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The European Water Framework Directive and sustainable water management

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Abstract

The scarcity and degradation of water resources is an important environmental problem in Europe. The use of water by the different economic sectors creates scarcity in some regions, and a widespread water quality degradation from point and nonpoint pollution. Water scarcity is serious in Southern countries, with a strong demand during summer for irrigation and tourism. Despite regulations and large investments in water treatment plants, water quality degradation remains high in many river basins. The improvement in water management requires better information and knowledge on surface and ground water and on their associated ecosystems. These tasks need time and resources, and the lack of data and knowledge on the underlying biophysical processes in the use of water resources, precludes and adequate and sustainable management. This knowledge is essential for designing reasonable control measures, such as the ones required by the Water Framework Directive.

Keywords: European Water Framework Directive, water scarcity, water quality degradation.

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Introduction

The problem of water stress and water quality is one of the main environmental issues in Europe, together with climate change, air quality, biodiversity and soil quality. With respect to water quantity, withdrawal of water resources in Europe is above 20 percent of renewable freshwater resources. The major pressures on water quantities occur during summer in Southern countries, because of irrigation demand and tourism activities. In the coming decades, the likely increase of withdrawals and climatic change will result in more intensive pressures on water quantities in these Southern countries.

With respect to water quality, the problems are driven by pollution of water resources. The pollutants are nutrients and organic matter, and dangerous substances such as heavy metals and chemical compounds. The nitrate emissions from agriculture have decreased somewhat in the last decade in most rivers, but there still remaining problems of eutrophication and pollution of drinkable water. There are less rivers strongly polluted as a consequence of reduction in organic matter loads, the use of detergents free of phosphates, and the operation of new treatment facilities in urban centers. However, around 20 percent of European surface waters still have severe pollution problems.

The European Framework Directive, approved in 2000, is an important initiative of the European Union, intended to protect all continental, subsurface and coastal waters. It has a great potential to solve water scarcity and water quality problems in Europe by 2021 when the first management cycle deadline ends, and by 2027 which is the final deadline for meeting the objectives.

However, there are two aspects in water resources management that are difficult to solve and may hinder the attainment of the objectives. One is the sustainable management of aquifers and the other is nonpoint pollution control, and the cause of the difficulties is that they are common pool resources characterized by serious problems when trying to implement policy measures that work.

The design of reasonable measures for the management of aquifers and nonpoint pollution requires information and knowledge on biophysical processes linked to aquifers dynamics and pollution transport and fate. Generating this information and knowledge is demanding in resources and takes time. The design of measures by the water authorities must also take into account the strategic behavior of stakeholders in the design of measures. Aquifer management and nonpoint pollution control involve cooperation among stakeholders (Albiac et al. 2007), and this is a daunting task for water authorities because of the difficulties in managing common pool resources.

Water Demand by Sectors and Water Scarcity Problems

Water abstractions in Europe for all uses reach at present 307,000 hm^3, of which 115,000 hm^3 are used in agriculture, another 104,000 in cooling and electricity production, 53,000 for urban demand and 35,000 for industrial demand (Table 1). Water for cooling and electricity production

Table 1. Water use in selected European countries (2001).

Country	Total water extractions (hm^3)	Urban use (hm^3)	Industrial use (hm^3)	Irrigation (hm^3)
Bulgaria	5.800	1.100	300	900
France	33.500	5.800	3.600	4.800
Germany	40.400	5.500	5.600	600
Greece	8.900	900	100	7.700
Hungary	5.600	700	200	500
Italy	56.200	10.100	9.600	25.900
Poland	11.600	2.200	600	1.000
Portugal	9.900	800	400	8.800
Romania	7.300	2.500	900	1.000
Spain	37.700	3.800	1.400	24.600
Turkey	39.800	4.300	3.500	31.000
United Kingdom	15.900	6.300	1.600	1.900
Total Europe	307.200	53.300	34.900	115.100

Source: EEA (2005b), INE (2004, 2005), IFEN (2005).

returns to water courses with small changes in quality. However most water is used for agricultural, urban and industrial purposes, which degrade the quality of water returns. These consumptive uses generate water stress in many European regions, and problems of point and nonpoint pollution of water courses. There has been a reduction of total water abstractions in the last decade, although tendencies differ widely among sectors. The likely outlook for next decades is increases in water use by agriculture and industry, strong reductions for cooling and electricity production, and stability in urban water use (EEA 2005a).

