Lessons for Spain: a critical assessment of the role of science and society

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Spain's water policy has changed dramatically in the last twenty years. This rapid evolution has been accompanied by increased water availability and quality problems and significant changes in the irrigation sector. Water scarcity, together with significant changes in farm policy, has gradually changed the crops and irrigation techniques. However, in real terms farm production has not increased, although labour, water and land productivity have increased in recent years as consequence of the reforms that make irrigated agriculture more efficient. Despite the profound transformation occurring in just one decade, the non-agricultural academic community and the media have ignored the evolution and formed a very negative view of the farm sector. In this paper, after reviewing with some detail some of the most outstanding changes, we reflect about the Spanish critical view of the irrigation sector. In most regions, changes in irrigated agriculture reflect current societal values and are guided by political and economic drivers. These reforms are contributing to make irrigated agriculture more sustainable.

Keywords: irrigation, water policy, water scarcity, climate change, agriculture

Table of contents

1 Introduction **3**

2 Monitoring water for food **4**

2.1 Water use 4
2.2 Land use 6
2.3 Crops produced 7
2.4 Environmental externalities 9

3 The tangible determinants of change **9**

3.1 Economic value of water and land-productivity 9
3.2 Capitalisation of irrigated agriculture 11
3.3 Technology and management revolution 13
3.4 Common Agricultural Policy of the EU 15
3.5 National policy 15

4 Emerging driving factors **16**

4.1 Rehabilitation of traditional irrigation districts 16
4.2 Cost of water and water trade 16
4.3 Water scarcity and climate change 18
4.4 Societal values 21

5 A critical assessment of future irrigation dynamics in Spain **21**

5.1 Irrigation enterprise 22
5.2 Science and technology community 23
5.3 Institutions 23
5.4 The significance of the Water footprint and 'virtual water trade' 24

6 Conclusions **25**

1 Introduction

The last 20 years have seen a major change in the way Spanish society perceives water problems. The perception that in all cases water for food competes with ecosystems and urban uses has been nurtured in the course of a number of high impact environmental extremes (e.g. 2001-4 drought), high profile organisations – both public and private – and international policy debates of high profile (e.g., biofuels and climate change). Deeply ingrained in the mentality of economists and the general public is the view that scarcity periods are exacerbated by water agricultural use. And yet the public perception does not fully recognise the capability of monitoring systems to describe the past and of science to offer quantitative assessments of the evolution of different technological and policy outcomes. This paper examines the role of monitoring and analysing the determinants of irrigation dynamics in the policy debate of water for food. Reviewing and compiling hitherto unexplored data, we make a case for rethinking the farm sector in a more positive way. The critical assessment of the role of these determinants on future rural landscapes and societies may provide information for future policy development.

Irrigation in Spain has evolved for over 12 centuries, but modern irrigation has progressed rapidly in the last 50 years, making a silent evolution of population settlement on landscapes that otherwise would not really support large numbers of people due to the aridity of the climate. The EU Common Agricultural Policy was from 1986 until 2003 a fundamental driver of farmers' decisions. Farm support programmes evolved from strong price support mechanisms to almost fully decoupled direct payments. This gradual change has interacted with two other recent policies: national water policy and the EU Water Framework Directive. In 2008, the prospective of irrigated agriculture has also changed entirely as a result of the global tensions of basic commodity prices.

The obvious dimensions of irrigation are the amount of water used, the irrigated land, the type of crops grown, and the environmental consequences. Tangible determinants of these changes are the economic value of production, policy, technology and science. There are also intangible determinants of change that represent societal values that influence views on the management of common and public resources. This paper speculates about the future prospective for water use in irrigation in Spain, in light of the most recent changes and the tangible and intangible determinants.

