CHAPTER 19
Intensive groundwater use in Spain

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ABSTRACT: Groundwater use in Spain is an important socioeconomic resource, both as a factor of production in agriculture and industry, and as a source of drinking water. The primary use of groundwater is for irrigation. In Spain, the direct economic benefits of groundwater use greatly outweigh the direct costs of obtaining that water, even when these are very high. The Spanish 1985 Water Act, and its 1999 reform, attempted to deal with the negative consequences of unplanned and intensive groundwater developments by significantly altering the institutional context for the management of groundwater resources. Groundwater user associations are called to play a significant role in the new framework. There exist some examples of successful groundwater user associations and effective cooperation between users and water authorities, but they are still few. The case of the Western Mancha aquifer is reviewed as a paradigmatic example of intensive groundwater use in Spain.

1 INTRODUCTION

Groundwater use in Spain has increased dramatically over the last several decades, with the total volume pumped growing from 2,000 Mm^3/yr in 1960 to more than 6,000 Mm^3/yr in 2000. Today, groundwater provides between 15%–20% of all water used in the country.

The intensive development of groundwater resources has brought about significant social and economic benefits, but their unplanned nature has also resulted in negative environmental, legal and socioeconomic consequences. In order to deal with these problems, the 1985 Water Act radically transformed the institutional context for the management of groundwater resources in Spain. Most significantly, it publicized groundwater ownership, allowing existing users to remain in the private property regime if they so wished, but requiring administrative permits for any new uses. It also regulates the concept of aquifer overexploitation, giving water authorities broad powers to regulate groundwater use in aquifers that were declared overexploited. In accordance with the law, 16 aquifers have been declared overexploited since 1985. While this declaration should be accompanied by strict regulatory measures, they have most often not been successfully implemented, and a situation of chaos still persists in many of these aquifers.

Groundwater use in Spain has significant socioeconomic importance, both as a factor of production in agriculture and industry, and as a source of drinking water for over 12 million people (almost one third of the total population). In spite of this importance, the quality and reliability of existing data on groundwater use and its associated economic value are insufficient. Available data points to the higher productivity of irrigation using groundwater compared with that using surface water. Given the importance of irrigation as a water user, and in the context of increased competition for limited water resources, it becomes imperative to improve the quality of data on groundwater use and its economic importance in order to inform water policy decisions in the future.

This chapter presents an overview of the situation of intensive groundwater use in Spain, with an emphasis on economic and institutional aspects. After a review of available data on groundwater use and a brief discussion of some regions where groundwater is used intensively, an analysis of the economic parameters associated with this use is presented, focusing on irrigation. The next section goes on to evaluate the institutional framework for the management of groundwater resources that has evolved from the 1985 Water Act and its 1999 reform. The chapter ends with a close analysis of the situation in the Upper Guadiana basin, perhaps the most salient example of intensive groundwater use in Spain.

2 GROUNDWATER USE IN SPAIN

Groundwater is a rather underutilized resource in Spain, particularly if compared to its use in other European countries. Table 1 presents data on the total volume of water used in Spain in the different sectors, and of the role groundwater plays.

Table 1. Groundwater use in Spain. Data from MOPTMA-MINER (1994), ITGE (1995), and MIMAM (2000).

Use	Total water used (Mm^3/yr)	Groundwater used (Mm^3/yr)	% of total use supplied by groundwater
Domestic supply	4,650 (13%)	1,000–1,500 (~ 20%)	~ 25 %
Agriculture	24,100 (68%)	4,000–5,000 (~ 75%)	~ 20 %
Industry	1,650 (5%)	300–400 (~ 5%)	~ 5 %
Power plant cooling	4,900 (14%)	–	–
Total	35,300 (100%)	5,500–6,500 (100%)	15–20 %

As is the case in most arid and semiarid countries, the principal use of water is for irrigation. There is some uncertainty associated with official data on total volume of groundwater pumped in Spain. Furthermore, there is a significant shortage of data on the breakup of groundwater use in the different sectors. In any case, groundwater supplies between 15%–20% of all water used in Spain, which is approximately 35,000 Mm^3/yr.

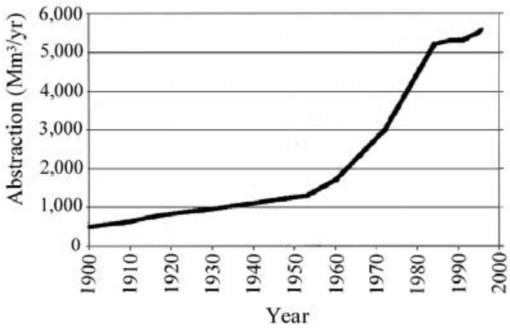

Figure 1. Evolution of groundwater abstracted in Spain. Modified from MIMAM (2000).

Figure 1 shows the significant increase in groundwater abstractions in Spain in the second half of the 20th century. For the most part, this development has been the result of the initiative of thousands of individual users and small municipalities that have sought out their own sources of water for irrigation and domestic or industrial water supply, with scarce public planning or oversight.

While groundwater use plays a major socioeconomic role in some regions, as will be seen throughout this chapter, it continues to play a minor role in Spanish national water policy. This situation does not correspond with Spain's significant hydrogeological potential. Rather, it is the result of a set of historical circumstances and a Hydraulic Administration that emphasizes surface water development projects over other water supply alternatives that could include groundwater.

2.1 *Urban groundwater supply*

According to the European Environmental Agency (EEA 1999), in European countries with sufficient aquifer potential, around 75% of domestic water supply usually comes from groundwater. As can be seen in Table 1, in Spain this percentage is only 25%. Roughly 12 million people use groundwater as their main source of drinking water. In communities of less than 20,000 inhabitants, approximately 70% of water comes from groundwater sources, whereas in larger cities 22% does (MIMAM 2000). Figure 2 shows that, in comparison to other European countries and with the exception of Norway, which has very little aquifer potential, Spain has the lowest percentage of groundwater used for urban supply.

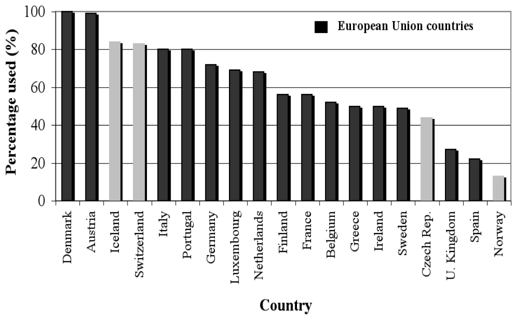

Figure 2. Percentage of groundwater used for domestic water supply in different European countries [Llamas *et al.* (2001). Data from EEA (1999)].

The amount of groundwater used for domestic water supply in Spain has fluctuated significantly with varying climatic conditions and the resulting availability of surface water supplies. For instance, as a result of the 1991–1995 drought period, the volume of groundwater used for urban supplies increased from the average 1,000 Mm^3/yr to 1,500 Mm^3 in 1995 (ITGE 1995, as cited in López Geta 2000). The biggest increases took place in the Tagus river basin (mainly for the supply to Madrid), in the South basin, and in Catalonia. But even the 1,500 Mm^3/yr represent only about 30% of the total water used in urban supply. It seems a low percentage for a country with the hydrogeological potential and the meteorological characteristics of Spain. In some cases groundwater could play a major role in guaranteeing water supply to cities during droughts.

Two sets of reasons can help explain the limited use of groundwater for domestic water supply in Spain. On one hand, urban water supply is the responsibility of municipal governments that in many cases lack qualified personnel in groundwater hydrology. Consequently, water sources are often chosen following tradition and not according to technical, economic or environmental criteria (Hervás 2001). As a result, surface water resources tend to be emphasized. In addition, water supply projects are usually designed by civil engineers, with very limited training in hydrogeology, and accustomed to deal primarily with surface water resources. But maybe a more important reason is the tradition of publicly subsidized construction of surface water development projects in Spain. Water supply companies lobby the State for the construction of surface water infrastructures that are primarily paid for with general revenues. More rational solutions from an economic and environmental point of view, which could rely on groundwater, are ignored, because they imply for these companies costs that are not financed by the State.

2.2 *Groundwater use for irrigation*

The dramatic increase in groundwater development in Spain has been primarily undertaken by thousands of individual farmers in different regions with very limited public involvement. In some regions (Castilla-La Mancha, Murcia, Valencia), groundwater is the primary source of water for irrigation. In the Balearic and Canary Islands, groundwater is practically the only available resource (see Fig. 3).

Many official statistics about water use for irrigation do not differentiate between surface and groundwater sources. This is primarily due to the fact that, until 1986, there were no comprehensive inventories of existing groundwater uses and no administrative permits were required to abstract groundwater. It is worth highlighting the Irrigation Inventory of Andalusia, made available by the Andalusian Regional Government in 2000 (http://www.cap.junta-andalucia.es/regadios). This is the first thorough regional inventory to include detailed information on all agricultural uses of water *and* their associated socioeconomic information.

Approximately 75% of groundwater abstracted in Spain is used for irrigation. Table 2 shows that groundwater provides 20% of all water used to irrigate almost 1 million ha, about 30% of the total irrigated area. That is, groundwater irrigation is significantly more efficient than surface water irrigation in Spain, using 4,700 m^3/ha/yr and 8,200 m^3/ha/yr, respectively. The reasons that may help explain this greater efficiency will be discussed in Section 3.

Table 2. Water use for irrigation in Spain (Llamas *et al.* 2001).

	Origin of water for irrigation			
	Surface water	Ground-water	Mixed	Total
Irrigated area (10^3 ha)	2,250	950	150	3,350
Average volumes used (m^3/ha/yr)	8,200	4,700	–	7,200
Total volume used (Mm^3/yr)	20,000	4,500	–	24,500

Figure 3. Regional map of Spain.

2.3 *Regional examples of intensive groundwater use*

The most significant cases of groundwater intensive use in Spain are related to the development of groundwater for irrigation starting in the late 1960s and early 1970s. Some cases are particularly relevant for their socioeconomic and hydrogeological importance and because of the conflicts that arose from the unplanned nature of the developments. A brief overview of some regions where groundwater is intensively used follows (see Fig. 3 for geographical locations). Some of them will be discussed in greater detail throughout this chapter.

- In Castilla-La Mancha the availability of groundwater resources from several large aquifers (primarily the Western and Eastern Mancha aquifers) has allowed the large-scale development of irrigation agriculture in the region. The case of the Western Mancha aquifer, analyzed in-depth in Section 5, is a paradigmatic example of the social and economic benefits that result from intensive groundwater use, and the environmental and social conflicts that result from anarchic use.
- In the Valencia autonomous region (encompassing Alicante, Valencia and Castellón provinces), groundwater plays a pivotal role

as a key resource for agriculture, a booming summer tourism industry, domestic water supply, and industry. The availability of groundwater has ensured the survival of a very vibrant agricultural sector even through the most severe drought periods. Over 25% of all groundwater abstracted in Spain is pumped in the Júcar river basin, which encompasses most of the Valencia region and a portion of Castilla-La Mancha (including the Eastern Mancha aquifer). As will be seen later, in this area there are many interesting examples of collective management of groundwater, as well as of joint use of surface and groundwater resources (see Sahuquillo & Lluria, this volume).