Agriculture accounts for more than a third of total water extractions, and the volume of irrigation water will grow to cover the expansion of irrigated acreage in the South of Europe, Hungary, and EU candidate countries such as Turkey. Economic development may increase the use of water by the industrial sector, in particular in Eastern countries and EU candidates. The use of water for cooling and electricity production will be cut by half, as a result of more efficient refrigeration systems in power generating facilities. The new tower cooling systems reduce the amount of water by two orders of magnitude per megawatt-hour, compared to current refrigeration systems with single circulation. Urban demand represents 20 percent of abstractions, and its evolution will be stable since it depends on countervailing factors such as household size and income, water prices, and technological change that improves water efficiency.

In Central and Northern European countries such as Germany, France and UK, the main water abstractions are for power generation, which will fall strongly in coming decades, while industrial use may increase. In contrast, the main water use in Southern countries is irrigation, with join abstractions by Spain, Italy and Turkey above 80,000 hm^3 (Table 1). Irrigation water demand would increase as a consequence of the expansion in irrigated acreage, and also because of the impact of climatic change on water crop requirements in the coming decades. Urban and industrial water demand will increase en Eastern countries and Turkey, following the rises in household incomes and industrial activities up to Western countries' levels.

In summary, Northern and Central European countries do not face problems of severe water stress, and their main extractions are used for power generation which return to watersheds. These extractions are going to decrease substantially and the outlook for next decades is less water stress in these regions. This is the case for the Rhin, Elbe, Loire, Vistula, Oder, Rhone and Garonne. The more serious problems of water scarcity take place in the arid and semi-arid regions of Southern Europe, such as the southern half of the Iberian and Italian peninsulas, and the Anatolian peninsula. The use of irrigation water is very large in these regions, and scarcity problems will worsen because of the expansion of irrigated acreage and the increase of water demand for tourism activities in coastal zones. In the coming decades, the effects of climate change would have also a negative impact on available water resources in Mediterranean countries.

Water Quality Problems

Surface, subsurface and coastal waters have different uses, including domestic, industrial, agricultural irrigation, recreation, and support of aquatic ecosystems. Human activities are linked to water and land resources and generate wealth, but these activities degrade also water quality through point and nonpoint pollution. To cope with this water degradation, different quality standards have been implemented depending on the final use given to water. There are two alternatives to reach the appropriate quality standard: one is to reduce the pollution loads at water courses, and the other is water treatment of the waters being used. The more demanding standards are those for drinkable water.

The volume of wastewater increased considerably during the last century, due to industrial development and the growing consumption of households. The effects of discharge of residual waters depend on the sewage network and treatment facilities, the industrial production processes, and the type of products consumed by households. In recent decades, there has been a surge in the urban population linked to sewage networks and treatment facilities, although there are considerable differences among European regions. Almost all the population in Northern European countries is connected to water treatment facilities, but only half the population is connected in the new member countries of the European Union.

The Urban Wastewater Treatment Directive, passed in 1991 and modified in 1998, required building depuration plants with secondary treatment in urban centers with population larger than 15,000 inhabitants by 2000, and with population larger than 2,000 inhabitants by 2005. The Central and Northern European countries have already depuration plants with secondary and tertiary treatment. Tertiary treatment is more advanced than secondary treatment, and reduces the emission loads of the nutrients phosphorus (up to 60%) and nitrogen (up to 90%). Tertiary emission loads of phosphorus and nitrogen are 0.1 y 2 kg per person and year, respectively. Countries in the South of Europe, together with France, Belgium and UK, only have depuration plants with secondary

Table 2. Water quality in selected European rivers (average 1999-2001).

