[1] LESSONS FROM INTENSIVE GROUNDWATER USE IN SPAIN: ECONOMIC AND SOCIAL BENEFITS AND CONFLICTS.

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ABSTRACT: Spain is the most arid country in Europe. Issues and conflicts related to water management are perhaps more relevant to the country's development than that of in other European countries. From this perspective the Spanish experience may be useful for other arid and semiarid countries. In July of 2001 the Spanish Parliament enacted the Law of the National Water Plan. This Plan stirred considerable controversy among diverse social sectors and lobbies: political parties, farmers associations, large construction firms, conservation groups, scholars, and others. Yet the real role of groundwater in Spain was mostly ignored in the initial proposal for the National Water Plan (NWP), except to provide rationale to the grand Ebro transfer proposed in the Plan. Designed for the transfer of one km^3 of the Ebro river water to several Mediterranean regions, this project was expression of the prevalence of old paradigms in Spanish water politics. Spain is among the countries with the largest number of large dams per person, and which uses the lowest proportion of groundwater for urban water supply within the EU. This may be the result of the central government's policy in the nineteenth Century, which restricted the use of groundwater as the source of supply for Madrid. This policy later spread throughout the rest of the country. The new government, elected in March 2004, decided to cancel the Ebro river transfer, replacing it with construction of more than dozen large desalinization plants. This solution is strongly opposed by most farmers.

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In Spain, like in most countries, farmers, ignoring the government's paradigms, have considerably increased the use of groundwater for irrigation during the last 30 to 40 years. Today about one million hectares, out of a total of 3.5 million hectares, are irrigated with groundwater. The economic value of the crops and the employment generated by the use of groundwater irrigation is several times higher than that from surface water irrigation, producing "more crops and jobs per drop". Most of this spectacular agricultural development has been made in Spain with scarce planning and very limited control by governmental agencies, providing evidence of the so-called *Silent Revolution of the Intensive Use of Groundwater*, which these authors consider *a worldwide phenomenon.* The process has given rise to significant conflicts and misgovernment in a few regions. In principle, according to the Spanish Water Act of 1985, and its further amendments, the solution for water management in the “overexploited aquifers” was the setup of Groundwater User Associations. Yet, by following a “command and control and top-down” approach, Water authorities have failed to make significant accomplishments, except in aquifers where farmers have received strong subsidies or where there was an approach bottom-up. Very scarce successful cases can be encountered in the long list of conflicts originating from intensive groundwater use.

In short, the NWP is a blend of new and old paradigms. The enforcement of the Water Framework Directive of the European Union may have profound impacts in the way water policies are drafted and applied in Spain. This is an external driving force, to which Spain must obey and that may lighten the political burden of replacing the old paradigm with the new water culture. In this paper, we provide an overview of the role of groundwater within Spain’s institutional framework and its future impact in water policy in Spain.

1. INTRODUCTION

1.1. Background

Spain is the most arid country in Europe. Groundwater development has significantly increased during the last half century in most semiarid or arid countries of the world (Shah, 2004). This development has been mainly undertaken by a large number of small (private or public) developers, with minor, if any at all, scientific, administrative or technological control. This is why some authors consider this new phenomenon as a *Silent Revolution* (Llamas and Martinez-Santos, 2005a and 2005b). In contrast, the surface water projects developed during the same period are usually of larger dimension and have been designed, financed, and constructed by government agencies that also take on the management and control of such irrigation projects or urban public water supply systems. This historical situation has often produced two effects: 1) most regulators have limited understanding and poor data on the groundwater situation and value; 2) in some cases the lack of control on groundwater development has caused serious problems that are later on reviewed in detail.

In Spain, and almost everywhere, these problems have been frequently magnified or exaggerated by groups with lack of hydrogeological know-how, professional bias or vested interests. For instance, the World Water Council (2000, page 13) states that: *"Aquifers are being mined at an unprecedented rate -10% of world's agricultural production depends on using mineral groundwater…"* However, this 10% estimation is not based on any reliable data. In recent decades, the term groundwater overexploitation has become a pervasive and confusing concept, almost a kind of *hydromyth*, that has flooded the water resources literature. A usual axiom derived from this confusing paradigm or *hydromyth* is that groundwater is an unreliable and fragile resource that should only be developed if the conventional large surface water projects are not feasible. This groundwater resource fragility concept has been dominant in Spain during the last twenty years (López-Gunn and Llamas, 2000). In the last decade a good number of authors have also voiced this fragility as a common issue (Postel, 1999; Seckler *et al*., 1998).

Another usual wrong paradigm or *hydromyth* is to consider that mining non-renewable groundwater is by definition a case of overexploitation, which implies that groundwater mining goes against basic ecological and ethical principles. Some authors (Llamas and delli Priscoli, 2000; Abdderraman, 2003) have shown that in some cases the use of non-renewable groundwater may be a reasonable option. This point of view has been approved by the UNESCO World commission on the Ethics of Science and Technology (COMEST), as can be read in Selborne (2001)

1.2. Purpose

This article provides an overview of the positive and negative aspects of the intense groundwater development in Spain during the last three or four decades. During this period, Spain has become an industrialized country. The analysis of the changing role of groundwater in Spain's water policy may be useful for other countries, which are undergoing or will undergo a similar processes. Llamas and Martinez-Santos (2005 a and 2005b) suggest that a worldwide debate on this topic is desirable. One step for this aim is the organization by the Interacademy Panel (IAP) of an International Symposium on Groundwater Sustainability (Alicante, Spain 24-27 January, 2006) The Spanish Water Act of 1985 is one of the few in the world, which sets provisions for '*overexploited aquifers'*. Relying on the Spanish experience, the main aim of this paper is to present and discuss: 1) the many meanings of the terms groundwater (or aquifer) overexploitation and sustainability; 2) the main factors to take into consideration in analyzing the pros and cons of intensive groundwater development; and 3) the strategies to prevent or correct the unwanted effects of intensive groundwater development.

What does intensively used or stressed aquifer mean? During the last decade the expression *water stressed-regions* has become pervasive in the water resources literature. Usually this means that there are regions prone to suffer now or in the near future serious social and economic problems resulting from water scarcity. The usual threshold to consider a region under water stress is 1000 m^3/person/year (United Nations, 1997, page 10-13), but some authors increase this figure to 1700 m^3/person/year. If this ratio is only 500 m^3/person/year the country is considered in a situation of absolute water stress or water scarcity (Seckler *et al.*, 1998; Postel, 1999). This is far too simplistic. Considering only the ratio between water resources and population has meager practical application. Most water problems are related to quality degradation, and accentuated drought cycles, but not to its relative scarcity. As an example, a good number of Spanish regions with a ratio lower than 500 m^3/year/person enjoy high economic growth and high living standards. Yet, development reinforces itself, and water demand increases, providing rationale for more public investment in water projects. In general, resource scarcity results from economic development, which in turn is endogenous to processes well beyond the boundaries of water policies. Often, the cause-effect direction is mistakenly reversed to conclude that making more water will promote economic development. This causality does not resist close scrutiny.

In its 1997 Assessment of Global Water Resources, the United Nations did a more realistic classification of countries according to their water stress. This assessment considered not only the ratio water/population but also the Gross National Product per capita (United Nations, 1997, page 138). Other experts, like Sullivan (2001), have also begun to use other more sophisticated indices or concepts in order to diagnose the current or future regions with water problems.

Groundwater development during the last decades has significantly contributed to Spanish agricultural and regional development. These improvements have also taken place in developing countries. There is a pressing need to manage groundwater development and mitigate the externalities of groundwater extraction, accounting for the temporary or intrinsic uncertainties related to water. Sustainable groundwater use requires, as a *conditio sine qua non*, the participation of educated and informed groundwater users and other stakeholders. This demands urgently the development of institutional arrangements for groundwater management where users can work jointly with the corresponding water agencies. But close cooperation among individuals does not come naturally, especially when societies face zero-sum gains (Livingston and Garrido, 2004).

2. WHAT DOES SUSTAINABILITY REALLY MEAN?

Since its early appearance in 1987, the concept of sustainability has been proposed by many as a philosophy to solve most water problems or conflicts. The European Union's Water Framework Directive, enacted in December 2000, establishes that it is necessary to promote sustainable water use. Probably, most people agree with this general principle, but its practical application in natural resources management is daunting. Shamir (2000) considers that the sustainability concept has up to ten dimensions: hydrology, ecology, economics, policy, intergenerational, intragenerational and others. It is out of the scope of this paper to elaborate more on this concept. However, as much as possible, it will be used with specific meaning.

In our view sustainability integrates the concept of future generations. But how many of these should be considered? No scientist is able to predict the situation one thousand years from now, and very few dare to present plausible scenarios for the 22nd century. Most current predictions refer to the needs of humans in one or two generations, i.e. not more than fifty years from now. The U.S. Geological Survey (1999) defines groundwater sustainability, though it does so from an exclusively hydrological point of view. It is clear that environmental problems have a natural science foundation, but also, and perhaps primarily, a social science foundation. Recently, Arrow et al. (2004) have argued that the accumulation of human capital at a larger rate than the consumption of natural stocks could be considered a sustainable growth path. While saving and investment can make growth sustainable, irreversible effects may warrant more precautionary extraction patterns.