- The region of Murcia occupies 60% of the Segura river basin, a semi-arid region whose *water-woes* have historically dominated the Spanish water policy debate. It is estimated that groundwater provides over 45% of all resources available in the basin (60% if external water transfers are not considered) (Tobarra 2001). The basin is the recipient of the largest interbasin water transfer in the country, the Tagus-Segura Aqueduct. Groundwater developments in this region have historically intensified following the announcement of new surface water infrastructures (Martínez Fernández & Esteve 2000). Agricultural lands would be converted to irrigation using groundwater resources in order to acquire rights to the expected availability of new surface water resources. However, demand has largely exceeded supply, and groundwater has been used to make up for the difference. As a result, groundwater development has been an unplanned and uncontrolled phenomenon. In fact, of the officially estimated 20,000 wells that exist in the basin, only 10% are registered or have the necessary permit (MIMAM 2000). The result has been significant drops in groundwater levels (up to 15 m/yr in many small aquifers), problems of saltwater intrusion, and even structural damage in the city of Murcia as a result of land subsidence, one of the few cases of such phenomenon in Spain (Martínez Fernández 2001). The environmental consequences of these developments have also been significant, with the disappearance of most of the region's groundwater dependant wetlands. But, most importantly, the absence of reliable inventories or any groundwater user organizations, and the existence of thousands of illegal users in the basin make the tackling of these problems particularly challenging.
- In some areas of Catalonia, particularly in the lower Llobregat river and in Tarragona, intensive use is related to the development of groundwater resources for domestic and industrial water supply. As will be later discussed in Section 4, users in the lower Llobregat aquifers have organized and manage their resources sustainably. In the case of Tarragona, on the other hand, groundwater abstractions increased dramatically in the 1970s as a result of the development of a petrochemical industrial complex in the region. This brought with it the development of related industries, significant population increases and economic growth. The development of the coastal municipalities as a popular summer tourist destination only served to aggravate the problem. Seawater intrusion threatened the adequacy of the water supply system in Tarragona and other urban centers, as well as the use of the resource in the industrial processes. The declaration of overexploitation of two aquifers in the region in 1988 did not result in significant groundwater management initiatives. The transfer of surface water resources from the Ebro river helped meet increasing demand, resulted in the recovery of the piezometric levels, and improved groundwater quality (in terms of salinity). On the other hand, it also resulted in a loss of interest in groundwater management and especially in its protection from pollution.
- The Campo de Dalías area, in Almería (southeastern coast of Andalusia), one of the most important cases of groundwater intensive use in Spain, which is discussed in greater detail in Section 3.3.2.
- In the Canary Islands, also described in Section 3.3.2, groundwater represents 80% of all water resources. Its unique hydrologic and geographical position has resulted in the existence of a specific legal regime. The 1990 Canaries Water Act (which revised a more restrictive but very unpopular 1987 version) rules water rights in the islands. The intensive development of groundwater resources has been achieved through the construction of wells and horizontal gal-

leries together with a complex network of thousands of kilometers of privately owned transportation canals and pipes.

- In the Balearic Islands, groundwater covers almost all water needs. Given the strategic importance of the resource, in 1968 an increasingly restrictive body of water law started to develop, which applied specifically to the management of groundwater resources in the islands. The 1985 Spanish Water Act superseded the regional legislation. But its implementation has been significantly facilitated by the existence of comprehensive inventories and the restrictions that were in place as a result of the regional laws. In spite of this advantage, some problems of continuous decline of groundwater levels and saltwater intrusion in some aquifers persist. With 34,000 registered wells, 285 Mm^3/yr are extracted from the islands' aquifers, an estimated 25 Mm^3/yr above the average annual renewable resources (Barón 2002).

Intensive groundwater use in these regions has resulted in significant economic and social benefits, contributing to employment generation and economic development, as well as guaranteeing industrial and domestic water supply. But negative impacts have also occurred. The most significant and widespread have been the destruction or deterioration of groundwater-dependant aquatic ecosystems, and water quality deterioration in coastal aquifers as a result of saltwater intrusion.

Several international meetings have been organized in Spain to discuss the concept of aquifer overexploitation and analyze the situation of intensively used aquifers (Pulido *et al.* 1989, Candela *et al.* 1991, Dijon & Custodio 1992, Simmers *et al.* 1992). Despite this, the negative consequences of intensive groundwater use continue to be emphasized while the characteristics and behavior of affected aquifers are not sufficiently studied (Llamas 1992, Custodio 2000). Declarations of overexploitation are based on abstraction and average recharge estimates, variables that are difficult to estimate. The perception of a continuous decline in groundwater levels, or localized instances of water quality deterioration or saltwater intrusion are often seen as evidence of overexploitation, without taking into account the transient state of the aquifer toward a new equilibrium (Llamas & Custodio, this volume: Chapter 1). Estimates of average renewable resources are considered to be constant when, in fact, they fluctuate in response to different pumping patterns. Aquifer characteristics such as size, transmissivity or storage capacity are also not taken into account. Most importantly, the social, economic and institutional aspects associated with intensive use are not considered. This limits the ability of managers and users to effectively address the problems.

In Spain, 16 aquifers have been legally declared overexploited in accordance with the 1985 Water Act. But independently of this legal declaration, which is often embedded in intense political and social debate, the Spanish water administration has identified overexploitation or salinization problems in 77 hydrogeologic units (MIMAM 1998), in addition to 15 other units in the Canary Islands and Catalonia, which have their own hydraulic administration. But these numbers are constantly evolving as groundwater abstraction and recharge estimates are updated and refined (Custodio 2002).

Following is a discussion of the economic, social and institutional aspects of intensive groundwater use in Spain, using data and examples from the different regions described above.

3 ECONOMICS OF INTENSIVE GROUNDWATER USE IN SPAIN

The legal definition of aquifer overexploitation in Spanish water law focuses on a comparison between volumes pumped and available renewable resources. Given the limitations associated with the concept of overexploitation that were discussed in Custodio & Llamas (this volume: introductory considerations), it may be useful to broaden the understanding of it beyond purely hydrological variables to include a comparison of the social, economic, and environmental benefits and costs that derive from a certain level of water abstraction. In this sense it would be necessary to evaluate both the private and direct costs and benefits of groundwater use that have clear monetary value; but also the social or external benefits and costs that are not reflected in the market and are more difficult to quantify, but that are, nevertheless, important.

When aquifers are intensively used, problems often arise because the direct benefits that users obtain from a certain level of abstraction greatly outweigh the direct costs of obtaining that water, even when these are very high. But the associated indirect or external costs, which could make some levels of abstraction economically or socially inefficient, do not accrue directly to the users. Rather, they are spread over space and time and are borne by others or society at large. As a result, the overall costs of intensive groundwater use do not motivate changes toward more economically and socially efficient abstraction regimes. In order to promote these changes, it is necessary to foster institutional arrangements that encourage users to limit consumption and invest in the long-term sustainability of the resource (Ostrom *et al.* 1999).

3.1 *Costs of groundwater use*

3.1.1 *Private or direct costs*

Private costs are those that are directly borne by the users. They include the costs of building and maintaining the well and associated infrastructure, and of pumping and distributing the water.

Pumping costs are a function of the quality of the well, the characteristics of the terrain, the pumping technology used, depth to water and energy costs. Historically, public subsidies have been granted for the conversion of dryland agriculture to irrigation. In some cases, regional governments continue to give economic assistance for the modernization of irrigation infrastructures. However, most often, Spanish farmers pay for all direct costs associated with groundwater irrigation. Table 3 presents some estimates of the costs involved in building and maintaining the well and pumping equipment, in some regions where aquifers are intensively used. Total costs are per well and include the costs of drilling the well, installing the necessary mechanical and electrical equipment, and annual maintenance costs estimated as a percentage of total investment (1% for wells, 2% for mechanical equipment and 5% for electrical equipment) (Ballester & Fernández Sánchez 2000).

In the case of groundwater used for irrigation, other important costs are those of the irrigation infrastructure, which will depend on the technology used (pivot, sprinkler, drop or gravity irrigation) and the type of crop. In Spain these costs are also often paid for fully by the farmers.

As Garrido & Livingston (this volume) point out, a significant cost component for groundwater users is energy consumption. In Spain there is no public support or subsidy for energy use by irrigators. Therefore, the relative importance of this cost component to the farmers is directly related to the depth of groundwater levels and the profitability of the crops. In the case of La Mancha region, described in detail in Section 5, Llamas *et al.* (2001) estimate that the energy cost of irrigating 1 ha, pumping water from a depth of 100 m, is about 84 €/ha/yr, which only represents about 5% of an *average* farmer's gross income. Therefore, increasing energy costs resulting from increasing pumping depths will hardly discourage farmers from continuing existing pumping patterns. However, in other areas of Spain, where groundwater levels are much deeper, energy costs can be much more significant. For instance, Rico & Olcina (2001) show how in some intensively used aquifers in Alicante (Southeastern Spain), where pumping depths are over 300 m, energy costs can represent up to 50% of the total operating budgets of some irrigator associations, and between 15% and 30% of individual farmers' gross incomes, depending on the value of the crops.

Distribution costs occur when various users share a well so that pumped water is distributed among them using networks that can be very complex. These types of well or irrigator associations are very common in coastal Eastern and Southeastern Spain. Pipelines are expanded as new users join the well association and it becomes necessary to service their land. The

Table 3. Pumping costs in different regions in Spain [Llamas *et al.* (2001) with data from Ballester & Fernández Sánchez (2000)].

		La Mancha	Planas levantinas (Valencia)	Campo de Dalías (Almería)	Llano de Palma (Mallorca, Balearic Islands)
Depth of well (m)	Min.	100	60	150	30
	Max.	200	160	400	70
Pumping capacity (L/s)		50	60	100	10
Total cost per well (10^3 €)	Min.	50	25	94.2	13.9
	Max.	79.8	51.4	218.8	18.4

design of these networks can therefore be very inefficient both from an economic and a resource use perspective. The costs involved in this category are the building and maintenance of the networks, as well as the construction of holding ponds to regulate distribution in some cases.