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	0,2*	0,2	0,02	0,1	0,01	0,15	0,58
Sweden	Dalalven	0,1*	0,1	0,02	0,5	0,02	0,37	1,46
Denmark	Gudena	2,6	1,3	0,10				
UK	Thames	2,0	7,4	1,36	3,3	0,10	1,27	6,63
Netherlands	Maas	2,6	5,2	0,21	3,4	0,21	2,34	4,47
Belgium	Meuse	2,2*	2,5*	0,70*	3,2*		1,00*	2,05*
Germany	Rhein	2,9*	2,6	0,14	3,8	0,20	2,99	8,59
	Elbe	8,8*	3,3	0,19	2,5	0,23	1,76	5,42
	Weser	2,2	4,0	0,17	4,5	0,20	2,03	4,40
France	Loire	3,7	3,3	0,26		0,37*		
	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*	2,27*		5,73*
	Ebro	5,0	2,5	0,20	7,7*	0,23*	0,64	1,61
	Guadiana	2,6	2,0	0,69*				
Portugal	Tejo	2,3	1,0	0,24	24,3*	5,00*	22,33	1,67
Italy	Po	2,2	2,1	0,23				
Greece	Strimonas	1,3*	1,4	0,08		0,64		
Turkey	Porsuk	1,2	1,2	0,07	4,3	5,00	6,33	5,00

Source: OECD (2005). The symbol * indicates that the average is for years 1993-1995. The Oxygen Biochemical Demand (BOD) measures pollution by organic matter, and water is considered drinkable for BOD between 0.75 y 1.50 mg O_2/l.

treatment, and the emission loads of phosphorus and nitrogen are 0.4 and 3 kg per person and year, respectively (EEA 2005a).

The Urban Wastewater Treatment Directive has achieved a significant reduction of polluting emissions on surface waters, curbing the environmental damages on aquatic ecosystems. However, the level of emissions from treatment plants remains high and may cause eutrophication problems in vulnerable areas.

The number of dangerous substances that may affect water quality is high, with very different sources. The manufacturing industry is responsible for most of the emissions of heavy metals (lead, mercury, cadmium), while other substances such as nutrients and pesticides come basically from agriculture. A few number of substances have been regulated in the last decades resulting in a fall of their emissions, but the emissions abatement is not general. Table 2 shows pollutant concentrations in selected European rivers. There are important pollution loads by nutrients (nitrates and phosphorus) in rivers Thames, Guadalquivir and Seine, and a high concentration of heavy metals in rivers Seine, Tajo, Guadalquivir and Porsuk.

There has been a reduction of phosphates in detergents used by households in last years, with a fall in the phosphorus load in treatment facilities from 1.5 to 1 kg per person and year. Meanwhile, the nitrogen load has remained constant at 5 kg per person and year. The phosphorus loads received by water courses originates from urban and industrial point sources and agricultural and livestock nonpoint sources, while most of the nitrogen loads come from nonpoint agricultural and livestock sources.

Although information on the status of aquatic ecosystems in Europe is quite scarce, it seems that the water quality in some rivers is improving. The improvement results from the abatement of emissions of organic matter and phosphorus linked to new treatment facilities in urban centers, and the abatement of heavy metals and chemical substances undertaken by industries. However, the nitrogen and phosphorus loads coming from agricultural nonpoint pollution are not controlled, and the relative importance of this pollution is increasing. Thus, between 50 and 90 percent of the nitrogen loads in surface waters comes from agriculture. Pollution problems from agricultural sources are characterized by the uncertainty of the source location, and by the impossibility (or very high cost) of measuring the emission loads of each farmer. This question has important implications for the design of pollution abatement measures, since point pollution control measures are useless, and more sophisticated measures are required.

The intensive use of fertilizers is a severe problem in Central and Northern European countries. Fertilizer consumption in these countries is above 150 kg/ha, while consumption in Southern countries is below 150 kg/ha. Fertilizer consumption corresponds to the sum of nitrogen (N), phosphorus (P_2O_5) and potasium (K_2O). Fertilizer consumption is above 200 kg/ha in Germany, Belgium, France, Netherlands, Ireland and UK. For example, the nitrogen surplus in soils is 215 kg/ha in Netherlands and 100 kg/ha in Belgium and Germany, compared to 40 kg/ha in Spain (EEA 2003), and this surplus is the origin of the nitrate pollution of water media. Therefore, the problems of water quality from agricultural nonpoint pollution are more serious in Central and Northern European countries, while the main problem in Southern countries is water scarcity.

Concern on water scarcity and water quality has resulted in the development of an extensive body of rules and regulations in the European Union: the Water Framework Directive (2000) and the directives of Drinking Water (1998), Integrated Pollution Prevention and Control (1996), Urban Wastewater Treatment (1991), Nitrates (1991), Dangerous Substances (1976, integrated in WFD in 2006), and Bathing Water Quality (2006).