The way to solve the existing water problems, mainly the lack of potable water, is not to persist on gloom and doom unrealistic campaigns, trying to create *environmental scares* and predicting *water wars in the near future* (see Kessler, 1998; The Economist, 1998; Asmal, 2000; World Humanity Action Trust, 2000) but to improve its management. In other words, there is not a crisis of physical water scarcity but of lack of water proper governance, capital and financial resources (Rogers and al. in press)

3. THE POLYSEMIC AND BECOMING USELESS CONCEPT OF OVEREXPLOITATION: OVERVIEW

In this section the concept of overexploitation will be firstly considered from a general perspective. Then, the failure of its application in Spain will be commented. The term overexploitation has been frequently used during the last three decades. Nevertheless, most authors agree in considering that the concept of aquifer overexploitation is one that resists a useful and practical definition (Llamas, 1992; Collin and Margat, 1993). Custodio (2000 and 2002) and Sophocleous (2000 and 2003) have most recently dealt with this topic in detail.

A number of conceptual approaches can be found in the water resources literature: safe yield, sustained yield, perennial yield, overdraft, groundwater mining, exploitation of fossil groundwater, optimal yield and others (see glossaries in Fetter, 1994, and Acreman, 1999). In general, these terms have in common the idea of avoiding *undesirable effects* as a result of groundwater development. However, this *undesirability* is not free of value judgments. In addition, its perception is more related to the legal, cultural and economic background than to hydrogeological facts.

For example, in a research study on groundwater fed catchments, called GRAPES (Acreman, 1999), three pilot catchments were analyzed: the Pang in the UK, the Upper Guadiana in Spain and the Messara in Greece. The main social value in the Pang has been to preserve the amenity of the river, related to the conservation of its natural low flows. In the Messara, the development of irrigation is the main objective and the disappearance of relevant wetlands has not been a social issue. In the Upper Guadiana the degradation of some important wetlands caused by groundwater abstraction for irrigation has stirred an ongoing conflict between farmers and conservationists (Bromley et al., 2001).

The Spanish Water Act of 1985 does not mention specifically the concept of sustainability in water resources development but indicates use rates should be in balance with nature. It basically considers an aquifer *overexploited* when the pumpage is close or larger than the natural recharge.

The Regulation for the Public Water Domain enacted in pursuant of the 1985 Water Act, says that "*an aquifer is overexploited or in risk of being overexploited, when the continuation of existing uses is in immediate threat as a consequence of abstraction being greater or very close to the mean annual volume of renewable resources, or when it may produce a serious water quality deterioration*". According to the law, 14 aquifers have been declared either provisionally or definitively overexploited, for which strict regulatory measures have been designed. However, to a large extent, these measures have not been successfully implemented and a situation of legal chaos still persists in many of these aquifers (MIMAM, 2000).

The misconception of considering that *safe yield* is practically equal to natural recharge, already shown by Theiss in 1940, has been voiced by many other hydrogeologists (see Custodio, 2000; Sophocleous, 2000; Hernández-Mora *et al.*, 2001).

Several national and international conferences have been organized by Spanish hydrogeologists over the past two decades to discuss and help dispel the misconceptions related to aquifer overexploitation (cf. Simmers *et al.*, 1992; Custodio and Dijon, 1991). Nevertheless, the success of these activities was rather limited in Spain and abroad.

It was suggested that a possible definition is to consider an aquifer overexploited when the economic, social and environmental costs that derive from a certain level of groundwater abstraction are greater than its benefits. Given the multi-faceted character of water, this comparative analysis should include hydrologic, ecological, socioeconomic and institutional variables. While some of these variables may be difficult to measure and compare, they must be explicitly included in the analysis so they can inform decision-making processes. Following Hernández-Mora *et al.* (2001), the basic categories of extractive services and *in situ* services are taken into account in the description of costs and benefits of groundwater development. The National Research Council (1997) recognizes that the monetary value of groundwater's *in situ* services (avoiding subsidence, conservation of wetlands, or maintaining the base flow of rivers, among others), is a rather complex and difficult task for which there is only limited information. Yet the WFD foresees that Member states must evaluate the environmental and resource costs, providing motivation to environmental economics to build on new applicable methods. More recently Llamas and Custodio (2003) have tried to present the concept of "intensive groundwater use" as a more practical concept. According to the editors of this volume "groundwater use is considered intensive when the natural functioning of the corresponding aquifer is substantially modified by groundwater abstraction". This concept only describes the physical changes but does not qualify its advantages or disadvantages from the many dimensions of the sustainability concept, including, ecological, hydrological, economical, social, intragenerational, intergenerational, and others. On the contrary, other terms such as overexploitation, overdraft, stressed aquifers, have a derogatory meaning for most people.

Fortunately, the scientific literature on intensive use of groundwater is increasing rapidly. In the book previously mentioned twenty chapters written by more than thirty well known authors are included. A second book dealing with intensive use has been recently published (Sahuquillo et al. 2005)

4. WATER RESOURCES OF SPAIN

4.1. Climatic and Hydrologic Setting

Spain has a surface of approximately 505,000 km^2. The average precipitation is 700 mm/year. However, this average has considerable spatial deviation, ranging from 100 mm/year in some islands in the Canary Archipelago to more than 2,000 mm/year in the humid North. The average annual temperature is 14 ºC. Average potential evapotranspiration is about 700 mm/year. In most of Spain potential evapotranspiration is higher than precipitation. The average stream flow is about 110 km^3/year (220 mm/year). From this amount, about 80 km^3/year (160 mm/year) is surface runoff and about 30 km^3/year (60 mm/year) is groundwater recharge. At least one third of Spain is endowed with good aquifers. These aquifers may be detrital, calcareous or volcanic (figure 1). The Water Administration has formally identified 411 aquifer systems or hydrogeological units (see Llamas *et al.*, 2001, table 4.1), which cover an area of 180,000 km^2, approximately.

The estimated *natural* recharge of these aquifers averages 30 km^3/year but varies with weather conditions between 20 and 40 km^3/year (figure 2).

4.2. Water uses

Spain's current total water uses are about 36 <u>km</u>^{3}/year or about one third of the total water resources (110 km^3/year). These uses are distributed between: irrigation, 24; urban Water supply and connected industries, 5; and independent industrial uses and cooling: 7.

Spain has about 43 million inhabitants. This means an average of almost 3,000 m^3/person/year, considering the whole country, but in some areas this indicator is in the range of 200 or 300. Table 1 shows the range of groundwater volumes used in Spain in recent years. The higher numbers correspond to dry periods in which groundwater use increases. The dramatic increase in the use of ground water during the last forty years is illustrated in figure 3.

This groundwater use growth has been the result of groundwater development by individuals, small municipalities and industries. It has not been planned by government agencies. As a matter of fact, Spain is a serious case of *hydroschizophrenia*; that is of an almost complete separation of surface and groundwater in the mind of water planners (Llamas, 1985). These water planners have been almost without exception conventional civil engineers working in the Ministry of Public Works (since 1996, in the Ministry for environment). The Ministry of Agriculture, independently of the general water resources policy driven by the Ministry of Public Works, promoted the initial use of groundwater for irrigation in Spain in the 1950s. As a result, Spain is among the countries with the highest number of large dams per person: 30 large dams per million inhabitants (figure 4). The pace of large dams construction in Spain during the last fifty years has been almost 20 large dams per year (figure 5).

Table 1. Spain's groundwater use summary (estimated from several sources).

Activity	**Volume applied (Mm^3/year)**	**Percentage of total water (surface + ground water)**
Irrigation	1,000-1,5000	~ 20%
Urban	4,000-5,000	~ 25%
Industrial and cooling	300-400	~ 5%
Total	5,500-6,500	15-20%

Source: Llamas et al. (2001, table 5.16).

Within the European Union, Spain has the lowest percentage (25%) of groundwater uses for urban water supply (see figure 6). The explanation of this anomaly is not the lack of aquifers, but the *hydroschizophrenia* of the government water planners of the water supply systems to large cities and for grand surface water irrigation schemes.

4.3. Groundwater ownership and markets

Until the 1985 Water Act came into force, groundwater in Spain was private domain. In contrast, surface water was almost always public domain, ruled by government agencies. Because of the real or imagined problems related to the uncontrolled development of groundwater, the 1985 Water Act declared all groundwater in Spain of public domain. Every new groundwater abstraction requires a permit granted by the corresponding water authority.

The groundwater developments made before the 1st January 1986 may continue as private domain, using the same amount of groundwater that they were using previously. All these wells, galleries or springs should be inventoried and registered within the basin agencies registries. The main problem is that the legislators and the water authorities underestimated the number of groundwater abstractions and did not provide the economic means to register all the grandfathered groundwater rights. Twenty years after the enactment of the 1985 Water Act the number of private groundwater abstraction rights remains uncertain, and by extension, the pumped volumes. Llamas *et al.* (2001, chapter 8) have estimated that the number of water wells in Spain is between one and two million. This means between 2 and 4 wells/km^2; however, this ratio is three times higher if it is applied only to the surface of the four hundred aquifer systems. The average groundwater withdrawal from each well is low (between 2500 and 5000 m^3/year), indicating that most are meant for domestic use or small irrigation. The 1985 Water Act states that it is not necessary a permit to drill a new well for abstracting less than 7000 m^3/year. Probably 90% of the private groundwater developments have an illegal or a-legal status. In order to cope with this complex situation, in 1995 the Government began a program (called ARICA) with a cost of 60 million Euros to have a reliable inventory of the water rights in Spain. The results of the ARICA program were discouraging and it was practically abandoned. In 2002 the Government began another similar program (this time called ALBERCA) with a budget of 150 million Euros. Detailed information on the progress of the ALBERCA program is not available yet. However, Fornés et al. (2005a) wrote that it would be necessary a bigger budget to clarify in full the inventory of groundwater rights.