In some areas, irrigator or well associations charge all pumping and distribution costs to their members using a tariff system that usually has a fixed component, proportional to the area with irrigation rights, and a variable component that is proportional to the amount of water used. Carles *et al.* (2001a) have calculated the direct costs that irrigator associations charge their members for their use of water in the Valencia autonomous region. Table 4 shows some of their results. For comparative purposes, the price paid by members in the same area for surface water or a mixture of surface and groundwater has been included. Three significant conclusions can be drawn from the table: 1) there is a great variability in costs throughout the region; 2) groundwater users pay a higher price for water since they pay for all direct costs; and 3) users never pay for the social or external costs of groundwater use. Therefore there is no relationship between resource scarcity and cost of the resource, except when that scarcity requires the deepening of existing wells or the drilling of new ones.

Table 4. Average cost of irrigation water in the Valencia autonomous region (see Fig. 3). Modified from Carles *et al.* (2001a).

Water management areas	Source of water	Crop	Average cost[a] (€/m^3)
Mijares-Plana de Castellón	Surface water	Citrus	0.05
	Groundwater	Citrus	0.15
Palencia-Los Valles	Mixed	Citrus	0.12
	Groundwater	Citrus	0.13
Alarcón-Contreras	Surface water	Citrus	0.02
	Mixed	Citrus	0.07
	Groundwater	Citrus	0.10
Serpis	Surface water	Citrus	0.05
	Groundwater	Citrus	0.15
Vinalopó-Alacantí-Vega Baja	Surface water	Various	0.08
	Groundwater[b]	Grapes	0.29
		Various	0.26

[a] Average values of all irrigator associations in each region weighed by the areas irrigated by each.
[b] Rico & Olcina (2001) found that groundwater costs in the region in 1999 were 0.51 €/m^3.

3.1.2 *External or social costs*

In addition to the private or direct costs, groundwater use results in external or social costs that are more difficult to quantify but that should be evaluated in order to accurately assess the economic viability and social desirability of different pumping regimes. Intensive and uncontrolled groundwater use can have some negative consequences such as: aquifer salinization or contamination; decreased groundwater discharges to dependant aquatic ecosystems (wetlands, rivers and streams); land subsidence; and impact on the rights of other surface or groundwater users.

All these effects have been discussed at length in previous chapters in this book, and will therefore not be further discussed here. They are all caused by the aggregate effect of the actions of each user, who does not perceive the damage to himself or to society, and therefore does not modify pumping patterns. The cumulative impact of all these individual users can nevertheless be significant.

3.2 *Benefits of groundwater use*

Groundwater is an essential economic and social resource both as a production factor in agriculture and industry, as well as a source of drinking water. These are the extractive values of groundwater. But groundwater also performs other services for society that are harder to quantify and are generated simply by maintaining certain water levels in the aquifer. An important service provided by groundwater when used in conjunction with surface water resources, is the supply guarantee or stabilization value, which is particularly relevant in areas subject to droughts. This value comes from the increase in total resources available to users when both surface and groundwater are used in conjunction, as well as from the increase in the average amount of water available to users in any year, and the decrease in uncertainty. The stabilization value of groundwater can represent up to 80% of all extractive values (National Research Council 1997). For a detailed discussion of this value see Tsur (1997).

3.3 *Economic aspects of groundwater use in Spain*

There is little data in Spain on the economic importance of groundwater use. The studies that do exist are constrained to particular regions or sectors. In spite of these limitations, Table 5 presents a rough estimate of the economic value of groundwater use in Spain.

The table does not include environmental or social benefits that have no direct monetary value. Although methodologies have been developed to value these benefits, few studies have applied them to Spain and they are therefore not included here. In spite of the clear limitations of the data presented, the magnitude of the economic contribution of groundwater is apparent. Given the overwhelming weight of groundwater use for irrigation and domestic water supply, the discussion has been limited to these two sectors. The economic importance of groundwater in industrial uses is also significant, but there is very little available data on these uses.

Table 5. Economic valuation of groundwater use in Spain.

	Total volume used (Mm^3/yr)	Range of average values (€/m^3)	Total economic value (10^6 €)
Irrigation	4,000–5,000	1.10–2.15 [b]	4,500–10,750
Domestic water supply	1,000–1,500	0.25–1.25 [c]	250–1,850
Industrial use [a]	300–400	10 [d]	3,000–4,000
Bottled waters	4	–	600 [e]

[a] Industrial uses not connected to urban infrastructures.
[b] Data from Corominas (2001) and Llamas *et al.* (2001), both for Andalusia. Both values refer to gross productivity, that is, average production per average price paid to farmers.
[c] Data from MIMAM (2000). The economic value is the cost of providing the service, assuming this is equivalent to the price paid by consumers. They are minimum costs and rarely include all infrastructure, maintenance and sanitation costs.
[d] Estimate of water productivity in industrial uses in Andalusia (Corominas 1999). No national data available.
[e] Total gross revenue for the bottled water sector in 1999 (Zafra 2001).

3.3.1 *Domestic water supply*

Available data does not allow comparisons between the economics of domestic water supply using surface or groundwater. However, a few comments will serve to illustrate the situation of the water supply sector in Spain. From an economic perspective, the price of water in domestic water supply in Spain is nil. Users pay for the distribution costs, but do not pay for the resource itself or for external or opportunity costs (Pérez Zabaleta 2001). Tariffs paid by home consumers in different cities vary widely, from the 1.27 €/m^3 paid in Barcelona to the 0.23 €/m^3 paid in the southern city of Jaén (Fig. 3). For the most part, there appears to be little relation between the scarcity of the resource and the tariffs in place. Most often, these tariffs cover only a portion of the distribution and sanitation costs, and they do not cover the costs of the necessary infrastructures associated with the service (dams, canals, etc.), which are usually paid for by general revenue of the national or local government responsible for providing the service.

The White Book of Water in Spain (MIMAM 2000) estimates that the average tariff, that results from dividing gross revenue of water supply companies by the volume of water actually metered, is of 0.43 €/m^3. This is much lower than the resulting tariffs in other European countries such as Germany (1.41 €/m^3), France (1.03 €/m^3), or Belgium (1.12 €/m^3). The comparatively low tariffs that urban consumers pay in Spain do not encourage savings or good management. In addition, they do not encourage water supply companies to do the necessary maintenance and improvements in the distribution networks, so that often, these are highly inefficient.

3.3.2 *Irrigation*

The primary economic contribution of groundwater in Spain is in irrigation. The following paragraphs present a more detailed discussion of the economic aspects of groundwater use in irrigation in some regions, where it is used intensively and economic data are available.

The most comprehensive analysis of the economic contribution of irrigation using groundwater is the Irrigation Inventory for Andalusia mentioned before. Using data from this study, Llamas *et al.* (2001) show that, in Andalusia, irrigated agriculture using groundwater is economically over five times more productive (in € per m^3 of water) and generates almost three times the employment than agriculture using surface water, per volume of water used. This difference can be attributed to several causes: 1) the greater control and supply guarantee that groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques and more demanding and profitable crops; 2) the greater dynamism that has characterized the farmer that has sought out his own sources of water and bears the full costs of drilling, pumping and distribution; and 3) the fact that the higher financial costs farmers bear, motivates them to look for more profitable crops that will allow them to maximize their return on investments.

Using data from the Andalusian study, Corominas (2001) shows that while irrigation using groundwater only occupies 25% of all irrigated agricultural land and represents only 15% of all water used for irrigation in Andalusia, it generates almost 50% of the economic value of irrigated agriculture's total output and 50% of employment. The same set of data serves to highlight the economic importance of groundwater not only for its extractive value, which is in itself significant, but also for its stabilization value, discussed in Section 3.2. The availability of groundwater supplies has allowed irrigation agriculture in Andalusia to survive during severe drought periods. Corominas (2000) shows how total agricultural output during dry sequences decreased by only 10%, while 60% of irrigated land received less than 25% of its average surface water allocations.

It could be argued that the difference in productivity between surface and groundwater irrigation in Andalusia is largely due to the influence of the Campo de Dalías aquifer area, located in the southeastern coast (see Fig. 3). In this region, intensive groundwater development for irrigation has fueled a most remarkable economic and social transformation. The combination of ideal climatic conditions, abundant groundwater supplies, and the use of advanced irrigation techniques in plastic greenhouses for the production of highly profitable fruits and vegetables, has allowed the phenomenal economic growth of the region since the 1950s, when irrigation begun. Today, irrigation of over 20,000 ha of greenhouses generates, directly or indirectly, an estimated 1,200 million €/yr, and it is very normal for farmers in the area to have gross revenues of 60,000 €/ha. This has allowed the population in the region to grow from 8,000 inhabitants in the 1950s to more than 120,000 in 1999 (Pulido *et al.* 2000). But the lack of any kind of planning or control of these developments by either the water authorities or the users themselves has resulted in social tensions from the inadequate integration of necessary immigrant labor, as well as problems of salt water intrusion in some areas, and the need to deepen or relocate some wells.

Table 6. Productivity of water for irrigation in Andalusia (€/m^3) (Corominas 2001).

Water source	River basins		Andalusia
	Interior basins	Coastal basins	
Surface	0.52	1.04	0.59
Groundwater and mixed	1.09	3.23	2.42
Total	0.58	2.22	0.99

The effect of the Campo de Dalías in Andalusian agriculture becomes apparent in Table 6, where it can be seen that irrigation in coastal basins, where aquifers are the primary sources of water, is almost four times more productive than in the interior, where irrigation is for the most part the result of major surface water infrastructure developments. However, the productive advantage of groundwater is also clear in the interior basins, where irrigation with groundwater is twice as productive as that using surface water.

Data from other regions in Spain serve to underscore the fact that the productive advantage of groundwater irrigation is not only the result of more advantageous climatic conditions. Arrojo (2001) shows that similar advantages are observed in the 8,000 ha irrigated in the Alfamén-Cariñena region, another area of intensive groundwater use in the Ebro river basin (see Fig. 3). According to his work, net water productivity in this region ranges between 0.15 and 0.50 €/m^3, depending on the type of crop (peach, apple, pear or cherry). Arrojo (2001) compares these results with the productivities of some large surface water irrigation networks in the region, such as Bárdenas or Monegros (Fig. 3), where he estimates productivity hovers around 0.03 €/m^3. This author estimates that while irrigation with groundwater occupies 30% of the total irrigated area and consumes only 20% of all water used for irrigation in the entire Ebro river basin, it produces almost 50% of the total agricultural output of the basin. Once again, the advantage can be attributed to the supply guarantee that groundwater provides, which allows farmers to invest in more sensitive and water demanding crops that are at the same time more profitable, thus helping them defray the higher costs of searching for and obtaining their own water supplies.

Another regional example of interest in Spain is in the Canary Islands (see Fig. 3). It is significant both for its insularity and the resulting need to be self-sufficient in terms of water resources, as well as for the strategic importance that groundwater plays, providing almost 80% of all available water resources in the islands. The general scarcity of water resources has resulted in a unique water supply and use system that is characterized by three factors: 1) the prominent role played by the private sector in the search, extraction and marketing of groundwater resources; 2) the widespread use of water-efficient irrigation techniques; and 3) the increasing use of alternative water sources, such as desalted and recycled water. Water resources have historically been distributed in the islands through the functioning of largely unregulated water markets where both the resource and the transportation canals and pipes are privately owned.