This legislation has attained important results in curbing point pollution from urban and industrial sources, due to the construction of treatment facilities in urban and industrial centers, and the fall in the emissions of dangerous substances from industrial processes. The consequence has been an improvement of the quality of surface and coastal waters, and less pressure on aquatic ecosystems. However, the problems of agricultural nonpoint pollution remain, in particular those of nutrients and pesticides (European Commission 2002), and also the problems of water scarcity in Mediterranean countries.

The Water Framework Directive

The European Union approved an important legislation to protect water resources, the Water Framework Directive, which was subsequently enacted in European Union member countries. The Directive creates a common framework of action in water policy, whit the objective of protecting continental surface waters, transitional waters, coastal waters and subsurface waters. This protection intends to avoid any further degradation of water quality and to improve the aquatic ecosystems conditions, promote the sustainable use of water preserving in the long run the available water resources, protect and improve water media through the abatement of emissions and discharges, reduce gradually the pollution of subsurface waters, and finally contribute to curtail the effects of floods and draughts. Water management is organized at the level of river basin district. The Directive aims at securing a sufficient supply of surface and subsurface water in good condition, attaining a balanced and equitable supply, and contributing to a significant water pollution abatement.

European countries have defined the river basin districts and basin authorities by 2003, and have completed the characterization of pressures, impacts and economic analysis of basins by 2004. The results have been used to evaluate the impact of human activities and to identify the areas requiring special protection, guiding the elaboration of the basin management plans and the programs of measures by 2009. Water pricing policies will be introduced in 2010, and the programs of measures will be operational in 2012, in order to reach the environmental objectives in 2015.

The Directive introduces the principle that water prices should be close to full recovery costs, to improve the efficiency in the use of water. The full recovery cost must include the abstraction, distribution and treatment costs, and also the environmental costs and the resource value. The Directive establishes a combination of emission limits and water quality standards, with deadlines to achieve appropriate quality for all waters ("good ecological status"). Water management should be based on basin districts and stakeholder participation, and water prices paid by users should approach full recovery costs.

The principle of cost recovery is one of the key elements in the economic analysis advocated by the Directive. The increase in water prices up to recovery costs is a very interesting measure in the industrial and urban sectors, since the industrial and urban water demand respond to water prices, and a higher efficiency in water use is obtained. To the contrary, water demand in irrigation does not respond to water pricing, and this fact questions full recovery costs in irrigated agriculture as a valid alternative for water quantity assignment.

Setting some minimum price levels for irrigation water will make farmers understand that water is not a free good. However, using water pricing as a mechanism to allocate water in irrigation is questionable, and Cornish and Perry (2003) and Bosworth el al. (2002) show compelling results from the literature and from empirical studies that demonstrate the impossibility of using water prices to assign water in irrigation, both in developed and developing countries. As alternative to water pricing, these authors indicate that introducing water markets is much more reasonable, although difficult to implement. Therefore, the emphasis of the Directive on water prices is useless to reduce irrigation demand in Mediterranean countries, and Spain is a clear example of this as discussed in the next section.

Table 3. Water resources extraction and utilization by sector in 2002 (hm^3).

	Total	Agriculture	Water companies	Other sectors	Cooling
Extractions	38,200	25,200	5,400	1,400	6,200
Surface	32,500	20,900	4,200	1,200	6,200
Ground water	5,700	4,300	1,200	200	
Network losses	5,500	4,500	1,000		
Utilization					
Agriculture	20,700	20,700			
Households	2,600		2,600		
Other sectors	3,200		1,800	1,400	
Cooling	6,200				6,200

Source: INE (2006) and Martínez & Hernández (2003). Figures do not include hydropower extractions, estimated by MIMAM (2000) at an average of 16,000 hm^3.

In order to reach the objectives of the Water Framework Directive, the measure of choice for water scarcity caused by urban and industrial demand is water pricing. Collective irrigation systems based on dams and canal networks should be controlled through command and control measures, while irrigation districts based on individual pumping from aquifers need sophisticated incentives schemes, that entice the cooperation of farmers in water conservation.

Additional measures against scarcity are reutilization of water from treatment plants and seawater desalination, although their use is quite limited at present. Another aspect is improving the conveying and distribution networks, since their condition affects largely total water extractions required to cover the demand of water sectors. Water losses in channeling networks are substantial in many European countries. Upgrading the conveying facilities would imply large savings but also large investments.