The paper is structured in 6 sections. Section 2, provides a brief chronological description of the water use for agriculture, commenting on the dynamics of land use, economic output, crops produced and environmental effects. In Section 3 we describe the tangible determinants of past irrigation dynamics and in Section 4 we discuss the less tangible emerging factors that affect current irrigated agriculture in Spain, including the role of perception by different groups of stakeholders and the changing societal values. Using these ideas, we then develop a critical assessment of the role of the irrigation enterprises, science and technology, and institutions in the future evolution of irrigation in Spain that may contribute to future understanding of water for food policy (Section 5). The final section draws some conclusions on the data and analysis provided in the paper (Section 6).

2 Monitoring water for food

2.1 Water use

Irrigation is a main user of water in Spain. From the mid 1950s to the 1990s agricultural water use increased dramatically due to the expansion of irrigated areas. Since the 1990s the sectoral structure of water use in Spain has not changed. Table 1 highlights the importance of agricultural water use in the ten largest regions in Spain (Autonomous Communities, ACs) that account for over eighty percent of the total national water use (INE, 2002). While the data presented in Table 1 is an adequate representation of a year with “normal” climate conditions, recurrent drought periods have as consequence water scarcity for irrigation in most regions. The latest data from the Ministry of the Environment (MMA, 2007) show that irrigation water use has changed very slightly in the last seven years in relation to the data presented in

Table 1. Nevertheless, these small recent changes may represent future trends. For example, the very small increases in irrigation in Extremadura, Castilla-La Mancha and Castilla-León represent minor expansion of irrigated areas, while the very slight irrigation decreases in Valencia, Aragón and Catalonia, in part due to the increased water scarcity problems arising by the recent extended drought periods, and the public and private initiatives to improve technology and efficiency in the irrigation systems.

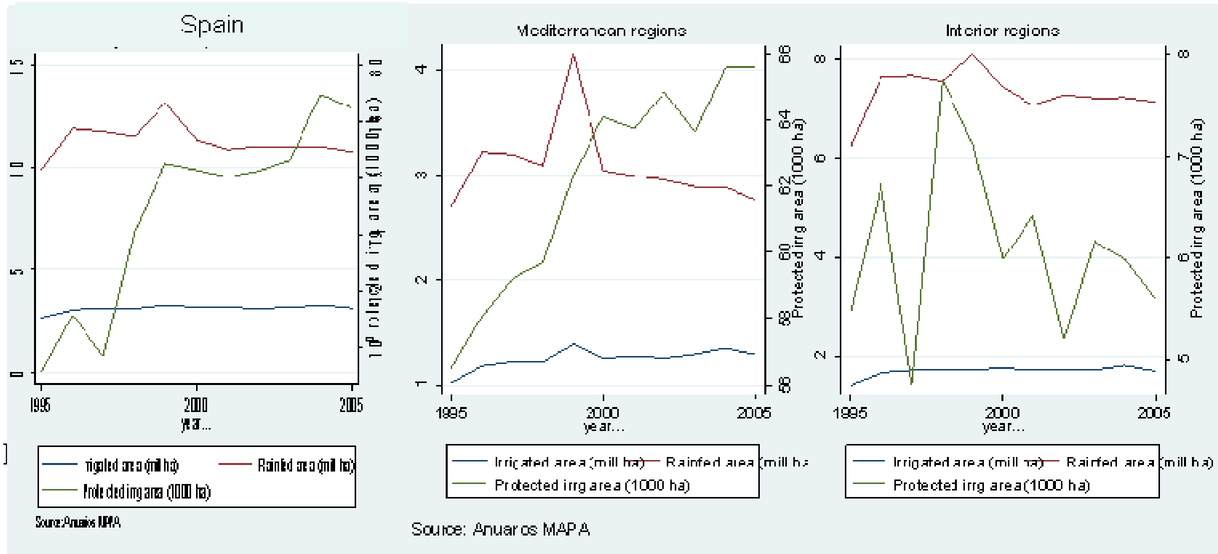
Table 1 Percentage of sectoral uses across main Autonomous Communities (ACs)