As is the case in peninsular Spain, the economic and social importance of agriculture in the Canary Islands has decreased significantly in the second half of the 20th century, rapidly losing ground to industrial production and tourism. In 1998, it was responsible for only 3.8% of the islands' total economic output and provided 7.5% of all employment. These values are equivalent to those observed in the rest of the country. In spite of the decline in relative importance, total agricultural output has remained constant and agriculture continues to be the primary water user in the islands, consuming 276 Mm^3/yr, or 60% of all water used.

Table 7 presents data on the economic value of the primary agricultural crops of the islands. No official data are available on the productivity of water, and no distinction is made between irrigation using surface water and groundwater. However, the amount of surface water used for irrigation is very small and it is used jointly with groundwater. Some rough calculations have been made using consumption data for the island of Tenerife (where no surface water is available), and for different crops. These results are comparable to those obtained for groundwater irrigation in other regions of Spain.

3.4 *Conclusions*

Groundwater is an important economic resource in Spain. Existing data for irrigated agriculture show that, in terms of its extractive value, groundwater is more productive than surface water resources. Some of the reasons that explain this higher productivity are the greater supply guarantee groundwater provides, which allows investment in better irrigation technologies; and the fact that users bear all private costs, thus paying a higher price per volume of water used than irrigators using surface water, and motivating them to look for more profitable crops and use water more efficiently.

While groundwater users pay for all private costs, they do not assume the external and social costs associated with intensive levels of abstrac-

Table 7. Water productivity in the Canary Islands [Irrigation Plan for the Canary Islands in the year 2000 (Autonomous Government of the Canary Islands)].

	Area (ha) [a]	Production (tons) [a]	Specific production (€/ha) [a]	Average consumption (m^3/ha) [b]	Water productivity (€/m^3) [b]
Bananas	8,923	362,313	15,867	14,960	1.06
Potatoes	5,643	56,063	3,877	3,595	1.07
Tomatoes	3,816	327,964	38,837	8,167	4.75
Ornamental	369	8,030	24,126	8,431	2.86
Flowers	334	6,830	9,073	8,431	1.07

[a] http://www.gobiernodeCanarias.org/agricultura/Estadistica/index.htm (Data for 1999).

[b] Average consumption values for the island of Tenerife, which cultivates 57% of the total Canaries area dedicated to bananas, 73% of potatoes, and 47% of ornamentals and flowers.

tion. Water productivity continues to be high even in areas with serious environmental or social problems. Given that the direct benefits of groundwater use in most cases greatly outweigh the direct costs of pumping that water, users are not motivated to modify pumping patterns. But high productivity does not imply economically or socially efficient levels of abstraction. The economics of intensive groundwater use do not motivate changes toward more sustainable pumping patterns. These need to be achieved through changes in the institutional arrangements (both formal and informal) in place for the management of groundwater resources.

4 INSTITUTIONAL ARRANGEMENTS FOR THE MANAGEMENT OF INTENSIVELY USED AQUIFERS

The Spanish case presents a good example of a legislation that has experimented with different solutions for the management of aquifers. From the liberal approach that characterized private property of groundwater resources under the 1879 Water Act, to the more government-controlled approach of the 1985 Water Act, responding to more intensive groundwater use. A review of the characteristics and evolution of Spanish water law might shed some light on the challenges encountered when trying to manage groundwater resources sustainably.

4.1 *Intensive groundwater use in Spain and the 1985 Water Act*

The 1985 Water Act radically transformed the institutional context for groundwater management in Spain. Three innovations are particularly relevant. First, groundwater was declared a part of the public domain, as surface water resources had been since the first Water Law of 1866 (Llamas *et al.* 2001). As a result, River Basin Management Agencies (*Organismos de cuenca* or *Confederaciones Hidrográficas*) acquired, at least on paper, a relevant role in the management of public groundwater resources. They also were responsible for granting permits for any uses that started after 1985. The decision to make groundwater part of the public trust was driven by the need to deal with situations of intensive and anarchic use of certain aquifers, in order to avoid significant negative ecological and even socioeconomic consequences. The aquifers in the Upper Guadiana basin, discussed in the following section, were perhaps the most salient example.

The Act created a registry system for public water use permits or concessions, the Registry of Public Waters (*Registro de Aguas Públicas*). In order to prevent legal claims of expropriation, the Act gave groundwater users existing prior to 1986 the option of remaining in the private property regime. They could therefore choose to register the permit in the Registry of Public Waters, as a “temporary use of private waters” for a period of 50 years, after which they would become part of the public trust; or in the alternative Catalogue of Private Waters (*Catálogo de Aguas Privadas*). In the latter case, they can continue using the resource as before, but cannot change any of the essential characteristics of the right, and have no administrative protection in the case of conflicts with other users. The legal debate continues to this day as to what an essential characteristic is (Del Saz 2002, Moreu 2002), but some examples include the location or depth of well, the volume of water pumped, or type and characteristic of use, like for instance the field being irrigated.

The 1985 Act also gave River Basin Agencies broad powers for the management of aquifers declared overexploited in accordance with the law. The Regulation for the Public Water Domain that developed the 1985 Water Act, considers that “an aquifer is overexploited or in risk of being overexploited, when the sustainability 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”. In accordance with the law, 16 aquifers have been declared either provisionally or definitively overexploited since 1985, 14 in shared river basins and 2 in the Catalonian autonomous region (see Fig. 4).

When an aquifer is declared legally overexploited, Basin Agencies have to draw up a management plan and determine annual pumping regimes. Restrictions apply to users in both the public and private property regimes. No new pumping permits can be granted. All users in the aquifer are required to organize themselves into Groundwater User Associations, and a General User Association that encompasses all user associations in one aquifer system has to be formed. The goal of these measures is to foster user par-

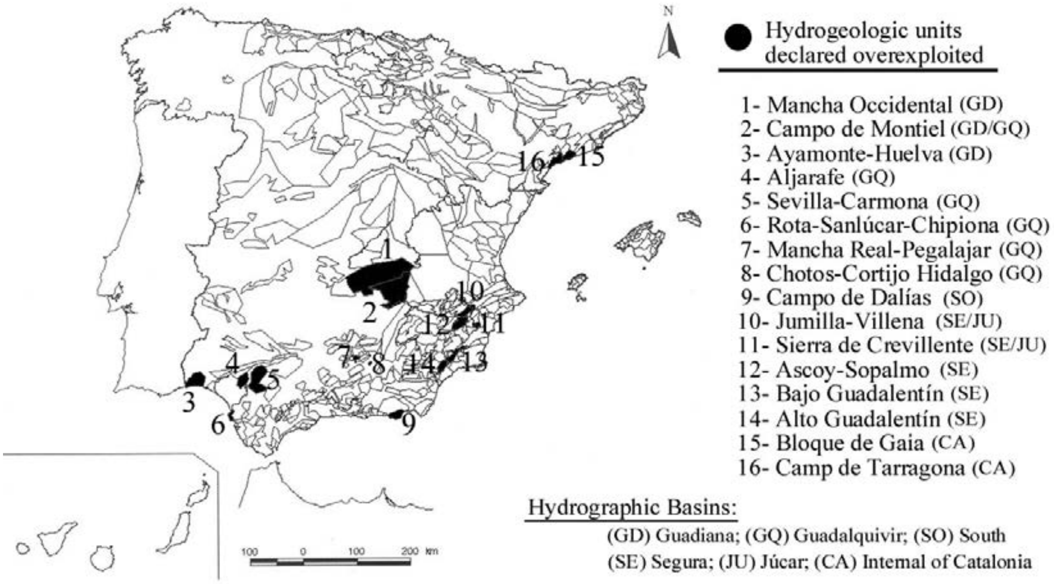

Figure 4. Hydrogeologic units legally declared overexploited. Modified from MIMAM (2000).

ticipation in the management of the resource, one of the guiding principles of the Act. These associations can represent the interests of the users and cooperate with Basin Agencies in the design and implementation of management plans. However, the practical implementation of these measures has not always been easy. User organizations have only been created in five of the 16 aquifers that have so far been declared overexploited, and management plans have so far only been elaborated and implemented in two of them: the Western Mancha and the Campo de Montiel aquifers, in the Upper Guadiana basin.

The third relevant change in what pertains to this chapter was the legal reaffirmation of the concept of user participation in water management. Under the 1879 Water Act, as well as historically, user participation in Spain was understood as the right of irrigators to organize self-governing institutions for the management of surface water irrigation systems. Since the appearance of the original water authorities in the 1920s, representatives of these irrigator associations (*Comunidades de Regantes*) were an integral part of their governing and management bodies. However, the 1985 Act expanded the concept of users to groundwater users and representatives of other interests and uses beyond irrigators. It created the River Basin Management Agencies by consolidating the old Water Commissioner Offices (*Comisarías de Aguas*), and the Hydrographic Confederations (*Confederaciones Hidrográficas*). It also established user participation quotas in the different participatory boards of the Basin Agencies: Governing Board, participatory management bodies (User Assembly, Public Works Board, Aquifer Management Boards, and Dam Management Boards), and in the basins' planning body, the Water Council (art. 24.1, Law 29/1985). While this participation is important, it has at times failed to be truly representative of all interests involved.

The changes introduced by the 1985 Water Act were necessary to deal with the challenges resulting from the more intensive use of groundwater resources in some areas. However, its implementation has encountered several difficulties, some of which are discussed below.

4.1.1 *Insufficient resources in Basin Management Agencies*

When the 1985 Water Act was approved, Spanish Basin Management Agencies lacked any experience in groundwater management, and the situation is still largely unresolved. Many have been unable to shift their focus from their traditional water infrastructure development and management responsibilities to their new broader water management goals. There is insufficient staff to deal with all the management responsibilities that derived from the 1985 Act. There is a need not only to increase the number of people in the Agencies, but also to bring in personnel with training in various disciplines to address the new management needs: hydrogeologists, sociologists, economists, ecologists, environmental education specialists, etc.

4.1.2 *Incomplete groundwater rights records*

More than 15 years after the Water Act came into effect, both the Registry of Public Waters and the Catalogue of Private Waters are incomplete. There is therefore no up-to-date record of existing groundwater uses, which makes effective management difficult. The White Book of Water in Spain (MIMAM 2000) officially estimates that there are approximately 500,000 operational wells in Spain (many argue this is a very low estimate). Of these, only half have been declared, and less than a fourth have actually been registered (see Table 8).

