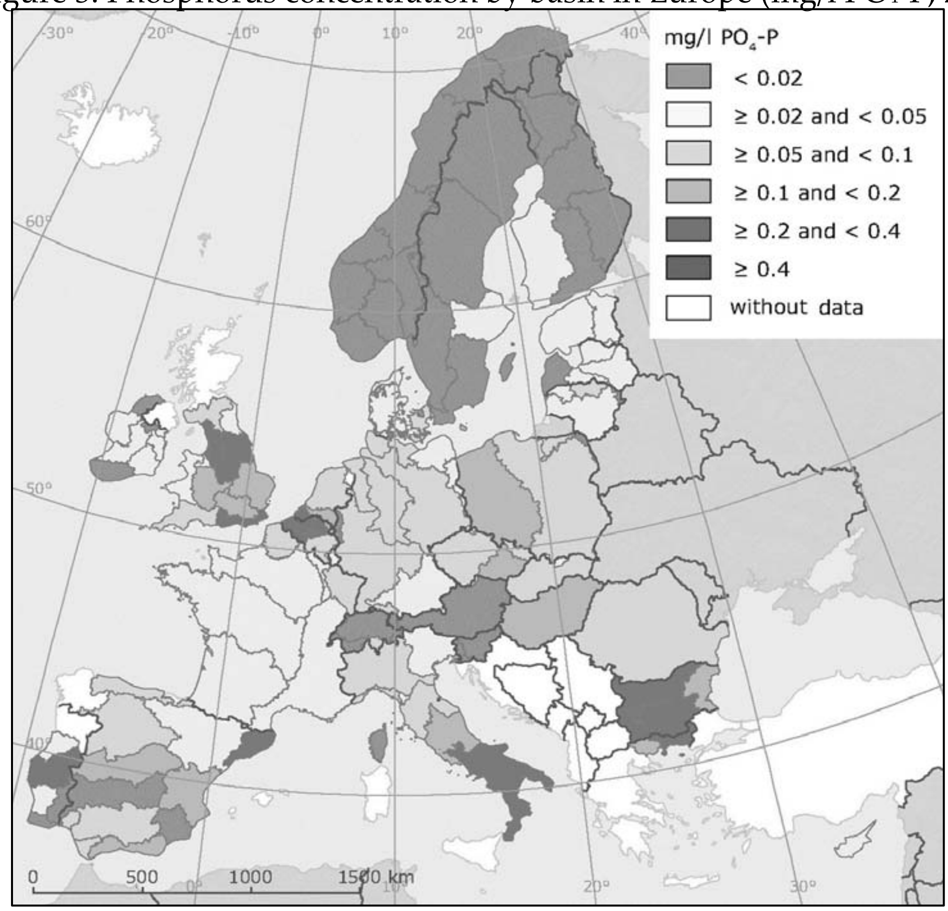


Source: EEA (2011).

the large investments in urban wastewater plants in recent decades. During the last twenty years, these investments have been above 100 billion Euros in the European Union, and close to 10 billion Euros in Spain. There are high nutrient loads in the Guadalquivir, Thames, Seine and Scheldt rivers, and high concentrations of heavy metals in the Seine, Scheldt, Tagus, Guadalquivir and Porsuk rivers (OECD 2008). Another difficulty for policy design is that the knowledge about the impacts of water quality on aquatic ecosystems is very scarce.

It seems that water quality is improving very slowly in Europe, but with some rivers undergoing even quality deterioration. An important pollution reduction should have been achieved in the loads of organic matter, nitrogen and phosphorus because of the urban wastewater treatment plants, and a reduction of heavy metals and chemical substances from industries.

Figure 3. Phosphorus concentration by basin in Europe (mg/l PO_4-P, 2008).