On top of these disappointing results, and prompted to increase the economic efficiency of both surface and ground waters, the 1985 Water act was partly amended in 1999, mainly to introduce in some way the water markets. This was mainly done to allow greater *flexibility* to sell or buy water rights. In principle, this new *flexibility* is not relevant to groundwater markets because in Spain still most groundwater resources are private ownership and they can be sold or bought and leased like any other private asset. The importance of these groundwater markets varies according to the different Spanish regions . In most cases, these are informal (or illegal) markets and the information on them is not reliable (Hernández-Mora and Llamas, 2001). The Canary Islands are an exception to this general situation. This autonomous Region of Spain has a different Water Code. Almost 90% of the total water uses are supplied with groundwater. Practically all groundwater is private ownership. Aguilera Klink (2002) has studied the pros and cons of the water markets in this Archipelago. But other than this, the 1999 amendment has not produced any substantial water reallocation, even under the 2005 pre-drought conditions prevailing in the country.

5. BENEFITS OF GROUNDWATER DEVELOPMENT

Groundwater sustainability must necessarily take into account the numerous dimensions of this concept and among them the socioeconomic and even ecological benefits that result from groundwater use. Socioeconomic benefits range from water supply to economic development, as a result of agricultural growth in a region. With respect to the potential ecological benefits, the use of groundwater resources can often eliminate the need for new large and expensive hydraulic infrastructures that might seriously damage the natural regime of a river or stream and/or create serious social problems (World Commission on Dams, 2000).

5.1. Drinking Water Supply

Groundwater is a key source of drinking water, particularly in rural areas and in island environments. In Spain, for example, medium and small municipalities (of less than 20.000 inhabitants) obtain 70% of their water supply from groundwater sources (MIMAM, 2000). In some coastal areas and islands the dependence on groundwater as a source of drinking water is even higher. Nevertheless, as it was previously mentioned, Spain is one of the European countries that less proportion of groundwater uses per public urban water supply to large cities. This situation has the historical roots explained in Llamas (1985). Essentially there were two main causes. The first one was a very centralized government system where all the decisions in relation to water policy were taken by a small and selected group of civil engineers working for the Ministry of Public Works. The second cause was the failure in the 1850s of a proposal of another selected group of mining engineers who worked also for the government. Between the two social groups there existed a certain professional concurrence. Mining engineers supported the use of groundwater to solve Madrid's serious water problems in the last half of the 19th century. They failed because neither the geology nor the water well technology at that time allowed the sufficient understanding about the functioning and potential development of the nearby aquifers.

5.2. Irrigation

In Spain, as in many arid and semiarid countries, the main groundwater use is for agriculture. Although few studies have looked at the role that groundwater plays in irrigation, those that do exist point to a higher socio-economic productivity of irrigated agriculture using groundwater than that using surface water. A 1998 study done for Andalusia, in Southern Spain showed that irrigated agriculture using groundwater is significantly more productive than agriculture using surface water, per volume of water used (Hernandez-Mora *et al.*, 2001). Table 2 shows the main results of the Andalusia study. It is important to note that these results were based on the average water volumes applied in each irrigation unit (or group of fields). The water losses from the source to the fields were not estimated, but in surface water irrigation are significant. Other studies have calculated the volumes used in surface water irrigation as the water actually taken from the reservoirs. For example, the White Paper of Water in Spain (MIMAM, 2000) estimated an average use of 6,700 m3/ha/year and 6,500 m3/ha/year for the two catchments that are the subject of the Andalusia study without differentiating between surface and groundwater irrigation. Using these new figures and the volumes given for irrigation with groundwater in the Andalusia study, a more realistic average volume used for irrigation with surface water of 7,400 m3/ha/year can be estimated. Table 2 shows that productivity of groundwater irrigation is 5 times greater than irrigation using surface water and generates more than three times the employment per m^3 used. It could be argued that the greater socio-economic productivity of groundwater irrigation in Andalusia can be attributed to the excellent climatic conditions that occur in the coastal areas. While good climatic conditions may influence the results, the situation is similar in other continental regions of Spain (Hernandez-Mora and Llamas, 2001). The updated data presented by Vives (2003) about the Andalusian irrigation confirm the previous assessment about the greater social and economic efficiency of groundwater irrigation.

Table 2. Comparison of irrigation using surface and groundwater in Andalusia.

Indicator for irrigation	Origin of irrigation water			Relation groundwater/surface water
	Groundwater	Surface water	Total	
Irrigated surface (10^3 ha)	210	600	810	0.35
Average use at origin (m^3/ha/year)	4000	7400	6500	0.54
Water productivity (€/m^3) [1]	2.16	0.42	0.72	5.1
Employment generated (EAJ/10^6 m^3) [2]	58	17	25	3.4

Source: Hernandez -Mora et al.. (2001).

[1] 1 € ≅ 1.3US$

[2] EAJ stands for Equivalent Annual Job, which is the work of one person working full-time for one year.

Table 3. Descriptive elements of Irrigation in Spain (in hectares)

Autonomous Community	Surface	Groundwater	Inter-basin Transfers	Water returns	Reuse	Desal-inised	TOTAL	Predominant irrigation technique (%)		
								Flood	Sprinkler	Drip irrigation
Andalucía	546.703	224.670	2.783	85	5.639		779.880	42	21	37
Aragón	373.886	20.315		21			394.222	80	18	2
Castilla-León	361.055	113.164		12.428	29		486.676	61	39	-
Castilla-La Mancha	124.262	228.528	1.011				353.801	32	55	13
Cataluña	205.031	53.043		6.377	342		264.793	69	12	19
Extremadura	207.337	3.151					210.488	69	26	5
Galicia	85.061	92					85.153	64	36	-
Murcia	42.553	93.810	51.104	360	1.600	271	189.698	60	3	37
Navarra	79.941	1.682		50			81.673	89	10	1
Rioja	45.771	3.564					49.335	66	29	5
C. Valenciana	146.691	154.821	40.258	4.178	4.534		350.482	80	1	19
TOTAL	2.218.291	896.840	95.156	23.499	12.144	271	3.249.838	59	24	17

Source: MAPYA (2001)

Table 3 provides an overview of Spanish irrigation, indicating the water sources and irrigation technologies. In general, drip irrigation and sprinkler systems are more common in the regions were groundwater is used more intensively.

When examining the data included in this section it is important to keep in mind the uncertainties of hydrologic data. However, the results are indicative of the greater productivity of irrigation using groundwater. This should not be attributed to any intrinsic quality of groundwater. Rather, causes should be found in the greater control and supply guarantee that groundwater provides mainly during droughts (see Llamas, 2000), and the greater dynamism that has characterized the farmers who have sought their own sources of water and bear the full (direct) costs of drilling, pumping and distribution (Hernandez-Mora and Llamas, 2001).

5.3. Hydrologic benefits

Other potential benefit of groundwater development is the increase in net recharge in those aquifers that, under natural conditions, have the water level close to the land surface. The drawdown of the water table can result in: a decrease in evapotranspiration, an increase in the recharge from precipitation that was rejected under natural conditions, and an increase in indirect recharge from surface water bodies. Johnston (1997) analyzed eleven American regional aquifers, showing that intensive groundwater development in nine of these aquifers has resulted in significantly increased recharge.

Shah et al. (2004) have studied from a point of view statistical and for the whole India the seasonal recovery of groundwater levels after the monsoon rain. They conclude that the depletion of the water table due to groundwater abstraction increases significantly the precipitation recharge. This is quite in agreement with the general hydrogeological principles. There is ample evidence showing that extractions increase the recharge rates augmenting the sustainable use level.

A clear example of this situation is the increase in available resources for consumptive uses that followed intensive groundwater pumping in the Upper Guadiana basin in central Spain (see Bromley *et al.*, 2001;). It has been estimated that average renewable resources may have increased between one-third -and one half- under disturbed conditions. Figure 7 illustrates these results. Prior to the 1970s, groundwater pumping in the Guadiana basin did not have significant impacts on the hydrologic cycle. Intensive pumping for irrigated agriculture started in the early 1970s and reached a peak in the late 1980s. As a result, wetlands that under semi-natural conditions had a total extension of about 25,000 ha, today only cover 7,000 ha. In addition, some rivers and streams that were naturally fed by the aquifers now have become net losing rivers.

The results of the decline of the water table have been two-fold. On one hand, a significant decrease in evapotranspiration from wetlands and the water table, from about 175 Mm^3/year under quasi-natural conditions to less than 50 Mm^3/year today. At the same time, there has been a significant increase in induced recharge to the aquifers from rivers and other surface water bodies. Consequently, more water resources have become available for other uses, mainly irrigation, at the cost of negative impacts on dependant natural wetlands.

6. DISADVANTAGES OF GROUNDWATER USE

6.1. Groundwater level decline

The observation of a trend of continuous significant decline in groundwater levels is frequently considered an indicator of imbalance between abstraction and recharge. While this may be most frequently the case, the approach may be somewhat simplistic and misguided. Custodio (2000) and Sophocleous (2000) remind that every groundwater withdrawal causes an increasing piezometric depletion until a new equilibrium is achieved between the pumpage and the new recharge (or capture). This transient situation can be long depending on aquifer characteristics.