In order to complete the inscription process, and given the lack of capacity of Basin Agencies to do so, the Ministry of the Environment initiated in 1995 the ARYCA Program (*Programa de Actualización Registros y Catálogos de Aprovechamientos*), with an initial budget of 42 million € (MOPTMA 1995). Its goal was to update both the Registry of Public Waters and the Catalogue of Private Waters, through the subcontracting of consulting firms that would support the work of Basin Management Agencies. However, the cost of the program had already exceeded 66 million € in 2000 (Villarroya 2000) and, as is evident from Table 8, the situation still needs to improve significantly.

4.1.3 *Inadequate resources for monitoring and control*

Staff limitations in Basin Management Agencies makes monitoring and control of even the declared wells difficult. In the Campo de Dalías aquifer, for instance, there are approximately 20,000 ha irrigated, and over 20,000 individual farmers. But the Southern Basin Management Agency only has one guard or inspector to supervise this area. Similar limitations can be seen in the Western Mancha aquifer, in South-central Spain. The Guadiana Basin Management

Table 8. Administrative status of groundwater use rights in Spain.[a]

Administrative status		MOPTMA (1995)	Villarroya (2000), or MIMAM (2000) [b]
Registry of Public Waters, Section A (uses started after 1/1/86)	Estimated	26,200	33,500
	Declared	14,850	25,390
	Registered	3,350	7,901
Registry of Public Waters, Section B (pumping < 7,000 m^3/yr)	Estimated	154,600	194,465
	Declared	47,250	98,063
	Registered	14,700	29,967
Registry of Public Waters, Section C	Estimated	99,100	96,428
	Declared	99,100	96,428
	Registered	69,900	77,208
Catalogue of Private Waters	Estimated	166,900	203,302 [b]
	Declared	62,350	73,489 [b]
	Registered	15,650	16,510 [b]
TOTAL	Estimated	446,800	458,966 [b]
	Declared	223,550	244,703 [b]
	Registered	103,600	109,021 [b]

[a] The information in this table refers to uses in shared river basins only. River basins within one autonomous region (including the Balearic and Canary Islands) are the responsibility of the regional governments and are not included here.

[b] These data correspond to MIMAM (2000) (with data from 1995 and 1997), because Villarroya (2000) are not available.

Agency has only one inspector for every 2,500 km^2. This is insufficient for an aquifer with an estimated 25,000 wells operating in 5,500 km^2.

In this context, groundwater user communities should play a decisive role in groundwater management. Increased cooperation is necessary between users and Water Administration, particularly in what pertains to the regularization of existing uses and their monitoring and control. However, in spite of the legal recognition of the need for a participatory framework for water management, effective user participation has often failed to materialize, as will be discussed in Section 4.3.

4.2 *The 1999 Reform and the 2001 National Water Plan: reinforcing the framework*

The 1999 Reform to the 1985 Water Act, Law 46/1999 of December 13th, attempted to reinforce the institutional framework for the management of groundwater resources, emphasizing the role users should play. The following aspects of the reform are particularly significant:

- The 1999 Law requires Basin Management Agencies to approve an aquifer management plan within two years of the legal declaration of overexploitation. This reform is intended to avoid situations in which declarations of overexploitation remain in the books but no action to mitigate the problems is taken. This has been the case in most aquifers declared overexploited in the 1980s and early 1990s, but where the responsible Basin Agencies have not drawn management plans, organized users, or initiated any other mitigating measure.
- As was mentioned earlier, in some cases Basin Agencies have attempted to organize users within an aquifer but have been unsuccessful. To deal with this problem, the reform allows the Agencies to temporarily assign the responsibilities of the user community in overexploited aquifers to an appointed board representing all stakeholders in the aquifer.
- The 1999 reform allows Basin Agencies to subscribe cooperation protocols with user communities in areas such as follow up of management plans, permitting, regulation of existing uses, etc. These protocols can include technical as well as financial support. Although the 1985 Water Act already contemplated the possibility of these agreements, the reform emphasizes their importance by including them explicitly in its text, and by highlighting the convenience of providing support. This novelty can prove to be particularly relevant. Existing user communities often complain of a lack of support from Basin Management Agencies as well as an unclear demarcation of each other's responsibilities with respect to management duties. By highlighting the possibility of subscribing these protocols or agreements, the reform might help solve some of these problems.

The National Water Plan (Law 10/2001), approved in July of 2001 after more than a decade of intense political debate, further reinforces the role of user groups in the management of groundwater resources. The Plan is a legal requirement of the 1985 Water Act and the basic framework to guide water resources management in the country. It is meant to coordinate Basin Water Plans and compensate for the uneven geographical distribution of water resources through inter-basin water transfers from basins with *surplus* resources to *water-deficit* basins[1].

The transferred waters can only be used for some specific purposes, among them "to eliminate current situations of unsustainability as a result of the aquifer overexploitation in the receiving basins, and reestablish environmental equilibrium while ensuring the subsistence of existing uses in those aquifers" (art. 17b, Law

[1] The Spanish terms *cuencas deficitarias* (river basins with water deficits) and *cuencas excedentarias* (river basins with water surpluses) are actually a part of the law. However, they have and continue to be subject to much criticism from academic, environmental and political circles because of the great uncertainty associated with the calculation of these terms. The surplus or deficit of each hydrologic planning regions (which may correspond to one or more river basins) is calculated in each basin's water plan as the difference between all existing and estimated future uses and the average available resources in the basin (both present and future under possible climate change scenarios). The basic assumption of the National Water Plan (and of the 1985 Water Act) is that surplus basins should transfer resources to water-scarce basins to compensate for existing and expected future water deficits. The Plan proposes a major transfer of water resources from the Ebro river basin or planning region in Northeastern Spain, to Catalonia, Júcar, Segura and South planning regions, all in the Eastern and Southeastern Mediterranean coast (Fig. 3), all areas where groundwater resources are intensively used.

10/2001). What is significant is that the Plan requires users in the receiving aquifers to be organized in user associations. It also establishes that the user community will hold the title to the transferred water and makes them responsible for reducing pumping rights proportionally to the volume of transferred water received, until total abstractions are reduced to sustainable levels. In essence the Water Plan puts users for the first time in charge of allocating and limiting water rights, thus making them responsible for aquifer management decisions together with Basin Management Agencies. The requirements of the Water Plan in terms of user participation and groundwater management are encouraging. However, it is still too early to ascertain what the real impacts of these changes will be and whether it will be possible to successfully implement them.

4.3 *Groundwater user associations and the management of intensively used aquifers*

Spain has a long-standing tradition of participation of irrigators in water management activities. Irrigator associations have existed from as far back as the 11th century. These traditional associations were originally organized around irrigation networks in order to build and maintain the canals, distribute the water among the different members, and resolve water-use related conflicts that could arise between them. Given this tradition, it seemed logical that the 1985 Water Act would encourage a similar participatory management structure for groundwater resources.

Today, there are thousands of irrigator associations in Spain. This includes approximately 1,400 groundwater user associations that are registered as public entities in accordance to the 1985 Water Act, and hundreds others that are organized as private corporations under private law and of which there is no official count. These *private* irrigator associations predominate in Eastern and Southeastern Spain, and in the Canary Islands, where groundwater for irrigation is for the most part managed collectively and privately.

There exists great variability among groundwater user associations. Their size and organizational complexity vary from a few members using the same well for domestic or agricultural use, to General User Communities that include thousands of individual irrigators, municipalities and irrigator associations in one aquifer. In spite of these differences, all groundwater user associations, whether of private or public nature, can be classified into two categories, according to their goals and objectives.

One category would include those associations whose objective is the common exploitation of a well or group of wells. In the terminology used by Carles *et al.* (2001b), these could be called *associations for the collective management of irrigation networks*. To a large extent, they operate like surface water irrigation associations, dedicated primarily to the distribution of water among their members. But in contrast to those, they typically pay for all drilling, installation, operation and maintenance costs.

The second and more interesting group includes those user communities that comprise all or a majority of users within one aquifer. In addition to pursuing their own interests, that is, maximizing the private utility in the exploitation of the resource, they also contribute to its conservation, that is, they also serve a social goal. They could be called the *associations for the collective management of the aquifers*. In terms of the tenets of the law, it is the associations included in this second group that can play a significant role in the management of groundwater resources. However, of the thousands of existing groundwater user associations, only 6 can be truly included in this group: 1) *Comunidad de Usuarios del Delta de Llobregat* (Catalonia); 2) *Comunidad de Usuarios Cubeta de Sant Andreu de la Barca* (Catalonia); 3) *Comunidad General de Usuarios del Acuífero de la Mancha Occidental* (Upper Guadiana basin); 4) *Comunidad de Regantes de Aguas Privadas del Campo de Montiel* (Upper Guadiana basin); 5) *Junta Central de Regantes de la Mancha Oriental* (Eastern Mancha); and 6) *Comunidad General de Usuarios del Alto Vinalopó* (Valencia region). Table 9 includes some basic characteristics of these organizations.

The *Delta del Llobregat* and *Cubeta de Sant Andreu de la Barca* user communities, both in Catalonia, deserve further comment. They were the first groundwater user associations created in Spain (even prior to the 1985 Water Act) and have been very successful at stabilizing groundwater levels through limiting extractions and artificial recharge, while guaranteeing dependant uses. Both are unique in that industrial and

Table 9. Characterization of groundwater user associations for the collective management of aquifers in Spain. Modified from Hernández-Mora & Llamas (2001).

Name	Comunitat d'Usuaris del Baix Llobregat	Comunitat d'Usuaris de la Cubeta de Sant Andreu de la Barca	Comunidad General de Usuarios del Acuífero 23[a]	Comunidad Regantes de Aguas Privadas Acuífero 24	Junta Central de Regantes de la Mancha Oriental	Comunidad General de Usuarios del Alto Vinalopó
Aquifer name	Delta and Valle Bajo del Llobregat	Cubeta de Sant Andreu de la Barca	Mancha Occidental	Campo de Montiel	Mancha Oriental	Several in Upper Vinalopó basin
Responsible river basin agency	Agència Catalana de l'Aigua	Agència Catalana de l'Aigua	Guadiana River Basin Management Agency	Guadiana River Basin Management Agency	Júcar River Basin Management Agency	Júcar River Basin Management Agency
Aquifer size (ha)	12,000	1,000	550,000	260,000	850,000	49,500
Declaration of overexploitation	No	No	1987	1988	No	1987 (Jumilla-Villena aquifer)
Primary use	Industrial and public water supply	Industrial and public water supply	Agriculture and public water supply	Agriculture and public water supply	Agriculture and public water supply	Agriculture and public water supply
Irrigated area (ha)	600 and decreasing	0	133,149	4,113	104,000	31,000
Population supplied	Barcelona and other urban centers	34,000	270,000	29,000	300,000 [b]	850,000
Annual volume of water pumped (Mm^3) and (year)	72.4 (1998)	6.4 (1998)	320 (2000)	5 (2000)	435 (historical average)	> 20 (1999) [c]
Year incorporated	1976	1985	1996	1988	1995	1996
Reason for organizing	Saltwater intrusion; drop of water levels	Decrease of natural recharge and drop of water levels	Legal requirement (declaration of overexploitation)	User initiative in response to declaration of overexploitation	Increase control over access and use	Manage common wells and surface water transfers
Motivation for organizing	Users' initiative with Administration's support and University assessment				Users' initiative with Administration's support	Joint Administration and user initiative
Members	150	31	12,000–15,000	101	900	45 [d]
Financing	Member contributions	Member contributions	Member contributions	Member contributions	Member contributions [e]	Member contributions [e]
Operating budget (10^3 €)	66.3 (2000)	30 (2000)	60.2 (2000)	42 (2000)	458 (2000)	1,970 (average)
Primary activities and future goals	Aquifer management and recharge. Aquifer monitoring. Monitoring of existing uses. Studies and technical reports. Information and education.		Implementation and control of Income Compensation Programme. Assistance to members in water right applications. Approval of aquifer management plans.	Implementation and control of Income Compensation Programme. Assistance to members in water right applications. Approval of aquifer management plans.	Hydrogeologic investigations. Inventory of existing uses. Digitalization of use and resource maps. Irrigation research and extension. Development and implementation of aquifer management plans.	Management of common wells. Management of regional water resources (future).