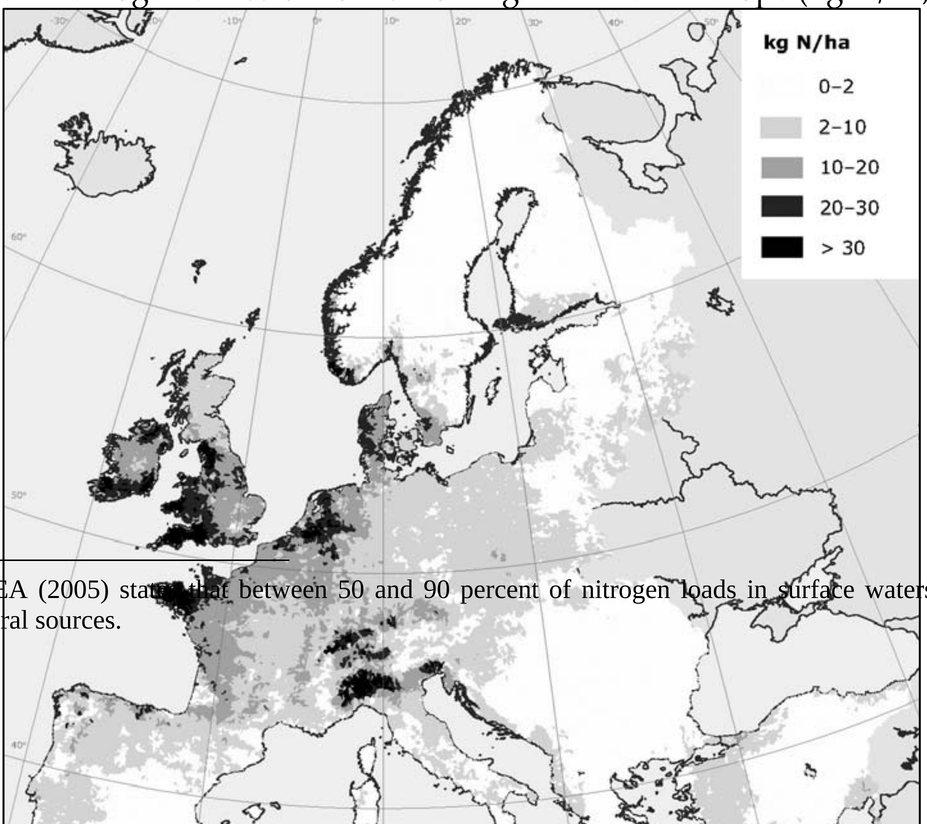


Source: EEA (2011).

The only available historical data series on water quality in rivers is published by OECD (2008). These data show the acute quality deficiencies in European rivers during the last thirty years, which have prevented their ecological recovery. The biochemical oxygen demand has improved in Spain in the beginning of 2000s, and also in the majority of European countries. Pollution by nutrients does not improve in Spain or in the majority of European countries, and even worsens in some countries. Information on heavy metals is very scarce, and the few available data indicate some reduction in Spain and other countries by the end of the 1990s.

A possible explanation for the poor performance of nutrient loads is that the agricultural nonpoint pollution of nitrogen and phosphorus is not controlled,[2] and these emissions compensate the presumed reductions achieved with the wastewater treatment plants (Figure 4). Another factor could be the increase in nonpoint pollution as a consequence of urban sprawling.

Figure 4. Nitrogen emission loads from agriculture in Europe (kg N/ha, 2009).



[2] The EEA (2005) states that between 50 and 90 percent of nitrogen loads in surface waters are from agricultural sources.

Source: EEA (2011).

In Spain, many public decision makers and environmentalists are in favor of supporting the more profitable and input intensive irrigation agriculture and the dismantling of the less profitable and less input intensive irrigated agriculture of inland Spain. However, profitable irrigated agriculture is the main responsible of the acute pressure and severe degradation of aquatic ecosystems.

The highly profitable crops are very intensive in capital and inputs, and generate pollution loads much larger than the low profit extensive crops of inland Spain. In the intensive greenhouse agriculture, fertilization is around 900 kg/ha of N, 400 of P_2O_5, and 1.200 of K_2O, whereas cereals under irrigation in inland Spain are fertilized with around 100 kg/ha of N (300 for maize), 70 of P_2O_5, and 40 of K_2O. In relation to pesticides, the intensive greenhouse agriculture uses around 40 kg/ha of products or 5,000 liters/ha (not including soil disinfection). In extensive irrigated agriculture producing cereals, the pesticide use is around 3 kg/ha of products or 370 liters/ha (herbicides and insecticides).

This water management approach of supporting highly profitable crops follows the motto “more money per drop of water”. It is the foundation for promoting water pricing as the silver bullet to solve water scarcity and quality degradation in irrigation. Most decision makers in the European Union institutions, their counselors, and many think tanks across Europe embrace this approach.

In the case of Spain, the most severe scarcity and quality problems occur in the Júcar, Segura, South and Guadalquivir basins, all of them located in the eastern and southern Iberian Peninsula. There is a dual situation in the Spanish irrigated agriculture. The eastern and southern areas have a quite profitable intensive agriculture, with severe pollution problems. On the other hand, inland Spain has an extensive agriculture not as profitable, but with much lower contamination problems.

The agriculture in inland Spain is based on collective surface irrigation systems and low profit crops, causing a moderate degradation of water resources. Basin authorities are capable to enforce the minimum ecological flows in surface water bodies, with the participation of users in the watershed boards. In the intensive agriculture of the eastern and southern regions, the control on water extractions is much more tenuous because of the importance of individual groundwater pumping. Groundwater users are not involved in watershed boards, and therefore extractions are beyond the enforcement capabilities of basin authorities. The increasing pressures in the eastern and southern regions are the consequence of the lack of control over groundwater extractions. The ensuing massive overdraft creates serious problems of water quality and quantity in entire river basins, with large negative impacts on aquatic ecosystems (Esteban and Albiac 2011).