With respect to the climatic cycles, in arid and semiarid countries significant recharge can occur only every certain number of years, which may easily be from 5 to 10 years. Therefore, continuous decline in the water table during a dry spell of a few years, when recharge is low and abstraction is high, may not be representative of long-term trends. Declines in water levels should indicate the need for further analysis. In any case, declines in the water table can result in a decrease in the production of wells as well as increases in pumping costs. This economic impact can be more or less significant depending on the value of the crops obtained. For instance, in some zones of Andalusia, the value of crops in greenhouses may reach 50,000 to 70,000 US$/ha/year. The water volume used is between 4,000 and 6,000 m^3/ha. The energy needed to pump one cubic meter 100 m high is from 0.3 to 0.4 kWh. If it is assumed an energy cost of US$ 0.03 kWh, this means an increase in energy costs in the order or US$ 0.01 to 0.02/ m^3.

The analyses on water irrigation costs are rather scarce. The WFD mandates that Member States should collect these and all relevant economic information related to the water services. A preliminary assessment has been done in Spain, which is mentioned by Estrela et al. (2004). Table 4 compiles a few studies that have attempted to evaluate the impact of tariff increases as a result of the implementation of the article 9 of WFD.

Table 4. The effects of the WFD on the irrigation sector

	Present rate		Tariff increase		Results		
RBA	Type	Levels[1] (€ per cm)	Medium	FCR[2]	Farm income	Water demand	Other results
Duero	Per hectare	0.01	0.04	0.06	-40% to -50%	-27% to -52%	Great influence of agricultural policies
Guadalquivir	Per ha & Vol	0.01-0.05	0.05	0.1	-10% to -19%	0 to -10%	Same
Duero	Per ha &Vol	0.01	0.04	0.1	-10% to 49%	-5% to -50%	Technical response
Guadalquivir	Per ha & Vol	0.01-0.05	0.06	0.12	-10% to 40%	-1% to -35%	Technical and crop response
Guadalquivir	Per ha & Vol	0.01-0.05	0.03	0.09	-16% to 35%	-26% to -32%	Technical and crop response
Guadiana	Per ha	0.005	0.03	0.06	-15% to 20%	-30% to -50%	Technical and crop response
Júcar	Per ha, Vol & hourly rates	0.03-0.15	0.06	0.15	-10% to -40%	0 to -40%	Technical response
Segura	Per ha, Vol & hourly rates	0.05-0.30	0.10	0.25	-10% to -30%	0 to -10%	Very inelastic demand

Source: Garrido & Calatrava (2005)
[1]Equivalent measure; [2] Full cost recovery rates

Table 4 provides indication that the application of FCR water rates may have a significant impact in farmers' rents and water demand. Yet, by no means it should be expected that the WFD will entail catastrophic results to the farming sector. This is proven by the evidence supported by the irrigation sector relying on groundwater resources. Generally, water costs are much closer to what the Table indicates as FCR prices, than to the current prices of surface water. Yet, irrigation relying on surface sources will need to adopt more efficient water conveyance and application technologies. Table 4 also shows the relevance of water conservation, resulting from FCR prices. Conventional wisdom about water demand for irrigation in Spain should be profoundly revised, in view of the likely reductions that will be achieved by better pricing.

In 2003 the Ministry for the Environment (MIMAM, 2004), in agreement with the Article 5 of the WFD, did a preliminary analysis of the cost of groundwater in Spain. This preliminary analysis estimates the cost of groundwater for irrigation and for urban water supply in each of the four hundred Spanish hydrogeologic units. The average groundwater irrigation cost for the whole Spain is about US$ 0.15 m^3, but there exists a great dispersion of values: from US$ 0.04 to 0.40 m^3. This assessment has been done without specific field surveys therefore it should be considered only as a preliminary approach. The analysis does not include an estimation of the average value of the crops guaranteed with the groundwater abstraction. Experience shows that in Spain the ratio between the value of the crop and the cost of groundwater irrigation is usually very small, usually smaller than 5 or 10 percent. In other words the silent revolution of the groundwater intensive use is mainly driven by the market (Llamas and Martinez-Santos (2005 a and 2005b), and will not be deterred by the increasing pumping costs of lower water tables.

A significant fact is that a large seawater desalination plant (40 Mm^3/year) has been completed in Almería (South Spain) in 2004. The main use of this treated water was supposed to be greenhouse irrigation. The price of this desalted seawater offered by the government to the farmers is in the order of US$ 0.40 m^3 . This is a political price subsidized by the European Union and by Spanish Government. The real cost might be about double. The farmers are reluctant now to accept the price of US$ 0.40 m^3, although in that area the value of the greenhouse crops obtained is in the order of US$ 60000/ha/year and the cost of the necessary 4000 to 6000 m^3/ha/year would be smaller than US$ 2000 or 3000/ha/year or less than 5% of the crop value. Probably the main reason for that is that in some cases they can buy or obtain groundwater at a lower price. They do not care about the right to abstract such groundwater because as it has been previously stated the administrative and legal situation of groundwater rights is usually chaotic, in other words most of the water wells in operation are illegal but the government is unable of controlling them. The preliminary economic analyses in the Jucar basin

(Estrela et al. 2004) seem to confirm that the market drives the silent revolution of groundwater intensive use. For instance in the Crevillente small aquifer in that basin the farmers are pumping their groundwater from a depth of almost 500 m at a cost of US$ 0.40 m^3. They grow special grapes for export with a value about US$ 20000 to 30000 /ha. They use about 3500 m^3/ha/year. Therefore the ratio of groundwater irrigation cost to the crop is less than 5%.

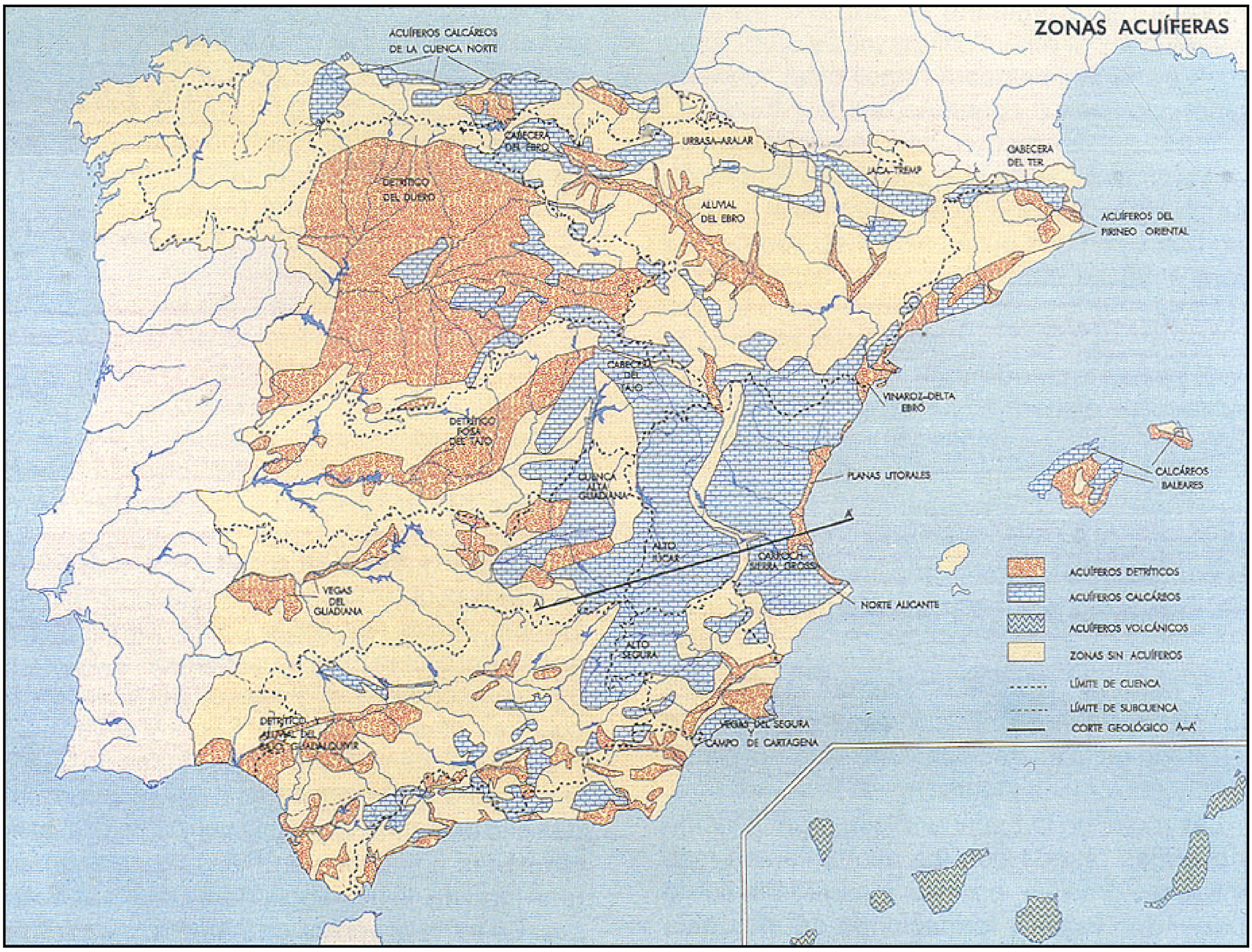

Figure 1. Spain's location and types of main aquifers. Source: MIMAM (2000, figure 2).