Applying the Water Framework Directive: the case of Spain

Water resources extraction and utilization by sector in Spain are presented in table 3. Extractions are close to 40,000 hm^3, of which 6,200 hm^3 are used for cooling in electricity production, and 32,000 hm^3 cover the demand from irrigation, water supplying companies and other industrial and service sectors. Losses in primary and secondary distribution networks are large and reach 5,500 hm^3. Household demand is 2,600 hm^3 with an average price of 1 €/m^3, and industrial and service demand is 3,200 hm^3 with an average price of 0.25 €/m^3. Net irrigation demand is 20,700 hm^3 and prices are related to the type of agriculture. In inland irrigation areas with collective systems of dams and canals, and field crops of low profitability, prices are below 0.06 €/m^3. In the irrigation areas of eastern and southeastern Spain with individual pumping from aquifers and high profit crops, the rank of prices is between 0.09 and 0.21 €/m^3.

The growing pressure of these economic activities has created problems of water scarcity and quality degradation, mostly linked to groundwater. The more severe problems are located in southeastern Spain, with pressures coming from agriculture, urban sprawling and tourism on the Mediterranean coast. In inland Spain, surface water resources are under the effective control of basin authorities that manage resources wisely.

The European Water Framework Directive approved in 2000 was enacted in the Spanish legislation in 2003, just after approval of the Spanish National Hydrological Plan (2001) and National Irrigation Plan (2002). The National Hydrological Plan involved large investments (19 billion euro) aimed at increasing water supply for agricultural, urban and industrial users. Its main project was the Ebro interbasin transfer from northeastern to southeastern Spain, to alleviate the severe degradation of water resources in the area. The National Irrigation Plan involves investments (5 billion euro) to modernize the largely outdated irrigation facilities, in order to save resources, enhance competitiveness and reduce pollution.

The National Hydrological Plan was subsequently modified in 2005, substituting the large Ebro water transfer that was its main project, by the AGUA project based on expanding water supply through seawater desalination. Both versions of the National Hydrological Plan, with the Ebro transfer or with the AGUA project, maintain the traditional approach of expanding water supply.

The National Irrigation Plan has a good potential of saving water and curbing pollution through investments in advanced irrigation technologies. These investments do not guarantee the solution to all problems, but it is obvious that technical innovations in irrigation systems facilitate the private and public control of water quantity and quality. Realizing the potential of the National Irrigation Plan will require strong coordination between water authorities and irrigation water user associations.

One reason for coordination is the issue of water returns after investing in networks and plot irrigation systems. Water losses in distribution canals and plot irrigation systems return to watersheds, and when water losses are reduced through investments in upgrading networks and irrigation systems, the problem may appear that farmers use the saved water in more water demanding crops or in expanding irrigation land. The consequence could be an increase in evapotranspiration and the reduction of water flows in watersheds. The solution is reducing water concessions to countervail the eventual evapotranspiration increases.

Water resources degradation in southeastern Spain is driven by the pressure of intensive agriculture based on individual abstractions from aquifers, together with pressures from urban development and tourism over the Mediterranean coast. Aquifer overdraft reaches 700 hm^3, in the Júcar (160), Segura (220), Sur (70), and upper Guadiana (220) basins. The massive overdraft is the consequence of decades of ground water mismanagement, despite the fact that ground water was declared public domain in 1985. Registration of both concessions and private rights of ground water is far from completed, and the number of illegal wells could be above one million. In contrast, water scarcity and degradation is rather moderate in inland Spain because irrigation is based on collective systems: basin authorities control concessions, river flows and dam reserves, while irrigation user associations manage irrigation districts. The experience and competence of this institutional setting ensures ecological flows, and the management of droughts and floods.

The basin authorities in southeastern Spain do not control the number of wells or the volume of individual extractions from aquifers linked to very profitable crops, and hence they can not impose recovery costs. Furthermore, the required price level to curb demand in these areas is above 3 €/m^3, which is politically unfeasible (Albiac et al. 2006). To the contrary, basin authorities may impose any water price in the areas of inland Spain based in low profitable crops, because they have absolute control in collective irrigation systems. But the question is then the following: why they should play around allocating water through water pricing when they can make direct and wise water allocations?.

Another hurdle for applying water pricing in irrigation comes from the results of the studies by Martínez and Albiac (2004 and 2006), showing that water pricing is the less cost-efficient measure to abate nitrate pollution from agriculture.