ACs	Agriculture	Industry	Services	Tot. Commercial Uses	Household Consumption	Total Uses Mm^3
Andalusia	89.8%	1.0%	2.6%	93.5%	6.5%	6,077
Aragon	96.4%	0.6%	0.9%	97.8%	2.2%	2,992
Castile-Leon	91.4%	0.3%	2.5%	94.3%	5.7%	2,471
Castile-La Mancha	93.3%	0.4%	1.9%	95.6%	4.4%	2,471
Catalonia	73.8%	4.7%	5.7%	84.2%	15.7%	2,118
Valencia	87.4%	0.7%	3.1%	91.2%	8.8%	2,718
Extremadura	95.4%	0.2%	1.1%	96.7%	3.3%	2,822
Galicia	13.3%	7.6%	22.7%	43.9%	56.1%	1,648
Madrid	22.6%	8.6%	17.8%	49.0%	51.0%	264
Murcia	80.6%	4.4%	3.4%	88.3%	11.7%	663
Rest of ACs	33.3%	4.2%	5.5%	43.1%	13.8%	2,766
Spain	84.4%	1.9%	3.8%	90.1%	9.9%	23,853

Source: INE (2002), using data from 1999, and own elaboration

2.2 Land use

Irrigation is a main component of the changes in agricultural land use over the last decade. Two extreme water scarcity episodes (1995 and 2004-2005) and major changes in the agricultural support measures in the European Union Common Agricultural Policy have taken place during this time (Garrido and Varela, 2008). Figure 1 shows the increasing trend of irrigated land in greenhouses (crop-protected, plotted in the right axis in 1000s ha) the stabilisation of total irrigated land and the slight reduction of planted crops under rainfed regime, both referred to the left axis in million ha. The latter is due to loss of agricultural land to urban, industrial and infrastructure development. The pattern of change is not uniform across the territory; the most striking changes have occurred in regions with the largest water deficit (Mediterranean regions) (Figure 1). Figure shows the remarkable growth of protected agriculture in the Mediterranean region reaching almost 66,000 ha in 2005. Note also the drought effects in 1995 in all variables plotted in both panels and the very slight reduction of planted area caused by the 2005 drought.



2.3 Crops produced

Irrigated crops have also changed dramatically over the last decade. Table 2 ranks the main irrigated crops in terms of total value for Spain, and the regions of Andalucia and Castilla-Leon, for years 1995, 2000, 2004 and 2005. We also report the rank in terms of each crop's surface and in value per hectare. National figures highlight the importance of Mediterranean specialty crops through the period, as 6 or 7 out of the most important crops can grouped as such, the remaining 4 or 3 being more 'continental' or 'arable crops' (corn, alfalfa, sugar beet). Notice the rank of 2005 as compared with that a decade earlier. While in 2005 tomato, vineyard and olive ranked 1, 2, and 8, in 1995 these two do not show up in the rank. Further, sugar beet went down from rank 6 to rank 10, and potatoes ranked 8 in 1995, and disappeared from the 10 top crops in 2005. In Andalucia (with 880,000 ha of irrigated hectares in 2005), the structure of the rank is quite stable, although cotton went down from rank 3 in 2000 to rank 10 in 2004 and disappeared in 2005. In Castilla-Leon the ranking is also quite stable along the 1995-2005 decade. There are large regional differences in relation to the three ranking criteria (total output, total acreage and value per ha). In most cases, the crops with largest acreage rank below 20 among in the rank of the most profitable crops. Furthermore, the crops with largest total acreage rank even lower in total value and per ha productivity. Despite these apparent regional differences, there are significant trends found at the national level. There is a clear retreat of subsidised crops, like corn and alfalfa, in the rank value, which has not been accompanied with a lowering rank in total surface. Corn and alfalfa ranked 2 and 4 in surface in 1995, and still were 1 and 5 in 2005. Olives and vineyard are the growing irrigated crops, ranking 3 and 6 in 2005 from 5 and 14 in 1995. Lastly, the structure of the rankings did not change between 2004 and 2005, despite the fact that 2005 was a very dry year.