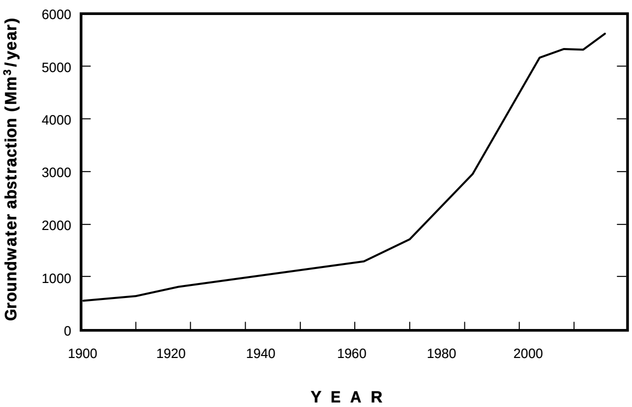

Figure 3. Groundwater consumption development of groundwater in Spain, showing its rapid increase from the 1960s to date. Source: MIMAM (2000, figure 339).

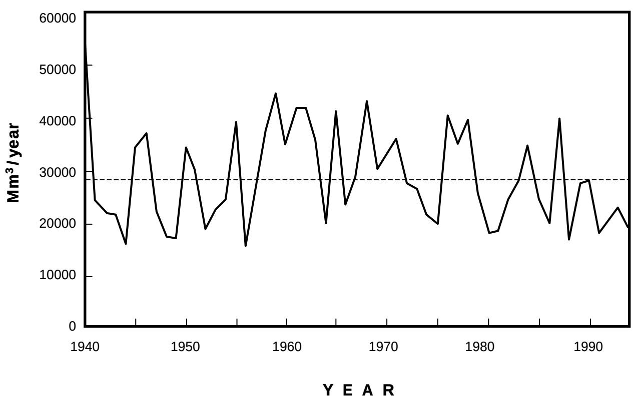

Figure 2. Estimated natural groundwater recharge in Spain from 1940 to 1995. Source: MIMAM (2000, figure. 124).

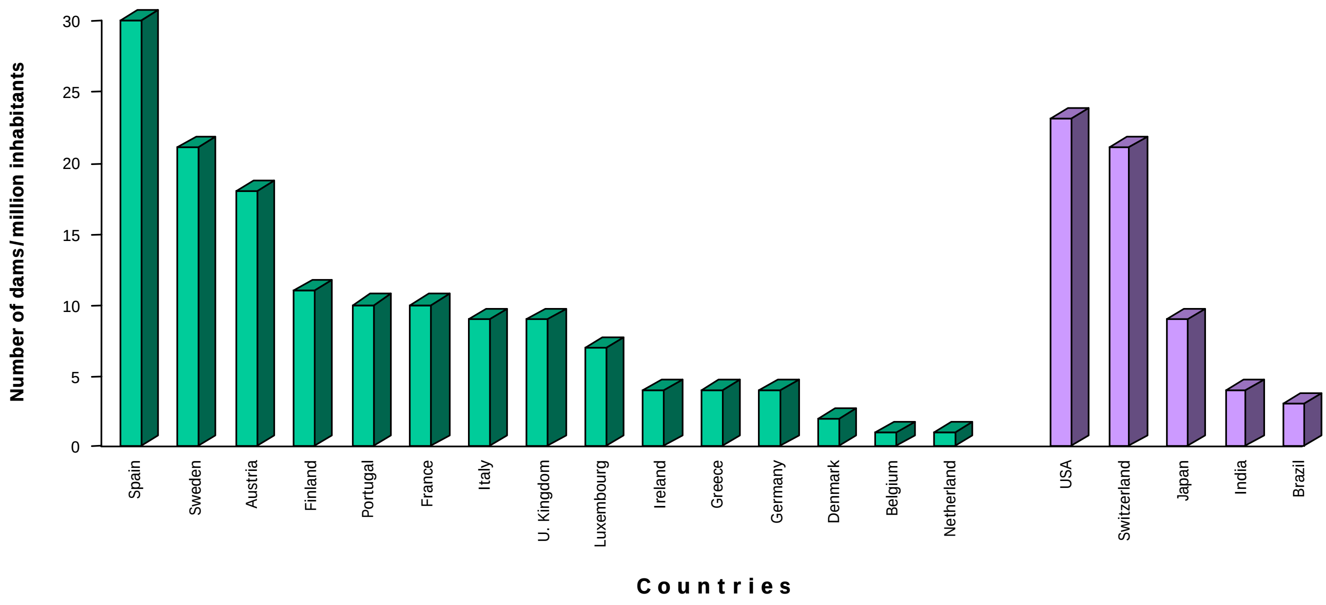

Figure 4. Number of dams per capita in different countries. Source: Llamas et al. (2001, figure 5.7).

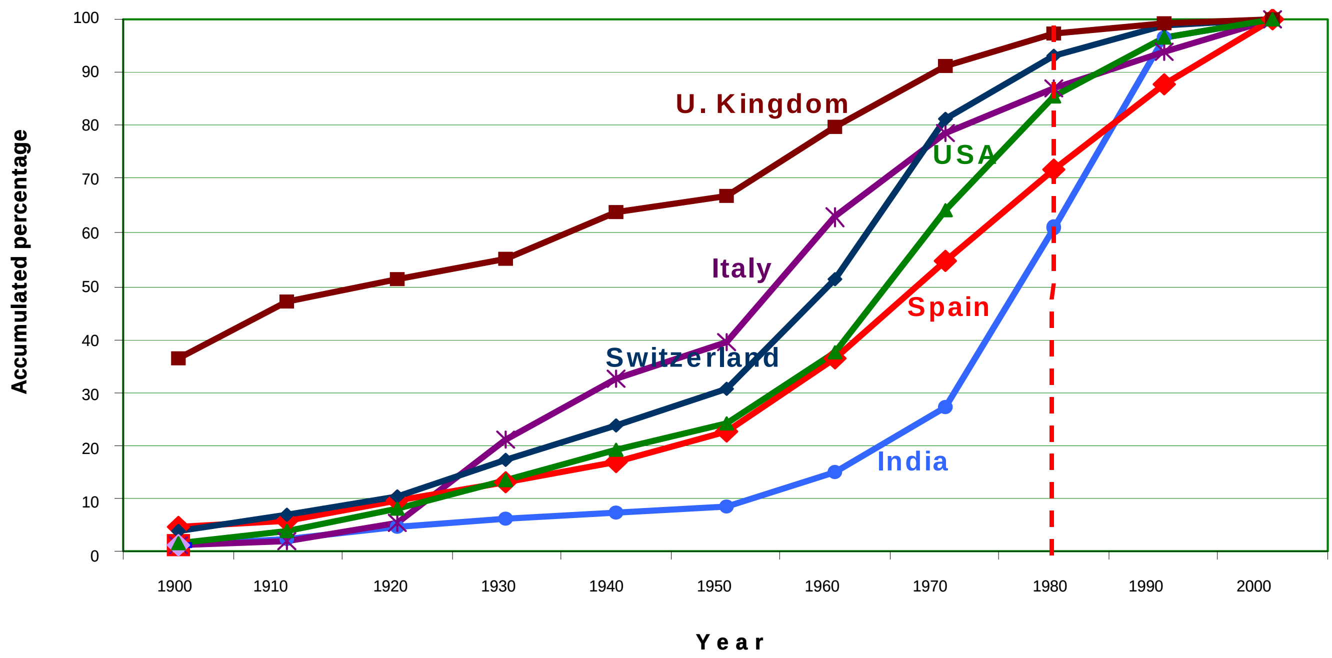

Figure 5. Temporal dam construction rhythm in several representative countries. Source: Llamas *et al.* (2001, figure 5.8).

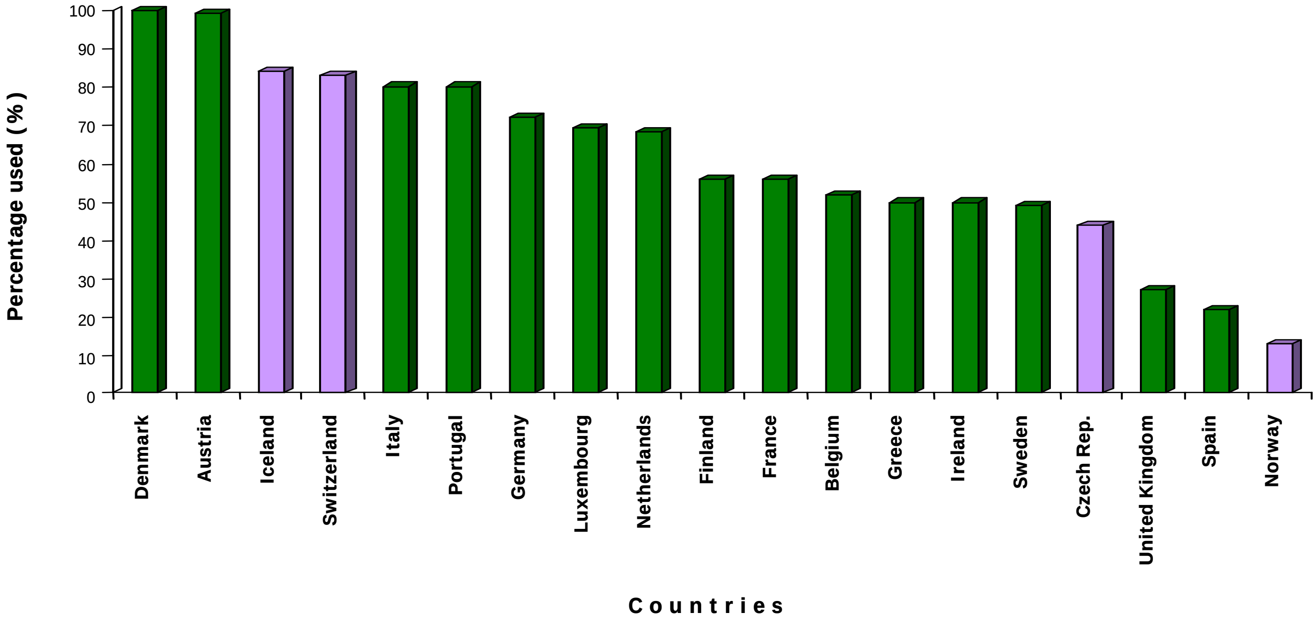

Figure 6. Percentage of groundwater used for urban supply in several European countries. Source: Llamas *et al.* (2001, figure 5.3)