[a] The Comunidad General de Usuarios del Acuífero 23 encompasses 20 groundwater irrigator associations in the Western Mancha aquifer. They all operate independently from each other, and have different operational capacities. However, they generally share similar goals and objectives.

[b] Includes over 5,000 individual irrigators that belong either as individual members or as part of member irrigator associations; and over 80 municipalities, including the city of Albacete. 170,000 inhabitants (in the Albacete municipality) will be supplied with surface water in summer 2002.

[c] The Alto Vinalopó General User Community manages directly over 30 wells that extract 20 Mm^3 from three aquifers and distribute it to 18 irrigator associations and 6 municipalities. The remaining 21 members joined the Community after 1996 and include water supply companies and irrigator associations that pump water directly from the aquifers. Their interest in joining stems from the need to strategically position themselves for the surface water transfers coming to the area in the near future. The General Community has no information on total volumes pumped, although it is working with its members to develop a common pumping monitoring system and management plan for regional water resources.

[d] They are associated institutions.

[e] General operating budget comes from membership contributions. Public subsidies are received for specific projects.

domestic water supply are the primary uses. In both cases, intensive groundwater use resulted in alarming drops in water levels and, in the case of the Delta del Llobregat aquifer, saltwater intrusion problems. Users in both aquifers in close collaboration with the water authority initiated an intensive research, information and education campaign that allowed them to identify the problems, propose viable solutions, and convince users and the public at large of the need to organize and limit use of the resource (Galofré 2001). They have both actively managed their aquifers, financing all their activities through membership fees.

Of the six user organizations characterized in Table 9, only two (*Comunidad General de Usuarios del Acuífero 23* and *Comunidad de Regantes de Aguas Privadas del Campo de Montiel*, in the Western Mancha and Campo de Montiel aquifers, respectively) were created in response to a declaration of overexploitation. The *Comunidad General de Usuarios del Alto Vinalopó* includes in its area of influence the Jumilla-Villena aquifer, which was legally declared overexploited in 1987 (Fig. 4). However, initial attempts to create a user community in response to the declaration of overexploitation failed. It wasn't until other motivating factors came into play (requirement to organize in order to manage previously public wells and receive surface water transfers), and the area of influence was sufficiently large to articulate feasible solutions, that organizational attempts succeeded. The Spanish Water Administration has not succeeded in creating similarly effective organizations in the other aquifers that are legally overexploited, and in many cases has not even tried. Given the challenges encountered by River Basin Management Agencies to create operative user associations in intensively used aquifers, it may be useful to enumerate some common keys to the *success* of those associations in acting as true resource managers. In this context, *success* is understood as the ability of the user associations to articulate common goals and objectives and establish mutually accepted rules regarding resource access and use, in order to guarantee the long-term sustainability of the resource and dependant uses. Some of these keys are:

- The appearance of crisis situations through which a collective understanding develops on the part of all aquifer users about the negative effects of uncontrolled patterns of use.
- Adequate knowledge and common understanding by all users and affected parties of the boundaries and hydrogeological characteristics of the aquifer.
- A sufficiently large area of influence and sufficient resources to be able to articulate effective solutions to the existing problems.
- The ability to articulate common interests and goals, which becomes more difficult as the geographic area increases or when more than one administrative or political jurisdiction are involved.
- The number and type of users. In this sense, the participation of users or stakeholders with economic means or technical knowhow can facilitate the creation and effective operation of user associations. This is the case of the Delta del Llobregat user community, where the *Sociedad General de Aguas de Barcelona*, owner of various wells for the supply of Barcelona, plays a significant role in the operation of the community, contributing financially and lending its expertise. The Technical University of Catalonia (UPC), and the International Center for Groundwater Hydrology Foundation (FCIHS), have also historically cooperated with the community and lent their expertise. It is also the case in the Eastern Mancha aquifer, where the *Junta Central de Regantes de la Mancha Oriental* is closely associated with the local University of Castilla-La Mancha, thus benefiting from their technical and scientific support. Similar ties exist between the University of Alicante and the *Comunidad General de Usuarios del Alto Vinalopó*.
- The influence of leaders that understand the problems associated with anarchic and uncontrolled resource use; feel the need to organize users in order to limit access and use; and are able to communicate their vision of a successful user community and motivate others to cooperate with their efforts.
- The existing social capital in the communities where the user associations are created. When there is a tradition of association or there exist close ties among users, it is easier to articulate common interests and goals. On the other extreme is the case of

the Western Mancha aquifer, with over 20,000 users that have operated independently from each other from the start.

- The existence of external factors that favor the creation of user associations. A clear example would be the need to organize in the Vinalopó basin in order to receive and manage water from future surface water transfers; or the need to organize in the Western Mancha aquifer in order to manage and receive the subsidies from the Income Compensation Programme (see Section 5.4).
- The attitude of the Water Authority toward the users and the resulting relationship that develops between them. The differences that can be observed between the Guadiana and Júcar River Basin Management Agencies serve to illustrate this point. In the Guadiana, user associations were formed in response to declarations of overexploitation, but the relationship between the Agency and the users is one of mistrust and rivalry. On the other hand, the Júcar Management Agency sees users as its potential allies in its efforts to achieve sustainable water use patterns. They have succeeded in supporting the creation of two user associations that are effectively tackling some difficult issues while at the same time minimizing conflict and maximizing cooperation among users, and between users and the Agency.

The new framework for the management of intensively used aquifers that has resulted from the 1985 Water Act and its 1999 reform, calls for active user participation through groundwater user associations. There exist some excellent examples of user associations that act as effective resource managers, but they are still few. In 2001 the Catalonian User Associations (which encompasses the Delta del Llobregat and Cubeta de Sant Andreu de la Barca user associations) promoted the creation of the Spanish Groundwater Users Association. Its members include, among others, some of the organizations characterized in Table 9. According to its founding charter, its goals are to coordinate and exchange groundwater use criteria; to promote user participation in groundwater management; and to promote the protection, defense and knowledge of groundwater resources and use in the different regions. The Association is a private entity, not affiliated with any public organisms. Given the role that the Catalonian User Association has played in promoting the creation of new user associations (two are currently being formed), whether of private or public nature, in intensively used aquifers, it is to be hoped that Spanish Association will play a similar role on a national level.

5 THE UPPER GUADIANA BASIN: AN EMBLEMATIC CASE OF INTENSIVE GROUNDWATER USE

5.1 *Characterization of the Upper Guadiana basin*

The Upper Guadiana basin covers an area of approximately 16,000 km^2. It has approximately 400,000 inhabitants (25 inhabitants/km^2). Figure 5 shows a general map of the Upper Guadiana basin, as well as its situation inside the Iberian Peninsula.

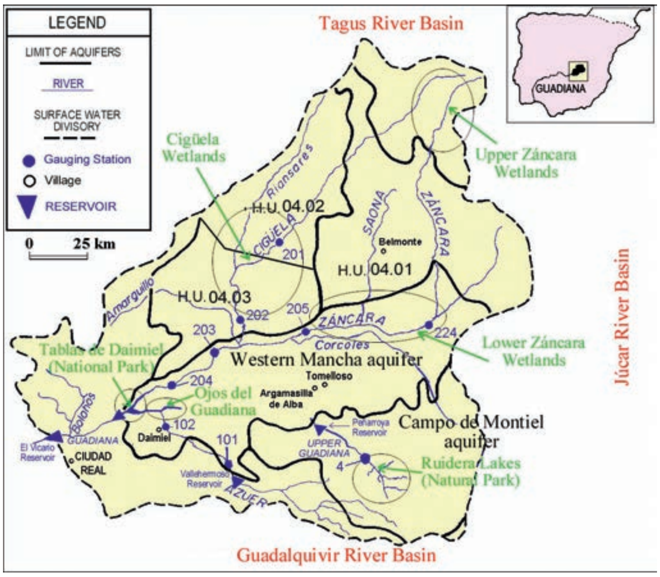

Figure 5. General map of the Upper Guadiana basin. Modified from Cruces *et al.* (1998).

With an average annual precipitation of about 400 mm, the Upper Guadiana basin is one of the driest river basins in Spain. Focusing on rainfall's specific contribution to runoff, it can be considered the driest, with an average lower than 30 mm/yr. The Segura river basin, the typical example of a dry zone in Spain, has an average value greater than 40 mm/yr.

Morphologically, the main part of the Upper Guadiana basin region is characterized by a smooth topography, with altitudes ranging 550–700 m.a.s.l. The smooth topography together with the geological characteristics of the region are responsible for the poorly defined surface drainage system, the interconnectedness of surface and groundwater resources, and the network of wetlands that lace the area and create the unique *Mancha Húmeda* ecosystem. UNESCO recognized the collective ecological importance of the 25,000 ha of wetlands that existed in the Upper Guadiana basin in 1980, when it designated the *Mancha Húmeda* Biosphere Reserve. In a largely arid region, these wetlands provide crucial nesting and feeding grounds for European migrating bird populations and are home to rare animal and plant species. The Tablas de Daimiel National Park (2,000 ha), a Ramsar Site, stands out for its significance as a symbol for the Spanish conservation movement. Another important water-dependant natural area is the Ruidera Lakes Natural Park, a system of 15 interconnected shallow lakes staggered along 35 km, with a joint extension of more than 3,500 ha.