Table 2 Main crops, ranked by total value in 1995, 2000, 2004 and 2005 (out of 94 irrigated crops in Spain)

	Spain			Andalucia			Castilla-Leon		
Year Total value	Total Area ha	Rank in value per ha	Crop	Total Area	Rank in value per ha	Crop	Total Area	Rank in value per ha	Crop
1995									
1	4	25	Alfalfa	1	65	Olives for oil	1	42	Sugar beet
2	13	4	Tomato	9	4	Tomato	4	23	Alfalfa
3	7	40	Oranges	4	35	Oranges	8	16	Corn
4	9	32	Mandarins	15	11	Lettuce	3	51	Forage Corn
5	21	7	Lettuce	8	45	Sugar beet	6	39	Potato
6	6	58	Sugar beet	11	38	Potatoes	2	58	Barley
7	2	71	Corn	5	62	Olives	15	4	Lettuce
8	8	60	Potatoes	17	27	Peaches	13	9	Carrot
9	28	5	Beans	6	63	Corn	16	8	Beans
10	31	11	Garlic	7	64	Rice	17	7	Garlic
2000									
1	5	24	Alfalfa	1	65	Olives for oil	3	36	Sugar beet
2	15	4	Tomato	11	5	Tomato	1	49	Corn
3	1	70	Corn	2	64	Cotton	6	19	Potato
4	9	44	Vineyard	6	50	Oranges	5	21	Alfalfa
5	11	40	Mandarin	8	48	Sugar beet	8	15	Forage Corn
6	14	28	Peaches	10	45	Potatoes	2	59	Barley
7	13	45	Potato	5	59	Rice	4	56	Wheat
8	7	58	Oranges	14	18	Lettuce	12	3	Carrot
9	3	69	Olives	13	4	Pepper	11	39	Beans
10	10	56	Sugar beet	7	61	Olives	20	8	Lettuce
2004									
1	6	28	Alfalfa	1	61	Olives for oil	3	29	Sugar beet
2	13	6	Tomato	11	3	Tomato	1	49	Corn
3	7	34	Vineyard	7	33	Oranges	6	19	Potato
4	1	70	Corn	9	42	Sugar beet	5	21	Alfalfa
5	9	40	Mandarins	14	14	Lettuce	10	16	Corn
6	8	46	Oranges	6	58	Olives	2	58	Barley
7	3	69	Olives for oil	10	37	Potato	15	1	Carrot
8	14	33	Peaches	5	60	Corn	4	54	Wheat
9	12	41	Potato	13	2	Pepper	11	35	Beans
10	11	50	Sugar beet	2	64	Cotton	16	31	Vineyard
2005									
1	12	4	Tomato	1	65	Olives for oil	4	28	Sugar beet
2	6	19	Vineyard	9	4	Tomato	1	46	Corn
3	5	34	Alfalfa	4	35	Oranges	6	17	Potato
4	13	18	Peaches	15	11	Lettuce	5	23	Alfalfa

5	1	68	Corn	8	45	Sugar beet	10	15	Forage Corn
6	8	53	Oranges	11	38	Potato	2	58	Barley
7	9	50	Mandarins	5	62	Olives	3	54	Wheat
8	3	71	Olives	17	27	Peaches	13	6	Carrot
9	19	14	Lettuce	6	63	Corn	19	1	Lettuce
10	10	49	Sugar beet	7	64	Rice	11	32	Beans

Source: Anuario de Estadística Agraria (MAPA, various years)

2.4 Environmental externalities

It is widely recognised that irrigated intensive agriculture is a source of water quality problems in many areas. For instance, aquifers' nitrates contamination was to found to be increasing in 45% of the hydrogeologic units. About 28% of the units had a chlorine concentration above 100 mg/l (MMA, 2007). The agricultural sector is responsible of serious non-point pollution, caused by fertilisers and plant protection crops. Lake eutrofization process is becoming a very serious problem in the Low Tagus basin, which will require prompt action in order to meet the Water Framework Directive quality standards in the waters flowing to Portugal (Garrido et al. 2008). In the Segura, Ebro, South and Guadinana basins, sulphate concentrations above 150mg/l were found in more than 25% of the monitoring stations.