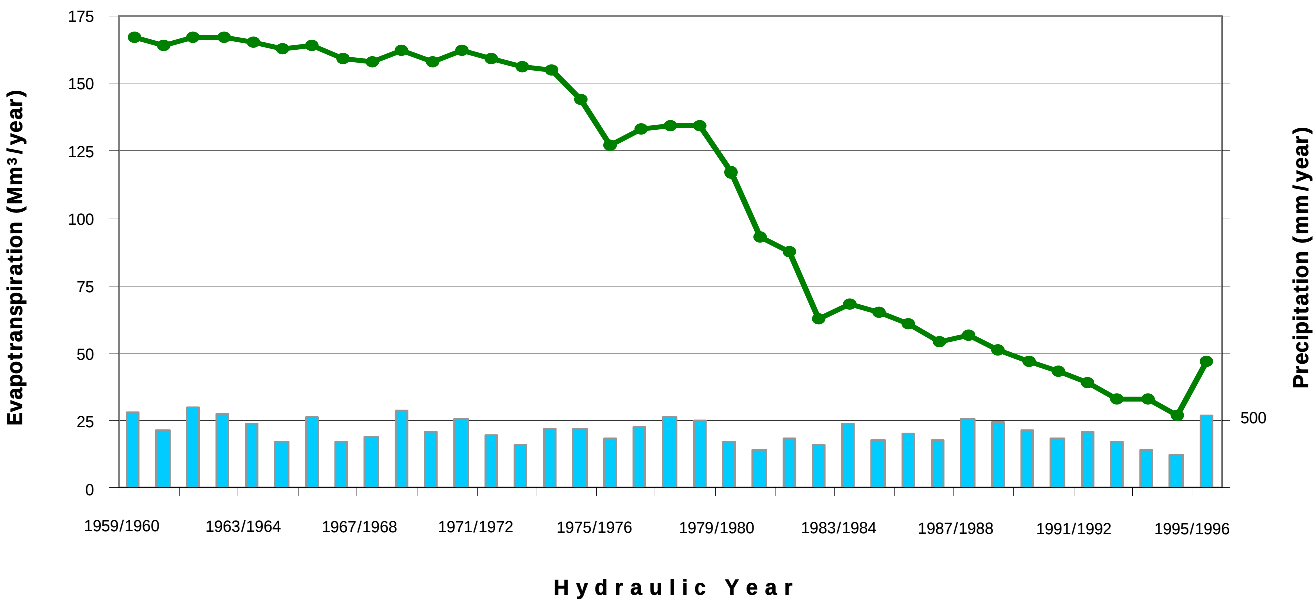

Figure 7. Temporal evolution of evapotranspiration from the water table in the Upper Guadiana basin, caused by water table depletion. Source: Martínez Cortina as cited in Llamas *et al.* (2001, figure 4.7).

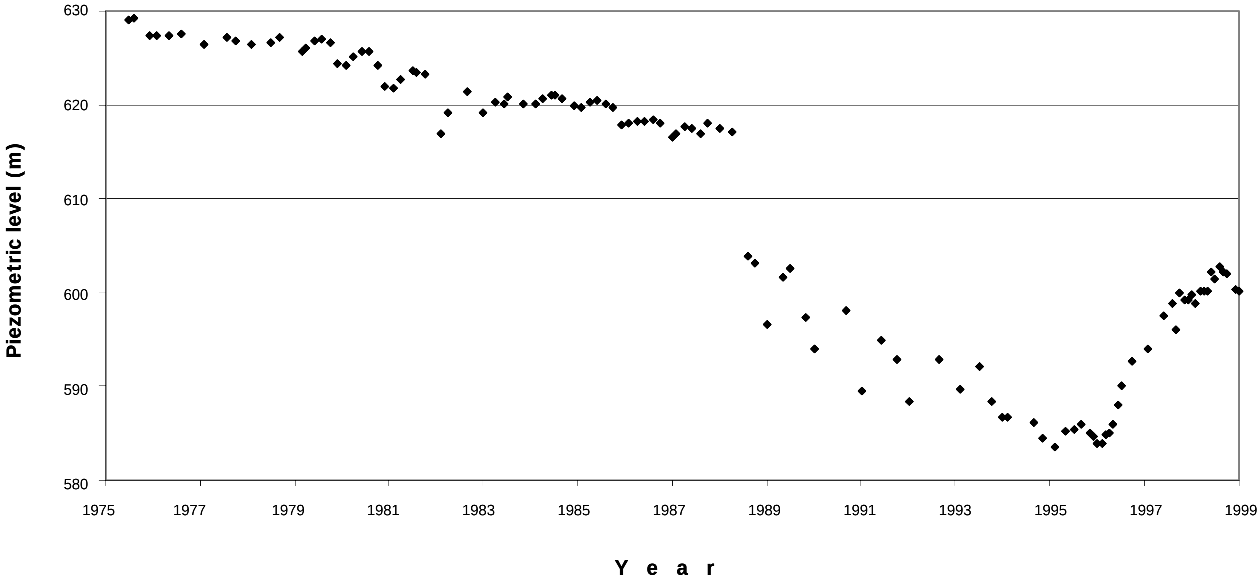

Figure 8. Water table evolution in Manzanares (Upper Guadiana catchment, Spain). Source: Martínez Cortina (2001) as cited in Hernández-Mora et al. (2001)

6.2. Degradation of groundwater quality

Groundwater quality is perhaps the most significant but not the most urgent challenge to the long-term sustainability of groundwater resources. Yet, according to the Kuznet's curve, countries implicitly accept a degradation of their environmental quality in return of higher living standards, up to a point where the preferences are reversed. This point has been empirically estimated to be in the range of US$ 6,000 to 10,000 US of per capita income.

Restoration of contaminated aquifers can be a very costly and difficult task. Most often, degradation of groundwater quality is primarily related to as point or non-point source pollution from various sources such as return flows from irrigation, leakage from septic tanks and landfills or industrial liquid wastes. These problems are not exclusive of industrialized countries but also may be serious in developing countries. The WFD emphasizes the recovery of groundwater quality in the EU but pays little attention to groundwater quantity problems. This situation may be caused by the insufficient participation of European Mediterranean experts in the preparation of the WFD. Therefore other arid and semiarid countries should be very prudent in taking the WFD as a good paradigm for their water policy. Groundwater abstraction can also cause changes in groundwater quality. Some indicators of the susceptibility of an aquifer to water quality degradation are given in Custodio (2000) Although groundwater pollution is possibly the most serious problem with a long term perspective, the quantitative issues may be the more urgent and politically pressing ones. In these cases, the problem is often related to inadequate well field location and not necessarily to the total volumes abstracted. Technical solutions to deal with problems of saline or lower quality water intrusion have been developed and applied successfully in some places such as California and Israel. Unfortunately, the public awareness in Spain about the groundwater pollution problems is still weak. This may be caused mainly for the scarcity of government reports and action to assess and to abate groundwater pollution.

6.3. Susceptibility to subsidence and/or collapse of the land surface

Aquifers formed in young sedimentary formations are prone to compaction as a result of water abstraction and the resulting decrease in intergranular pore pressure. For example, this has been the case in the aquifers underlying Venice or Mexico City. More dramatic collapses are a common occurrence in karstic landscapes, where oscillations in water table as a result of groundwater abstractions can precipitate the occurrence of karstic collapses. In both cases, the amount of subsidence or the probability of collapses is related to the decrease in water pressure. Fortunately, these types of geotechnical problems are not relevant in Spain.

6.4. Interference with surface water bodies and streams

Decline in the water table as a result of groundwater withdrawals can affect the hydrologic regime of connected wetlands and streams. Loss of baseflow to streams, dissecation of wetlands, and transformation of previously gaining rivers to losing rivers, may all be potentially undesirable results of groundwater abstraction and serve as indicators of possible excessive abstraction. The already mentioned Upper Guadiana catchment in Spain is a typical example of this type of situation. According to the WFD most groundwater abstraction in the Upper Guadiana basin in Spain must be cancelled because of its evident interference with the surface waters and its ecological impacts. However, the WFD states that when this solution may imply serious social problems the corresponding Member State may ask for derogations based on the hydrological, economic and social consequences. Most likely Spain will request derogations to the EU not only in the Upper Guadiana Basin but also in many other aquifers where an intensive use of groundwater exists.

6.5. Ecological impacts on groundwater-dependant ecosystems

The ecological impacts of drawdown of the water table on surface water bodies and streams are increasingly constraining new groundwater developments (Llamas, 1992). Drying up of wetlands, disappearance of riparian vegetation because of decreased soil moisture, or alteration of natural hydraulic river regimes, can all be used as indicators of overexploitation. Reliable data on the ecological consequences of these changes is not always available, and the social perception of such impacts varies in response to the cultural and economic situation of each region. The lack of adequate scientific data to evaluate the impacts of groundwater abstraction on the hydrologic regime of surface water bodies makes the design of adequate restoration plans difficult. For instance, wetland restoration programs often ignore the need to simulate the natural hydrologic regime of the wetlands, that is, not only restore its form but also its hydrological function. Similar problems result in trying to restore minimum low flows to rivers and streams. Oftentimes minimum streamflows are determined as a percentage of average flows, without emulating natural seasonal and year-to-year fluctuations to which native organisms are adapted.