Nutrient pollution results from the use of fertilizers in the Spanish agriculture, which consumes 1.05 million tons of nitrogen (N_2), 0.56 million tons of phosphorus (P_2O_5), and 0.43 million tons of potasium (K_2O). By state, Castilla-León, Andalucia y Castilla-La Mancha have substantial acreage under cultivation with a large consumption of fertilizers. However, the basins in Spain displaying the worst concentration of nutrients in rivers and streams are the Júcar, Gualdalquivir and Cataluña basins for nitrates, and the Júcar, Cataluña, Sur and Tajo for phosphorus. The aquifers with the higher concentration of nitrogen are located in the Guadalquivir and Júcar basins, and the aquifers with the higher concentration of salinity are located in the Sur and Segura basins (Hernández et al. 2010).

There are two general policy approaches in Spain to deal with quantity and quality problems faced by irrigated agriculture in the eastern and southern regions. One is the traditional water policy approach based on expanding water supply. The other is the approach based on new water management initiatives. These initiatives are based on instruments such as abstraction limits on surface and subsurface waters, revision of water rights, water reuse and regeneration, and water pricing and water markets. Following the Water Framework Directive most of the policies are based in increasing water prices up to full recovery costs, or some other economic instrument such as water markets. But the problem with these water policies is that economic instruments seem to be inefficient to control nonpoint pollution or to deal with water scarcity in irrigation (Albiac et al. 2009).

There are several studies by Orús et al. (2000), Uku (2003), Martínez and Albiac (2004 and 2006), Mema (2006), and Esteban (2010), which analyze measures to control nitrogen and salinity pollution from irrigation in the Ebro basin located in northeastern Spain. The empirical results from these studies challenge the current European Nitrates Directive, which is based on penalizing the Common Agricultural Policy (CAP) payments of uncomplying farmers drawn by chance. This mechanism seems inadequate and the empirical results point in a different direction. An example is the large pollution reduction achieved with the Spanish National Irrigation Plan, which is documented in the studies by Uku (2003) and Mema (2006).[3] The empirical results from these studies are very relevant for the design of the program of measures of the Water Framework Directive. These results highlight that the water pricing instrument promoted by the Water Framework Directive is inadequate to reduce nitrogen and salinity emissions. The demand of irrigation water does not respond to prices, and therefore water pricing is far from being an efficient measure to abate pollution. The modernization of irrigation systems is a very interesting measure, because it achieves substantial pollution abatement at quite reasonable costs for farmers in terms of net income losses.

Mema (2006) indicates that irrigation modernization reduces the use of irrigation water and fertilizers, achieving a 40 percent fall in nitrate emissions (7,000 t) and a 50 percent fall in salinity emissions (500.000 t). These results are confirmed in the studies by Martínez and Albiac (2004 and 2006), where the dynamics of nitrogen in the soil are taken into account in analyzing nitrate pollution, presenting results for different crops and types of soil. These findings demonstrate that water pricing is the worst possible measure to abate nitrate pollution from agriculture. As indicated above, the type of instrument for nonpoint pollution abatement cannot be an individual incentive on each farmer separately, because then the non-cooperative solution is achieved (or Nash equilibrium, see figure 1 above). What is needed is a cooperative solution, where farmers choose the pollution abatement with the higher collective welfare. The empirical results by Esteban (2010) on salinity pollution show that the best abatement instruments are those that induce farmers' cooperation based on measurable pollution load limits within the appropriate institutional setting.

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[3] The study by Mema covers 380,000 ha of irrigated acreage in the middle Ebro, where 2,500 Mm^3 of water are used with 900 Mm^3 of returns, which draw large loads of nitrates and salinity. Annual nitrogen pollution loads are close to 19,000 t ($N\text{-}NO^3$), coming from nitrogen fertilizers. Salinity pollution loads are around one million tons, mostly from the Flumen, Cinca and Arba watersheds. The control measures analyzed include taxes and quantitative limits on irrigation water and nitrogen fertilizer, taxes on nitrates and salinity emissions, and investments in upgrading the irrigation systems.

Cooperation between water users is a necessary condition to achieve a sustainable management of water resources. Current policies consist of compensating interventions using market instruments for private benefits of individual farmers who cause the damages. These policies are not efficient and quite expensive to implement because of the information problems. Collective action approaches achieve higher efficiency levels as shown in section 3, and require less information. This argument is supported by Byström and Bromley (1998), who propose an economic incentive promoting cooperation between farmers to solve nonpoint pollution problems. They suggest a tax instrument over all farmers if they exceed a threshold previously established by the regulatory agency.