There are some examples of unconvincing water policies being applied in Spain. One is the Plan of the Upper Guadiana, currently under discussion. The Plan of the Upper Guadiana aims at curbing overdraft in the Western La-Mancha Aquifer and recovering the Tablas de Daimiel natural park, one of the main wetlands in the country. Previous efforts to sanction illegal abstractions were turned down by the central Spanish administration, which implies sending the wrong signal not only to those exploiting illegal wells but also to those with legal wells but pumping in excess and depleting the aquifers. Instead of curtailing abstractions, the plan anticipates investments of 4 billion euro to eliminate 220 hm^3 of overdraft. What is surprising in this enormous investment is that no economic valuation study has been undertaken on the environmental damages caused by the loss of this wetland, that could justify the large investments. Furthermore, the large investments in the Upper Guadiana will not work without careful designed incentives to gain farmers' cooperation. If the plan approach is generalized to the 500 hm^3 of aquifer overdraft in the Júcar, Segura and Sur basins, then the investments needed would amount to 10 billion euro.

A second example of a questionable water policy is the current AGUA project. The AGUA project includes investments of 1.2 billion euro to build desalination plants and expand supply by 600 hm^3, of which 300 hm^3 are for irrigation purposes in the coastal fringe. Although there is a potential irrigation demand in the area from greenhouses and other high-profit crops, the pumping costs are much lower than desalination costs, and farmers will not buy desalinated water. Public investments in desalination are only justified if basin authorities are able to strictly enforce a ban on aquifer overdraft, forcing farmers to buy desalinated water. But the solution found by the water authorities is subsidizing desalinated water up to the level farmers are willing to pay (pumping costs).

An aspect of water management in Spain that should be stressed here is the institutional, technical and organizational competence of basin authorities dating back one hundred years. Basin authorities in Spain (Confederaciones Hidrográficas) have a richness of information which is lacking in most European countries, and they are very competent in managing surface water. There is also a high level of competence in the water business sector (construction, distribution, depuration and desalination) and in the dynamic irrigation agriculture of southeastern Spain.

The problem for achieving a sustainable water management in Spain is not a lack of technical capacity, physical capital or human resources, but the absence of political will in the design and implementation of reasonable measures. Solving the degradation and mismanagement of water resources in southeastern Spain is the key issue for moving towards a sustainable management of water resources in Spain. Any supply side policy of expanding water availability, such as the former Ebro interbasin transfer or the current AGUA project, is questionable as far as groundwater mismanagement continues. Demand side policies such as forbidding aquifer overdraft or taxing water abstractions are technically and politically unfeasible, because basin authorities can only deal at present with surface water. Although there are informal water transactions in southeastern basins, the introduction of formal water markets requires enormous and persistent efforts. The Water Law was modified in 1999 to promote formal water markets, but it has not spurred any significant transaction in almost ten years. In any case, the introduction of formal water markets would require the control of ground water. The experience of water markets in Australia and California demonstrates that economic instruments alone fail to protect water resources, and therefore command and control instruments have an important role to play.

The tasks ahead for basin authorities in Spain are quite challenging, since aquifers are common pool resources with impure public good characteristics (rival but non-excludable) and with environmental externalities. Their sustainable management requires that public authorities setup incentives that give rise to cooperation among agents managing the resource, in order to achieve the collective action needed for water conservation.

Summary and Conclusions

One of the important environmental questions in Europe is the scarcity and degradation of water resources. In Europe, the annual extraction of freshwater attains 20 percent of renewable resources, and the main pressures derive from the urban, industrial and irrigation consumptive uses. These uses create water scarcity in some regions, and a widespread water quality degradation from point and nonpoint pollution. Water scarcity is a serious problem in Southern European countries, with a strong demand during summer for irrigation and tourism. Water quality degradation is driven by human activities which generate pollution from nutrients, organic matter, heavey metals and other chemical byproducts.

There are no serious problems of water scarcity in Northern and Central European countries, and their main extractions for energy production are going to diminish. In the semiarid regions of Mediterranean countries, such as the southern half of the Iberian, Italian and Anatolian peninsulas, there is a massive use of water for irrigation. In these regions the scarcity outlook will dim because of expanded irrigated acreage and tourism in coastal areas, and because climate change will reduce available resources.