The social perception of the ecological impacts of groundwater abstraction may differ from region to region and result in very different management responses. GRAPES, a European Union-funded project, previously mentioned, looked at the effects of intensive groundwater pumping in three different areas Greece, Great Britain and Spain (Acreman, 1999). In the Pang River in Britain, conservation groups and neighborhood associations with an interest in conserving the environmental and amenity values of the river that had been affected by groundwater abstraction mainly drove management decisions. In the Upper Guadiana basin, dramatic drawdown in the water table (30-40 m) caused jointly by groundwater abstraction and drought (see Figure 8) resulted in intense conflicts between nature conservation officials and environmental non-governmental organizations (NGOs), irrigation farmers and water authority officials. The conflicts have been ongoing for the past 20 years and have not yet been resolved. Management attempts to mitigate the impact of water level drops on the area's wetlands have so far had mixed results (Fornés and Llamas, 1999; Bromley *et* *al.*, 2001). On the other hand, in the Messara Valley in Greece, the wetland degradation caused by decline in the water table has not generated any social conflict. This situation seems to confirm that ecological awareness is deeply related to economic value of water and to the cultural background of each region.

7. STAKEHOLDERS PARTICIPATION IN GROUNDWATER MANAGEMENT

Spain has a long tradition of collective management of common pool resources. Probably the *Tribunal de las Aguas de Valencia* (Water Court of Valencia) is the most famous example. This Court has been meeting at noon every Thursday for many centuries at the entrance of Cathedral of Valencia to solve all the claims among the water users of a surface irrigation system located close to Valencia. All the members of the Court are also farmers. The decisions or settlements are oral and cannot be appealed to a higher court. The system has worked and it is a clear proof that *The Tragedy of Commons* is not always true. Further evidence of social cooperation in Spain are the about six thousands of *Comunidades de Regantes* (Irrigation Communities of Surface Water Users Associations). Some of them have been in operation for several centuries. Currently these *Communities* are legally considered entities of public right. They are dependent of the Ministry for the Environment and traditionally are subsidized with public funds, mainly for the maintenance of the irrigation infrastructures.

The 1985 Spanish Water Act preserved the traditional *Comunidades de Regantes* that existed before its enactment and recommended these institutions for surface water management. It is also extending this type of collective institution to groundwater management, and required the compulsory formation of *Comunidades de Usuarios de Aguas Subterráneas* (Groundwater Users Communities) when an aquifer system was legally declared overexploited. A short description of these institutions is contained in Hernández-Mora and Llamas (2000).

A more detailed description of the nature and evolution of some of these new groundwater user associations and communities can be read in Lopez-Gunn (2003). The current situation can be summarized as follows:

1. It seems clear that the key issue for the acceptable functioning of these institutions is a bottom-up approach from the outset on the part of the governmental water authorities. This explains the almost perfect functioning of the Llobregat delta groundwater user association, which is in operation since the

1970s, i.e. under the previous 1879 Water Act. In that Water Act groundwater was legally private ownership but the corresponding Water Authority officers and the groundwater users (mainly water supply companies and industries) were able to work jointly. Something similar has occurred in the implementation of the Groundwater User Community fore the la Eastern La Mancha aquifer located in continental plateau. In this case the groundwater users are mainly farmers and the irrigated surface covers about 900 km^2. This aquifer has never been declared legally “overexploited” by the corresponding Water Authority.

2. In two important aquifers the situation has been the opposite. The Western La Mancha and the Campo de Montiel aquifers are also located in the continental Spain. Their total area is about 7,500 km^2 and the irrigated area in them about 2,000 km^2. The Guadiana River Water Authority legally declared both aquifers overexploited in 1987, in a typical top-down and control and command approach. Only in 1994 the corresponding Groundwater User Communities were implemented. And this was only possible thanks to a generous economic subsidies plan (paid mainly by the European Union) to compensate the decrease in the groundwater abstraction. Nevertheless, a good number of farmers have continued to drill illegal water wells and they are not decreasing their pumpage. On the other hand, after ten years the economic incentives from the European Union have been discontinued. The Spanish Parliament asked to the Government in July 2001 to present by July 2002 a Plan for the sustainable use of water in this area. This requirement has not been accomplished yet and probably the government within 2005 will not approve this Plan.

As the chief engineer for groundwater resources in the Ministry for the Environment states (Sanchez, 2003), serious difficulties have been faced to enforce the setting up of the groundwater users associations in the aquifers legally declared “overexploited”. Only two out if seventeen Groundwater User Communities that have to be implemented in the corresponding legally declared “overexploited aquifers” few are operative (Llamas *et al.*, 2001, chapter 9; Hernández-Mora and Llamas, 2001). As recognized in the White Paper on Water in Spain (MIMAM, 2000), the main cause is that these new groundwater users communities were established top-down, that is the water authorities imposed their implementation without the agreement of the farmers who are the main stakeholders. Both, the 1999 amendments to the 1985 Water Act and the 2001 Law of the National Water Plan, have provisions to overcome these difficulties and to foster the implementation of institutions for collective management of aquifers with ample participation of the stakeholders under a certain control of water authorities. It is too early to assess the results of these provisions.

In Spain, in addition to the communities born under the auspices of the 1985 Water Act, there are a large number of private collective institutions or associations to manage groundwater. Only a few years ago a group of them set up the Spanish Association of Groundwater Users. This is a civil (private) association that is legally independent of the Ministry for the Environment. Despite the wide recognition of the benefits of this type of associations, it is early to ascertain whether the needed economic, tax, and operational incentives are in place.

8. HYDROSOLIDARITY AND GROUND-WATER MANAGEMENT IN SPAIN

8.1. Overview

In Spain, like everywhere, ethical factors play a crucial role in water uses and in water management. Several recent publications address this topic (see Selborne, 2001; Delli Priscoli and Llamas, 2001). Human solidarity is one of the ethical principles that underlay most water policy agreements or treaties. One of the meanings of the concept of solidarity, as it applies to the use of natural resources, is that a person's right to use those resources should be constrained or limited by the rights or needs of other or future human beings, including protection of the natural environment.

Nowadays, few people would dare to speak openly against hydrosolidarity (the need to share water resources). In practice, however, it might be difficult to find constructive ways to facilitate an equitable and fair share of water resources among concerned stakeholders, particularly in densely populated arid and semi-arid regions. Lack of knowledge, arrogance, vested interests, neglect, institutional inertia, corruption, are some of the obstacles frequently encountered to achieve hydrosolidarity (Llamas and Martinez-Santos, 2005 b). The noble and beautiful concept of hydrosolidarity may also be used in a corrupt or unethical way by some lobbies in order to pocket *perverse subsidies*, which are bad for the economy and the environment (Delli Priscoli and Llamas, 2001). An example of the improper use of hydrosolidarity is that of the Segura catchment area. It has influenced the approval of the large aqueduct for the Ebro River water Diversion included in the first National Water Plan in Spain, which was approved as a Law in July 2001 by the Spanish Parliament, and rebuffed after the general election of March 2004.

8.2. The Segura Catchment

This section is mainly taken from an invited paper presented by Llamas and Perez Picazo in the 2001 Stockholm World Water Week. The term "Hydrosolidarity" has been coined mainly by Prof. Falkenmark and Lundquist who were the organizers of this water week

Hydrology

The Segura catchment is located in southeastern Spain. Its main features are: a) surface area 19,000 km^2; b) average annual precipitation of 400 mm, ranging from 800 mm in the headwater to 200 mm in the coastal plain. c) annual potential evapotranspiration: 800-900 mm; d) average streamflow: 1000 Mm^3. The relief is abrupt with mountains that reach an altitude of 2000 m. The geology is complex with numerous faults and thrusts. Calcareous aquifers cover about 40% of the catchment's surface. Natural recharge is estimated at about 600 Mm^3/year (about 60% of the total streamflow). The climate is typical of Mediterranean regions: hot summers, frequent flash floods and long droughts.

Water Development Until the 1960s

Sixty percent of the Segura river basin is within the Murcia Autonomous Region with the reminder 40% divided between the Autonomous Regions of Valencia and Castilla-La Mancha. The mild climate and the important baseflow (typical of a karstic catchment) of the Segura river encouraged the development of an important agricultural economy in the region. It was based on an irrigation network on the floodplains of the middle and lower part of the catchment area, which dates as far back as the Muslim occupation twelve hundred years ago. Vegetables, citrus and other fruits have been cultivated in the region for many centuries. Agroindustry (food processing) has also been significant at least since the beginning of the 20th century. Collective systems to manage surface irrigation were implemented several centuries ago.

Until recently agriculture was the main revenue generating activity in the Segura catchment area. Murcia was considered the orchard of Spain. Since the integration of Spain in the European Union (1986), the demand of its agricultural products increased significantly. The scarcity and/or variability in the availability of surface water resources have motivated the construction of two dozen reservoirs that provide total storage for about 1,000 Mm^3. Although good at preventing floods, they have not satisfied the farmers' water demands for irrigation at an almost nominal price. Politicians and engineers who have advocated for the transfer of water resources from the "humid" Spain to the "dry" Spain have backed the old paradigm, with intense reliance on subsidies. In 1933, the first formal proposal to transfer water from the Tagus river headwaters (in central Spain) to the Segura River was formally made, but became operative in 1979.