3 The tangible determinants of change

Overall, most of the irrigation-related decisions depend on farmer's expectations as to the profitability of the activity and the benefits and cost of irrigated relative to rainfed farming, The principal determinants of the profitability of irrigated agriculture in Spain include: markets; availability of water and cost; costs of other agricultural inputs such as labour, capital, and energy; environmental concerns and regulations; and institutions that influence how water might be used and the opportunity costs of water for irrigation.

3.1 Economic value of water and land-productivity

The price that farmers receive for their crops is a critical determinant of their decisions to irrigate. The extraordinary expansion of irrigation in Spain over the last decades reflects, in part, its economic value. Figure 2 shows the farm output in constant euros from year 2000, again differentiating interior and Mediterranean regions. In the left panel the instability of rainfed agriculture's is sharper than with irrigated agriculture. Note that farm output in protected agriculture is about half that obtained in irrigated agriculture, but crop land is about one 20th as shown in Figure 2. In interior regions, farm output in irrigated land exhibits a gradual upward trend, with no signs of drought impacts. Rainfed farm production is more unstable.

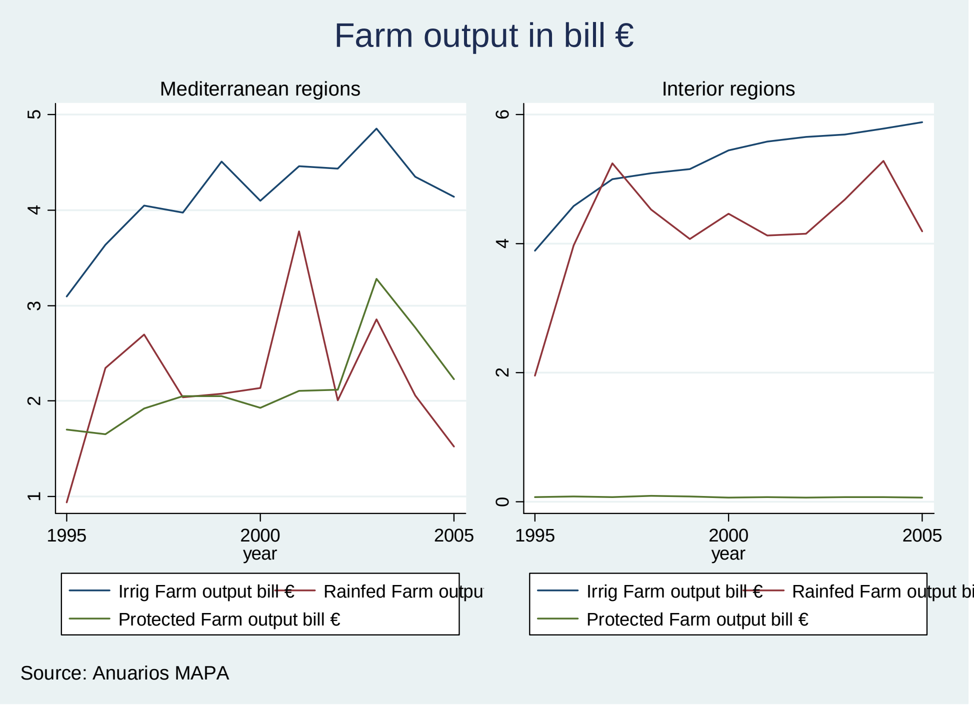
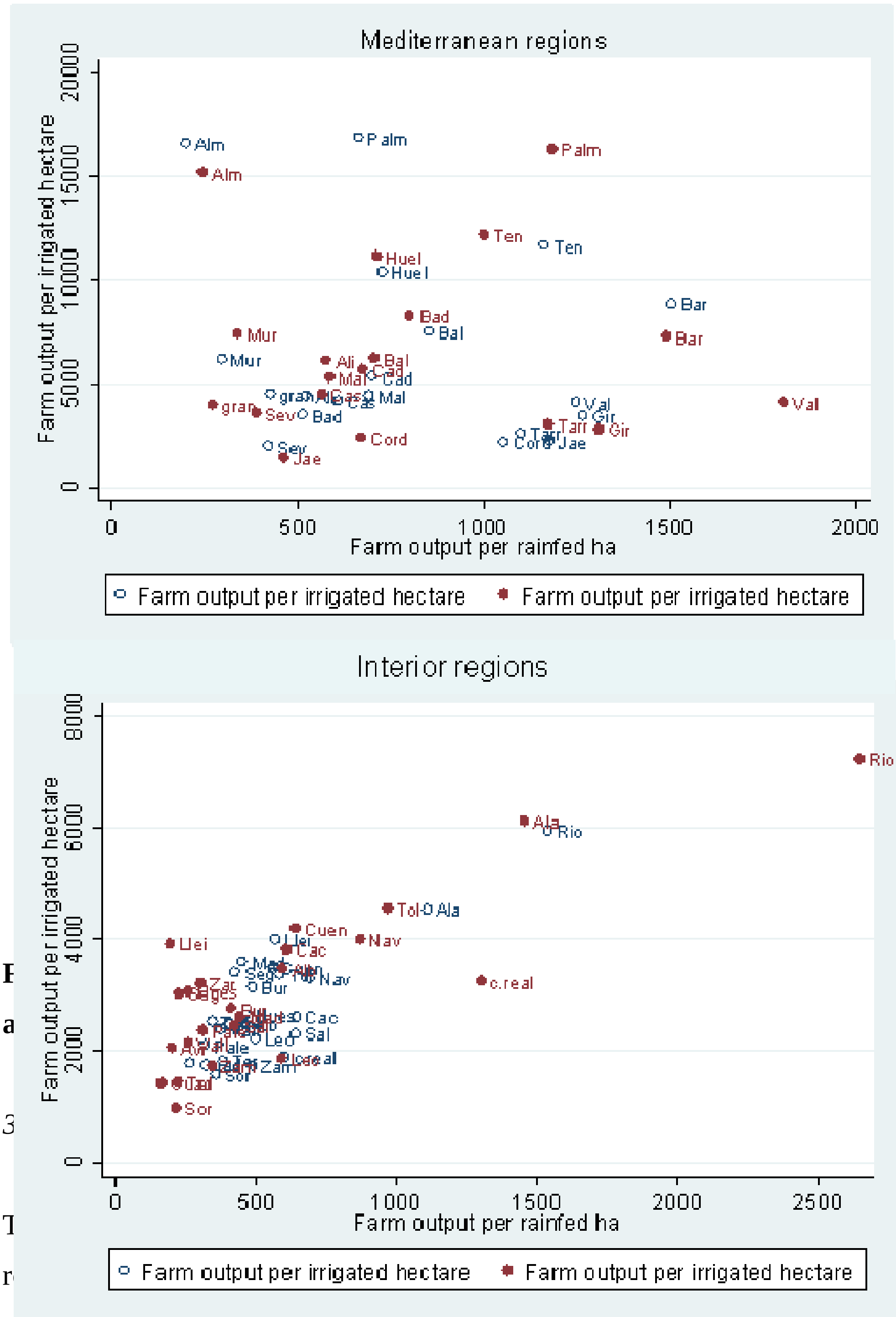


Figure 2 Farm output

In Figure 3, we plot irrigated output (in € of 2000) per hectare both in irrigated land and rainfed land, differentiating 1995 and 2005. Each dot represents one province of the Mediterranean region, with the solid dot being the 2005 observation. If farm productivity had grown we would witness movements to the Northeast region of the graph. What we find instead is that either irrigated productivity or rainfed productivity goes down, with the other going up, or both going down. Only in Murcia (Southeast Spain) both productivities increase. For the interior provinces, the result is blurred for most provinces, but showing remarkable productivity increases in Rio (La Rioja), Ala (Alava), Tol (Toledo), Na (Navarra) and C.Real (Ciudad Real). In all these provinces, either the wine or the olive oil industries are among the most important.