The implementation of cooperation is not an easy task, and the difficulties increase with the number of agents and their heterogeneity. But cooperation is feasible under the appropriate institutions and using the correct instruments, as demonstrated by the case of the Eastern La Mancha aquifer in Spain. The large extractions during the last 30 years caused an important depletion of the aquifer. The pressures from downstream users and the possibility of a ban of extractions from the basin authority made farmers cooperate in groundwater extractions. The creation of the institutional setting (Water User Association) made cooperation feasible and it is an example of successful cooperation among stakeholders.

The task of abating nonpoint pollution is quite difficult for water authorities not only in Spain or Europe, but all over the world. In Spain, water quality and water scarcity problems are important and intertwined issues, aggravated by the pervasive degradation of river basins in recent decades. The pending tasks for water basin authorities are a true challenge, because both irrigation water and agricultural nonpoint pollution are common pool resources which have also significant environmental externalities for ecosystems. Furthermore, the effects of climate change are going to reduce the available resources in the coming decades, especially in the more arid regions of the Iberian Peninsula. The sustainable management of water resources by basin authorities would entail setting up the right incentives. These incentives have to be capable of bringing about the cooperation among agents managing the resource, in order to achieve the needed collective action in the protection of water resources and dependent ecosystems.

4. Conclusions

The control of nonpoint source pollution is a complex task because of the difficulty in identifying the polluting agent, and the exact location and amount of emissions at the source. There is a large body of literature addressing water resources scarcity and quality problems from theoretical and empirical perspectives, with recommendations to engage the widespread degradation of water bodies. Within the context of the pervasive and escalating mismanagement of water resources worldwide, this article explores the reasons that could explain the failure of water policies in reducing or dampen down the degradation of water resources.

Current pollution policies consist of using economic instruments to compensate the private benefits of agents causing pollution, or using public funds in financing investments in pollution abatement technologies. But such policies alone do not seem effective in curtailing the large nonpoint pollution loads in river basins around the world. What might be useful is the cooperation of stakeholders managing the water resources. The economic argument supporting this collective action approach is that water resources are mostly common pool resources, requiring cooperation rather than just economic instruments that are harder to implement in the case of public goods.

The Water Framework Directive relies heavily on economic instruments, by advancing water pricing and "full recovery costs" as the key policy measures. But water pricing does not seem to be good enough to curb nitrate pollution, since the pollution driver is fertilizer and not water. This reliance of the Water Framework Directive on economic instruments is based on the "polluter pays" principle, where economic instruments such as emission taxes on individual polluters result in non-cooperative solutions with insufficient abatement. However, nonpoint pollution requires suitable measures applied over the set of polluters to induce cooperation.

In Spain, water quality and water scarcity problems are important topics because of the unrelenting degradation of river basins. Another reason is the large negative impacts that climate change would have in Spain, aggravating further the current water degradation problems.

The basins in Spain with the higher concentration of nutrients in rivers and streams are Júcar, Gualdalquivir and Cataluña basins for nitrates, and Júcar, Cataluña, Sur and Tajo for phosphorus. The aquifers with higher concentration of nitrogen are located in the Guadalquivir and Júcar basins, and the aquifers with higher concentration of salinity are those of the Sur and Segura basins.

Results from studies in northeastern Spain raise questions on the European Nitrates Directive, based on penalizing uncomplying farmers drawn by chance. This mechanism seems inadequate because it only applies to crops over aquifers declared officially polluted, not to cultivation over whole basins. The enforcement mechanism is too weak and unable to induce cooperation, and leaves out very polluting crops not receiving subsidies. These studies show that the Spanish National Irrigation Plan has achieved large reductions of pollution loads at reasonable costs to farmers. These findings are quite relevant for the program of measures of the Water Framework Directive, because they show that water pricing is far from being an efficient measure to abate pollution. The best abatement instruments for nutrients and salinity pollution are those that induce farmers' cooperation based on measurable limits of pollution loads. Pollution abatement would be more effective if focused on nurturing collective action, and providing the right institutional setting to support it.

The control of nonpoint pollution from agriculture is not an easy task, and the conventional economic instruments being implemented are not achieving good results. Successful policies to reduce emission loads involve the cooperation among farmers, because of the lack of information on pollution at the source and on the transport and fate processes. Under cooperation farmers would reveal the information required to achieve optimum abatement.

Institutions play an essential role to promote cooperation and create rules of enforcement among farmers. Without the involvement of stakeholders in institutions, the public authorities lack legitimacy and knowledge of local conditions. The achievement of collective action resolves the information problem, while decreasing the transaction and administrative costs of policies.

The case of the Eastern la Mancha aquifer in Spain is a good example of cooperation working among farmers to care for the aquifer. We think that this is an important accomplishment, and eventually some lessons learned from this experience could be relevant for the design of nonpoint pollution abatement policies.

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