5.2 *Groundwater intensive use in the Upper Guadiana basin*

Traditional agriculture in the Upper Guadiana basin was based on dry farming, primarily vineyards and cereals. Groundwater was used primarily for domestic water supply and small family orchards, in areas with shallow piezometric levels. Pumping was done through traditional *norias* (water wells) placed in excavated, generally shallow wells.

Starting in the 1960s, a dramatic land use transformation took place in the region, with the expansion of groundwater-irrigated crops like corn, sugar beet, sunflower and alfalfa.

Irrigation development in the Upper Guadiana basin concentrated in the Western Mancha aquifer (hydrogeological unit 04.04), the central and most important aquifer in the basin. In little more than 20 years, from the mid-1960s until the end of the 1980s, water abstraction in this aquifer increased seven-fold.

Figure 6 shows the evolution of total abstractions and groundwater irrigated area in the Western Mancha aquifer. In 1974 it was estimated that 30,000 ha were being irrigated with 160 Mm^3/yr. By 1989, over 125,000 ha were being irrigated with almost 600 Mm^3.

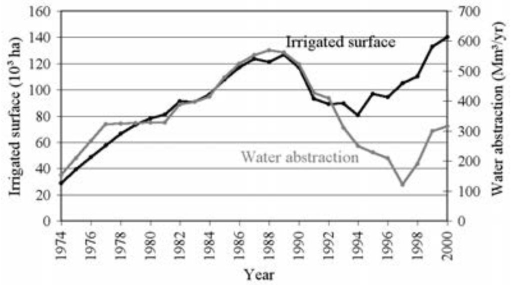

Figure 6. Evolution of irrigated area and groundwater abstracted in the Western Mancha aquifer (Martínez Cortina 2001).

On January 1st, 1986, the new Water Act came into effect, requiring all new groundwater users to request a permit from the water authorities. However, in the Western Mancha aquifer the uncontrolled construction of new wells continued.

The expansion of irrigation resulted in significant economic and social progress in the region. Farmer rent increased, and an important industrial activity related to agriculture developed.

But at the same time, the increased pumping resulted in significant drops in the water table, reaching up to 50 m in some places of the aquifer. Some older shallow wells became dry, and it became necessary to deepen many wells in order to maintain their productivity. But the most alarming consequences of the water level drops were the changes in the groundwater flow patterns and in the form, function and quality of many wetlands. Areas that had received the natural discharge from the Western Mancha aquifer, such as the Tablas de Daimiel National Park, became natural recharge zones, and only survived artificially thanks to the water transfers that came from the Tagus-Segura Aqueduct starting in 1988.

It is important to note that the disappearance of some wetlands in the *Mancha Húmeda* ecosystem was not always a direct result of the drops in groundwater levels, but rather were the consequence of misguided management decisions. In effect, conservation policies in the area have failed to look at the entire ecosystem. For instance, in order to make the transfer of water from the Tagus river to the Park more efficient, water authorities dredged and deepened the bed of the Cigüela river (see Fig. 5). As a result, many riverine wetlands of singular ecological importance became disconnected from the river and disappeared. Altogether, human activities in the area since the 1960s has resulted in the disappearance of more than 60% of the 25,000 ha of wetlands that under natural conditions composed the *Mancha Húmeda* ecosystem (Cruces *et al.* 1998).

5.3 *The importance of evapotranspiration. The increase of the renewable resources*

While the loss or significant deterioration of over 60% of all wetlands in the Upper Guadiana basin can be considered an ecological disaster, it has also significantly affected the amount of annual renewable resources. In the mid-1970s, with a total wetland area of approximately 200 km^2, total evapotranspiration in the Upper Guadiana basin was approximately 175 Mm^3/yr (around 125 Mm^3/yr in the Western Mancha aquifer alone).

The reduction in wetland area due to the drawdowns in water levels has produced a spectacular decrease in total evapotranspiration. A numerical groundwater flow model developed in the University of Cantabria (Cruces & Martínez Cortina 2000, Martínez Cortina 2001) evaluates this reduction. As can be seen in Figure 7, during the 1990s total evapotranspiration had decreased to an estimated 50 Mm^3/yr. The moderate increase in evapotranspiration during humid periods occurs primarily in aquifers adjacent to the Western Mancha, primarily in the Campo de Montiel. This aquifer is very responsive to changes in precipitation, so those humid periods result in the rapid recovery of the Ruidera Lakes. This is not the case of Western Mancha aquifer, where current evapotranspiration is only at about 10% of what it was under natural conditions. The piezometric levels remain well below the surface, and historic wetlands have not recuperated.

From the exclusive point of view of the water budget, the drastic reduction of evapotranspiration directly affects the estimation of the basin's

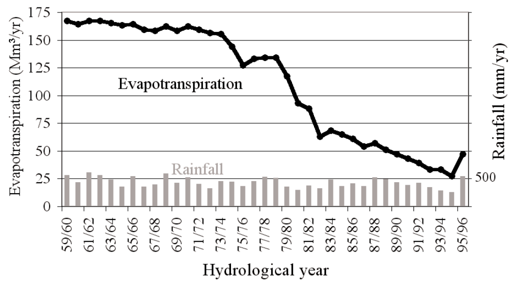

Figure 7. Evolution of the evapotranspiration in the Upper Guadiana basin (Martínez Cortina 2001).

renewable resources. These can be calculated as the difference between aquifer recharge from precipitation and losses from evapotranspiration. Consequently, the decrease in evapotranspiration results in an increase in renewable resources. The results of the above-mentioned numerical model suggest that, under natural conditions, average renewable resources were approximately 260–300 Mm^3/yr. With the decrease in evapotranspiration as a result of the disappearance of wetlands and humid areas, renewable resources in the 1990s were estimated to be in an average range of 385–425 Mm^3/yr. Notwithstanding the ecological and environmental loss, the intensive use of groundwater in the Upper Guadiana basin has resulted in an increase of almost 50% in the annual renewable resources.

5.4 *Institutional responses to intensive groundwater use*

The most relevant responses to the intensive use of groundwater in the aquifer are two, and are interrelated. First, the approval of the Water Act in 1985 allowed the Water Administration to intervene in the area and attempt to rein in a situation that was out of control. In 1987 the Western Mancha aquifer was declared provisionally overexploited. This allowed the Guadiana Basin Agency to impose severe pumping restrictions, prohibit the drilling of new wells for irrigation as well as the deepening of existing ones, and impose the organization of user communities. Management Plans (*Regímenes de Explotación*) have been annually approved for the aquifer since 1987, and they establish allowed pumping volumes for each irrigated hectare. These volumes are calculated on the basis of what is called *normal consumption*, set at

4,278 m^3/ha/yr, and are modulated in relation to the amount of land being irrigated, so that the larger the surface the smaller the amount of water allocated per hectare. In 1993, the Guadiana Basin Agency presented the Aquifer Restructuring Plan (*Plan de Ordenación de Extracciones*), thus declaring the aquifer definitively overexploited (López Sanz 1998).

These plans and restrictive measures have established the basis for improved management in the aquifer. However, the continued existence of thousands of illegal wells in the aquifer questions their success, since restrictions and controls apply only to legal wells. In fact, total irrigated area continued to increase in the aquifer until 1989, when the historical maximum was reached, with more than 125,000 ha irrigated with groundwater. The maximum abstraction was reached in 1988, with almost 600 Mm^3.

The effects of the declaration of overexploitation began to appear in 1990, when the total irrigated area started to decrease. Nevertheless, the most significant measure to reduce abstractions was the approval, in 1992, of the Agrarian Income Compensation Programme in the hydrogeological units 04.04 of the Western Mancha and 04.06 of the Campo de Montiel. The Agricultural Department of the Castilla-La Mancha Regional Government and the National Agricultural Ministry jointly submitted the Programme for approval to the European Commission. As originally designed, its goal is to contribute to rationalize the use of groundwater in the two aquifers and help mitigate the negative environmental consequences of excessive pumping. It was approved as part of the European Union's (EU) agro-environmental programmes (Regulation CEE 2078/1992), an integral part of the 1992 CAP (Common Agricultural Policy) reform. Known in the area as the *Wetlands Plan*, the Programme offers economic compensation to farmers in exchange for a reduction in the amount of water used per hectare for irrigation, as well as a reduction in the use of chemical fertilizers, pesticides and herbicides. Financing for the Programme is shared between the EU (75%), and the Regional (12,5%) and National (12,5%) Governments. The first phase of the Programme was approved for a five-year period (1993–1997), and had wide acceptance among farmers (see Table 10). The total cost was 96 million €. In 1997, a second phase was approved that will last through 2002. Among the innovations of the second phase was the requirement that all participating farms have flow meters installed to more effectively control pumping.

Table 10. Total surface area participating in the Income Compensation Programme for the reduction of irrigation in the Western Mancha and Campo de Montiel aquifers [Viladomiu & Rosell (1998) for 1993–1996. Department of Agriculture, Fisheries and Nutrition of Castilla-La Mancha Regional Government (pers. comm.) for the 1997–1999 period (unpublished data)].

Year	Participating hectares	Total theoretical savings (Mm^3)
1993	57,973	182.39
1994	74,853	235.97
1995	85,410	298.19
1996	85,834	302.16
1997	85,838	310
1998	85,020	Not available
1999	61,127	Not available

Many in the region have seen the wide acceptance of the Income Compensation Programme among area farmers, and the resulting water savings, as a positive development. However, it is important to analyze the data in Table 10 cautiously. In what pertains to the water savings, these are in fact theoretical. They are calculated in comparison with an average consumption that the Programme estimates at 4,200 m^3/ha/yr. But in reality, the management plans issued by the Guadiana Basin Management Agency over the past decade often limit extractions to volumes below this estimated average, so some savings may have occurred even without the Programme being in place. It would also be important to evaluate the savings in the context of the total volume of groundwater pumped from the Western Mancha aquifer, which is unknown given the volume of illegal abstractions. In addition, the success of the Programme in achieving long term structural changes in land and water use patterns is questionable. The evaluation of the first phase of the Programme by the European Commission (Viladomiu & Rosell 1998) indicated that farmers' primary motivation to participate was the desire to receive economic compensation for the restrictions that resulted from the implementation of successive aquifer management plans. Environmental protection or the desire to switch to agricultural practices that are more in accordance with the region's natural characteristics were not motivating factors. In view of these results, it is not clear what will happen once the subsidies end, although it is widely believed that a significant increase in total abstractions from the aquifer will once again take place.

In any case, the Income Compensation Programme has had two very positive effects. On one hand, it has significantly contributed to create a network of user communities in the aquifer, since it has been from their inception their main source of financing. On the other hand, it has also contributed to develop among farmers an appreciation for groundwater as a scarce and valuable resource in the region. However, given the significant cost of the Programme, it is pertinent to question whether similar and more permanent results could not have been achieved through other means.