What explains the weak real growth of land productivity in the 1995-2005 decade? Primarily, it is the fact that crop prices have remained low during the decade. This added to the fact that yields have grown very slightly or remained stable, explains why farmland's productivity growth has been meagre. The exceptions are found in the provinces were the typical Mediterranean crops, olives and vineyards, have experimented more growth.



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provinces have lost about 6,000 farm operators per annum. The figures about hired workers are less trendy. In fact, there are provinces in which the number of hired workers has gone up (Gil, 2008).

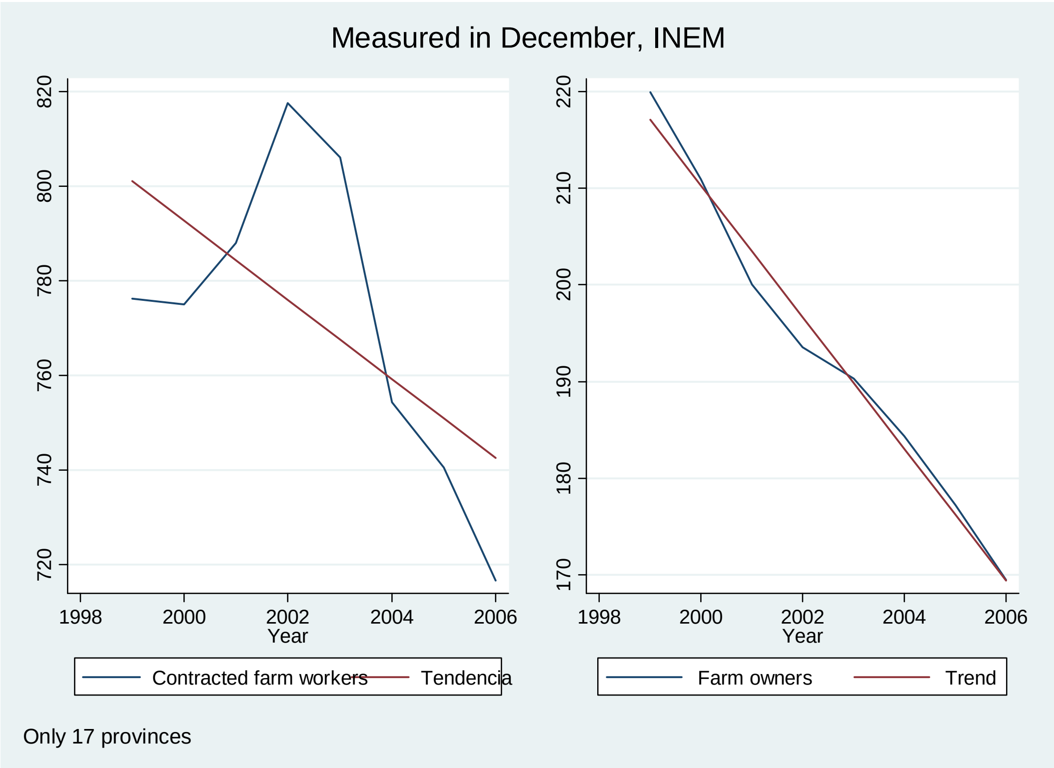