The Groundwater Abstraction Boom

In the 1950s and 1960s, the Spanish Ministry of Agriculture launched a significant effort to promote groundwater irrigation in Spain. This promotion can be told that was totally independent of the National Water Policy that, as mentioned earlier, was driven by the corps of civil engineers of the Ministry of Public Works This initial activity, heavily subsidized with public funds, was soon a catalyst that promoted intensive water well drilling by many private farmers in many regions of Spain. The most active region in this respect was the Segura catchment area. There were several reasons for the special development of groundwater abstraction in this region: a) the area had a long tradition of irrigation with surface water and a traditional capacity to market high value crops in Spain and abroad; b) many farmers had the expectation that these groundwater irrigated areas would have some kind of preference in the allocation of surface water coming from the Segura reservoirs, from the Tagus rivers water transfer or, more recently, from the future Ebro River water transfer project. In 1976 several years before the arrival of the first Tagus water, the new areas irrigated with groundwater required more water than the total theoretical water to be transferred to the Segura catchment in the eighties.

In Spain, according to the Water Law of 1879, groundwater was private ownership. The landowner could drill a water well in his/her land and pump as much groundwater as he/she wished, unless a third person was affected. Nevertheless, in the 1950's special regulations were enacted by the Government that theoretically made groundwater a part of the public domain in the "Vegas del Segura" (Segura floodplains). The lack of experts in hydrogeology inside the Segura Water Authority made this regulation difficult to enforce.

Even after the enactment of the 1985 Water Act the control of the old and new water wells in the Segura catchment area is rather scarce. The situation can accurately be described as one of administrative and legal "chaos" (see Llamas and Perez Picazo. 2002). For example, the official White Paper on Spain's Water (MIMAM, 2000, page 343) admits that in this region only about 2,500 water wells -out of more than 20,000 drilled- are legally inventoried by the Segura Water Authority.

8.3. The Tagus River Water Transfer and the Future Ebro River Water Transfer

In 1979, almost fifty years after the first formal proposal, water from the Tagus River was transferred to the Segura catchment through a 300 km long aqueduct. The capacity of this aqueduct is about 33 m^3/second or 1,000 Mm^3/year, but the maximum volume approved for transfer during the first phase was only 600 Mm^3/year. The reality is that the average volume transferred during the first two decades of operation of the aqueduct has been about 300 Mm^3/year. The theoretical 600 Mm^3 to be transferred were distributed in the following way: 110 Mm^3 for urban water supply, 400 Mm^3 for irrigation and 90 Mm^3 as estimated losses during transfer. It was also stipulated that when the water transferred is smaller that this theoretical amount, urban water supply had a clear priority. One interesting aspect of this project is that the beneficiaries of the transferred Tagus water pay a tariff for the water that is significantly higher than the tariff usually paid by surface water farmers in Spain (~0.005 €/m^3). In this case, they pay an average of about 0.1 €/m^3, although water for urban supply has a higher tariff than water for irrigation. The Law of the National Water Plan enacted in 2001 approved a new water transfer of 1,050 Mm^3/year from the Ebro River in Northern Spain to several regions along the Mediterranean coast. Almost 50% of this volume was for delivering to the Segura catchment area. The planned aqueduct was almost 900 km long. Out of the total volume transferred, about 50% is for urban water supply and the rest to supply water to areas in which groundwater abstraction has been excessive and has impacted the storage and groundwater quality of the aquifers. The Ebro water transfer has met strong opposition among many and different groups, parties and area-of-origin regional governments. Contrary and supporting demonstrations summoned hundreds of thousands in Zaragoza (against) and Valencia (pro). According to the government, the real cost of the Ebro water transfer will be about 0.30 €/m^3, but analysts argued it would be much higher.

8.4. The Conflict about the Ebro Water Transfer: Lack of Hydrosolidarity or False Paradigms?

In 2001 a poll was taken about the social perception of the Ebro water transfer. Fifty percent of those interviewed were in favor of the transfer, 30% were against and the remainder had no opinion on the issue. One could think that those who were against the Ebro transfer lacked solidarity with the Mediterranean regions because they denied water to *thirsty areas*, while the Ebro River has a surplus of water, which is wasted uselessly into the Mediterranean Sea. Most people, in every culture or religion think that it is a good action to give freshwater to the thirsty. In our Western civilization this is a biblical tenet. Nevertheless, are the people in the Segura catchment region really thirsty? Definitely, not. Almost 90% of the water used in this area is for irrigation of high value crops and not for urban water supply. The irrigation economy in Segura is flourishing and very efficient. Table 5 shows the evolution of irrigated lands in the Segura catchment region. It is shown that this surface has almost tripled since 1933, when the use of surface water reservoirs and groundwater was minimum.

Table 5. Evolution of irrigated area in the Segura catchment area.

Year	Area (ha)
1933	90,000
1956	104,000
1963	115,000
1983	197,000
1993	235,000
2000	252,000

Source: Llamas and Pérez Picazo (2001).

The second old and current false paradigm is that farmers cannot (and should not) pay the *full cost* of the infrastructures to bring them water from the Ebro River. Most authors consider that if the *full cost* of the transfer was passed on to the farmers and urban users through water use fees, they would not support the Ebro water transfer or be willing to pay for it, since there are cheaper and faster solutions to meet their water needs. As discussed in 5.2, detailed studies undertaken in Andalusia, Spain, have shown clearly that groundwater irrigation is much more efficient than surface water irrigation: it produces about 5 times more cash per m^3 used; and three times more jobs per cubic meter. The analysis done for Andalusia (a sample of almost one million hectares), and the conclusions drawn from it, can be applied to most irrigated areas of Spain (3,5 million ha). Other studies shown in Table 4 support this conclusion. .

Llamas and Pérez Picazo (2001) considered that nowadays both paradigms are obsolete. However, some time will be necessary to change the mentality of the general public. These false paradigms are also frequent in other countries, as it is mentioned in Llamas and Martinez-Santos (2005b). It seems probable that the conflicts between the farmers and the conservation lobbies will increase in the near future. To avoid or mitigate such conflicts a stronger policy of transparency, accountability and general education (without obsolete paradigms) seems important.

9. CONCLUSIONS

In Spain, like everywhere, complexity and variability characterize water management problems in general and even more so in the case of groundwater. Uncertainty is an integral part of water management. This uncertainty relates to scarcity of data, strong non-linearities in groundwater recharge values, scientific knowledge and changing social preferences. Honesty and prudence in recognizing current uncertainties is necessary. At the same time, there needs to be a concerted effort to obtain more and better hydrological data on which to base management decisions.

Intensive groundwater development is a new situation in most arid and semiarid countries. Usually, it is less than 30-40 years old. Four technological advances have facilitated this: 1) turbine pumps, 2) cheap and efficient drilling methods, 3) scientific hydrogeology advance, and 4) cheap and accessible energy. Full cost (financial, operation and maintenance) of groundwater abstraction is usually low in comparison to the direct benefits obtained.

Mainly individual farmers, industries, or small municipalities have carried out groundwater development. Financial and technical assistance by conventional Water Authorities has been scarce. This is why this new situation can be properly described as a ***SILENT REVOLUTION*** done by a great number of modest farmers at their own expense.

The lack of planning and control of groundwater development has resulted in ecological or socio-economic impacts in a few regions. Property rights and institutional uncertainty is now worrying the beneficiaries, but despite them none seems to be withdrawing and many other risk becoming users beyond the Law and the public control.

Aquifer overexploitation is a complex concept that needs to be understood in terms of a comparison of the social, economic, and environmental benefits and costs that derive from a certain level of water abstraction. It is meaningless and misleading to define overexploitation in purely hydrogeological terms given uncertainties in recharge and abstraction values and the fact that the amount of available resources in a catchment area is variable and can be influenced by human actions and management decisions. The assumption that a long trend (10 years, for example) of decline in groundwater levels implies real overexploitation or overdraft may be too simplistic and misleading. This concept has been used in Spain to provide grounds for public action, igniting a top-down sort of policy that has failed to deliver significant benefits.

Increasing emphasis on cost-effective and environmentally sensitive management practices places a new thrust on broad public involvement in any water management decision-making process. But guaranteeing effective public participation in management processes requires informing and educating the public on increasingly complex scientific and technical issues. Effective information and education campaigns are therefore essential. The conflicts that are often a part of water management processes require the use of innovative conflict resolution mechanisms that will allow for the discovery of feasible solutions that are accepted by all and can be successfully implemented. Up to now in Spain, very little has been done in this direction.

Because of the persistence of obsolete paradigms, the wonderful concept of Hydrosolidarity was recently improperly used in Spain to promote *perverse subsidies* mainly through the Ebro River water transfer to the Mediterranean regions. In the opinion of these authors, fortunately, the construction for the Ebro River diversion has been cancelled because it would be a wasteful use of public money. However, the initial solution proposed by the new government is equally prone to “perverse subsidies”. The difference is that the public funds will be employed in the construction of more than a dozen large desalting plants. The probability that farmers accept this solution is small. The main reason for this rejection is that abstracting or buying groundwater is significantly cheaper than to pay desalted water. Probably, in most cases this abstraction of groundwater may not be sustainable and it is against the spirit and the provisions of the WFD. However, logically under the current administrative and legal chaos in groundwater development farmers are not very concerned on the need of achieving an environmentally sustainable groundwater development. They are much more concerned with the economic and social sustainability of groundwater development .Yet the amended Law of the National Water Plan includes a certain number of articles that, if are actively enforced, would contribute efficiently to introduce a new water culture in Spain.

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