The industrial development and the growing consumption by households during the last century explain the strong degradation of water resources. The efforts to curb pollution in Western Europe were started in the seventies through several European directives. This legislation addressed the effects of point pollution emissions from urban and industrial discharges, which depend on sewage collection and treatment facilities.

Despite these efforts undertaken by public administrations in the last decades, pollution by nutrients and heavy metals remains high in many watersheds of the more important river basins in Europe. The extensive European regulation has facilitated large investments in water treatment plants and technological innovations in industries and households, which have limited or reduced the emissions of some pollutants, but the abatement of emissions is not general. The efforts on urban and industrial point source emissions should continue, and effective control on nonpoint pollution is needed such as abatement of nutrients and pesticides from agriculture.

The future of water resources in Europe would depend on the management measures taken to solve the different problems in each European region. Water scarcity in Southern Europe could worsen considerably by further uncontrolled extractions and the effects of climate change. Solving the scarcity problem may require reallocating some water from off-stream use by agricultural, urban and industrial users to environmental uses both in aquifers and streams, and also in the coastal wetlands. There are serious problems of water quality degradation in almost all European countries, although their characteristics depend on the local pressures of human activities and the measures being taken in each region.

The case of Spain shows that the implementation of the Water Framework Directive is not an easy task. Both the Spanish Ministry of Environment and the European Commission Environment Directorate advocate water pricing in irrigation and using the Common Agricultural Policy to penalize farmers. Research projects funded by the European Commission and some other studies recommend also these flawed policy options.[1]

But the problems of scarcity and quality degradation can not be solved with these two policies. Water pricing is a very good instrument for industrial and domestic demand, but it is useless for irrigation. Water pricing is not a workable option because (1) there is no control on the huge number of illegal wells and the quantities pumped from aquifers; (2) water shadow prices are above 3 euros/m^3, a price politically unfeasible since desalination costs are 0.50 euros/m^3 and urban water prices are around 1 euro/m^3; and (3) the administration lacks the information on aquifer dynamics precluding the enforcement of sustainable extractions.

The Common Agricultural Policy is also useless to influence water extractions in southeastern Spain, because CAP subsidies are targeted towards continental products such as field crops, while production in the area consist in Mediterranean crops such as fruits and vegetables which have negligible CAP subsidies.

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[1] An example is the article by Downward and Taylor (2007) on Almería, which states that sustainable management can be achieved by water pricing and augmenting water supply through desalination. Irrigation water use in Almería is around 260 hm^3, and domestic and industrial use is around 90 hm^3. Water pricing could affect industrial and domestic demand, but not irrigation aquifer pumping. Since the growing urbanization pressure on the coast will take over any water pricing savings in industry and urban demand, scarcity from irrigation aquifer overdraft will continue. Desalination can not work either, because farmers will not buy desalination water unless a strict enforcement of overdraft is in place, a daunting task for the administration. The implication is that the measures advocated by Downward and Taylor can not deliver the collective action required for water conservation. Examples from EU research projects are: 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).

The design and implementation of reasonable measures required by the Water Framework Directive is a difficult task not only in Spain or the Mediterranean member countries, but also in the whole European Union. The improvement in the management of water resources involves better information and knowledge on surface and subsurface resources and on their associated ecosystems. These tasks need time and resources because of the complex biophysical, spatial and intertemporal dimensions involved. At present data on water quantity are not very good in the European Union, and data on water quality are even more limited. The quantity figures of the European Environment Agency do not match national figures (for example Spain and France), and water quantity information from countries such as Italy is not available.

Knowledge on the underlying biophysical processes is critical for water management, specially for managing aquifers and controlling nonpoint pollution, and this requires the availability of basic facts on aquifer and pollution characteristics and dynamics at local watershed scale. Regarding pollution, information is needed on the emission loads, the pollutants transport and fate processes, and the ambient pollution in water courses. Also, the lack of economic valuation of damage costs to aquatic ecosystem from aquifer overdraft and nonpoint pollution, precludes the assessment of the benefits of policy measures.

Even when all the biophysical knowledge is available, managing the quantity and quality of surface and ground water 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 water stakeholders, setting up incentives for cooperation in order to achieve water conservation through their collective action. Both aspects, biophysical knowledge and collective action, are unlikely to be in place by 2020 not only in Europe but worldwide.

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