Figure 6 showed that, throughout the 1990s, the evolution of total abstractions from the aquifer has not matched the growth in irrigated area. Several reasons may help explain this disparity. One is the progressive substitution of water-intensive crops with others that require less water. Figure 8 shows the historical evolution of the irrigated area dedicated to several crops in the Western Mancha aquifer. It shows that crops with high water needs, such as vegetables, and specially corn and fodder crops, have practically disappeared. On the other hand, the area dedicated to crops with lower water needs, such as cereals and especially vineyard, have remained constant or increased. In 1996, vineyards and cereals occupied 80% of the irrigated agricultural lands, up from 50% in 1986 and 30% in 1976.

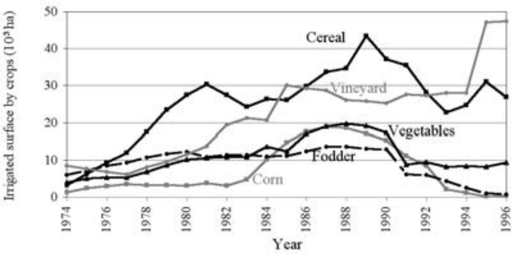

Figure 8. Evolution of irrigated surface of several crops in the Western Mancha aquifer (Martínez Cortina 2001).

Another important reason behind the reduction in total abstractions, which may also help explain the move toward less water-intensive crops, is the subsidies farmers receive through the Income Compensation Programme. As a result of the Programme, while official data for total irrigated hectares remains high, the total area actually irrigated, and the volume of water applied per hectare, has decreased significantly. It is also necessary to keep in mind that part of the reduction has resulted from the humid sequence that occurred in the late 1990s, following an important dry period. This reduced the need to irrigate some crops, such as vineyards.

A final possible explanation is the official underestimation of total groundwater pumping as a result of the existence of large numbers of illegal wells. The completion of a thorough inventory of all existing wells in the aquifer might help provide an accurate picture of the situation.

5.5 *User communities in the Western Mancha aquifer*

Groundwater development in the Upper Guadiana basin has been primarily an individual endeavor. As a result, it has been extremely difficult to organize and rationalize the actions of thousands of users acting independently. Following the declaration of overexploitation of the aquifer, the Guadiana River Basin Management Agency started the process of fostering the organization of groundwater user associations in compliance with the 1985 Water Act. Twenty groundwater user communities (officially called *irrigator communities*) have been organized in the aquifer, each encompassing the territory of one or more municipalities. Their size ranges between the 761 ha irrigated and 450 members of the smallest one, to the 35,923 ha and 1,431 members included in the largest user community. They finance their operations through the contributions of their members: a fixed fee per irrigated hectare (usually 1.20 €/ha), as well as a fee per hectare participating in the Income Compensation Programme (6 €/ha). As a result of this method of financing, there exist significant differences between large and small user communities with respect to their operating budgets and their resulting operating capacities. The relevance of the Income Compensation Programme as a primary source of funds is also evident.

Following the definitive declaration of overexploitation in 1994, the Guadiana River Basin

Agency worked to create a General Groundwater User Community encompassing all the individual communities in the aquifer. It was formally constituted in 1996. Parallel to, and in competition with the General User Community, members of 7 user communities in the aquifer formed the Castilla-La Mancha Groundwater User Association. These communities felt the Guadiana River Basin Agency had forced the creation of the General Community, and imposed a method of representation (voting rights are proportional to volume of water rights), that was detrimental to their interests. The existence of both organizations, often acting independently from each other, has hindered the articulation of common management goals for the aquifer.

The work of irrigator communities has focused on the management of the Income Compensation Programme and on providing support to irrigators throughout the water rights inscription process. They also participate, although to a much lesser extent, in the elaboration and implementation of aquifer management plans, through their elected representatives in the Basin Agency's management board. In effect, in 1996, representatives from the General Association were elected to represent Western Mancha aquifer groundwater users in the different participatory planning and management bodies of the Guadiana River Basin Agency. An Aquifer Management Board for the Western Mancha aquifer was also formed. Table 11 shows the distribution of representation in the various participatory governing boards of the Agency[2].

The creation of user communities and their participation in the different governing bodies of the Guadiana Basin Agency is theoretically an ideal institutional design for the management of an aquifer. However, in the case of the Western Mancha aquifer this design has so far not been truly effective. Conflicts among users and between these and the Basin Authority have been the norm.

[2] The 1985 Water Act establishes the functions and composition of each participatory board. Groundwater Management Boards are responsible for coordinating aquifer management and use when aquifers are declared overexploited. The User Assembly is made up of the members of all surface and groundwater Management Boards in the basin, and is responsible for coordinating management and use of hydraulic infrastructures and water resources in the entire basin. The Water Council is in charge of debating and approving the Basin Water Plan as well as its periodic reviews.

Table 11. User representation in the Guadiana River Basin Agency. Calculated with data from CHG (1996, 1997).

	Governing Board	User Assembly	Management Board for Western Mancha aquifer	Water Council
Spanish Central Government	6 (23%)	2 (2%)	1 (3%)	14 (28%)
Autonomous Provinces	7 (27%)	5 (4%)	2 (5%)	14 (28%)
Basin Authority	4 (15%)	4 (3%)	1 (3%)	3 (6%)
Users (total)	9 (35%)	113 (91%)	35 (90%)	19 (38%)
- Municipal water supply	2 (8%)*	15 (12%)	3 (8%)	2 (4%)
- Irrigation	5 (19%)	81 (65%)	31 (79%)	12 (24%)
- Hydroelectric	1 (4%)	7 (6%)	–	1 (2%)
- Industrial	–	8 (6%)	–	2 (4%)
- Environmental	1 (4%)	2 (2%)	1 (3%)	2 (4%)
Total	26 (100%)	124 (100%)	39 (100%)	50 (100%)

* Percentages are calculated over the total members. Therefore 2 representatives of municipal water supply represent 8% of the total 26 members of the Governing Board.

There are various possible explanations for the difficulties of the institutional framework to provide effective management structures. First, while the 1985 Act radically transformed the property regime and management activities for groundwater resources in Spain, there was little effort to achieve consensus among stakeholders prior to the passing of the Act. Once the Act was approved, there was a complete lack of educational and informational efforts by the Guadiana River Basin Agency; so users were for the most part confused as to their new responsibilities and obligations. The administrative chaos that still persists in the Western Mancha aquifer, where thousands of illegal users continue to operate and many still do not have their rights adequately registered, is consequence of this lack of communication between the legislator, the Administration and the users and stakeholders.

Secondly, while stakeholder participation is one of the principal tenets of the 1985 Act, the structures in place for groundwater management are not truly participatory. On one hand, it has been difficult to create groundwater user associations *by decree*. The process used in the Western Mancha and other aquifers with problems of overexploitation has been authoritarian. As a result users have often responded by creating alternative associations and fighting over issues of influence and turf. On the other hand participation is limited to those with rights to use water, and representation is apportioned in relation to the relative weight of the use. The result is that irrigators have majority representation among the users, as can be seen in Table 11. This puts important uses such as municipal water supply in a minority position and irrigator interests tend to predominate. Also, non-consumptive uses such as recreational or environmental interests, are not necessarily represented.

The issue of representation is further complicated by the fact that rights over groundwater use continue to be poorly defined. Efforts to complete the registration of existing rights have been extremely complicated and insufficient. The water rights recognition process has been one of the main points of conflict between users and basin authorities. In this context it is difficult to establish and enforce management plans for the recuperation of degraded aquifers.

Perhaps the most significant limitation of the 1985 Water Act has been the absence of a concerted effort to inform and educate the public and to establish open routes of communication between the Administration and the stakeholders. This has led to entrenched positions and frequent conflicts around water management issues. In the case of the Western Mancha aquifer, today there still does not exist a generally accepted understanding of the physical characteristics of the aquifer, of the need to restrict use, or of the interconnection between the actions of the different users, etc. Significant progress has been made but more work remains to be done. While there are daily contacts and consultations between the Guadiana Basin Agency and the users, there is no systematic program or department within the Agency dedicated to information and education activities.

The highly individualistic nature of the users, the size of the aquifer, the sheer amount of users involved, and the absence of a reliable inventory of existing uses, have complicated the situation in the Western Mancha aquifer. In addition, the existence of thousands of illegal users that are not subject to any restrictions or control further complicates the problem.

But in spite of these difficulties, groundwater user communities in the aquifer have evolved significantly since their inception. They are widely accepted as the legitimate representatives of the users and they act as intermediaries between them and the Basin Agency. However, they need to consolidate their transition from defenders of the interests of the users, to promoters of responsible and sustainable groundwater use patterns, that is, to effective resource managers.

6 CONCLUSIONS

Intensive groundwater development in many regions of Spain, primarily since the 1970s, has brought about significant social and economic benefits. But the unplanned nature of these developments has also resulted in unwanted social and environmental consequences.

Available data indicate that the economics of intensive groundwater use are such that the direct benefits obtained from a certain level of abstraction greatly exceed the costs of obtaining that water, even when these are very high. This is true even in areas where intensive aquifer use has resulted in dramatic drops in the water table, saltwater intrusion, wetland degradation, and significant social conflict. These environmental and social costs are spread over space and time and do not accrue to the direct user, but to society at large. Therefore there is no economic incentive to modify pumping patterns that would be socially and economically inefficient, if both direct and indirect benefits and costs were considered.

In order to deal with the problems associated with intensive and unplanned use, the 1985 Water Act radically transformed the institutional context for the management of groundwater resources in Spain. By making groundwater part of the public domain, the Act gave Basin Management Agencies the power to limit access to and use of the resource. Following a well established Spanish tradition of user participation in water management, the Act created the figure of groundwater user associations, giving them a prominent role in the management of groundwater resources. While hundreds of user associations exist throughout the country, a vast majority act as mere water distributors among their members, and very few can be considered true resource managers.

The few examples of groundwater user associations that have become effective resource managers have two things in common: they have successfully articulated common goals and objectives, and they have established mutually accepted rules regarding resource access and use, in order to guarantee the long-term sustainability of the resource and dependant uses. The variety of circumstances under which these user associations operate; their ability to bring together thousands of independent users and sometimes manage large and complex aquifer systems; the way in which some are working cooperatively with water authorities to establish sustainable management regimes; are all promising developments. The fact that most were created, not as a result of the statutory requirements of the 1985 Act, but because of a combination of user initiative and administrative support, points to the limitations of searching for a general solution through regulatory means.

The case of the Western Mancha aquifer serves to illustrate the complex nature of the problems associated with intensive groundwater use and the difficulties encountered when trying to find a solution through legislation alone. The regulatory measures contained in the 1985 Act have proved to be insufficient to solve the problems of the aquifer. However, they have effectively established a base from which to articulate viable solutions that necessarily include the implementation of truly participatory management structures and a cooperative relationship between the water authorities and the stakeholders.

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