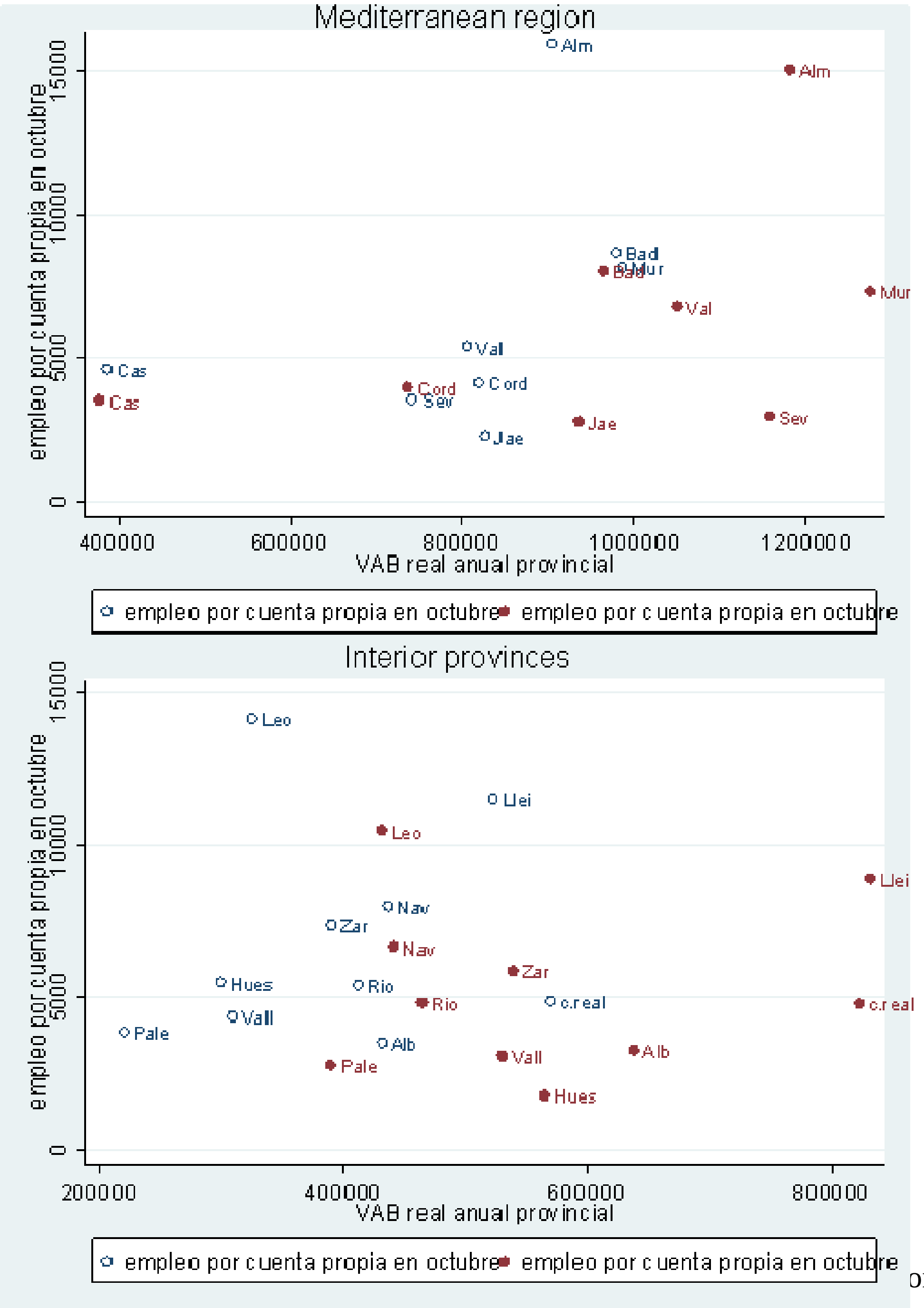


Figure 4 Farm labour (contracted and owners) in the most important 17 provinces.

Figure 5 presents the data for each province included in the Mediterranean and the interior regions the amount of farm operators and the total value added of the whole farm sector (measured in constant euros), for two years 1999 and 2006. This data include animal and total crop production. In this case, the movement is primarily to the right, except in Cas (Castellón). The number of farm operators has gone down very slightly, but the farm sector has been significantly more productive. In the interior regions, the trend is unambiguous. Total farm product has increased quite significantly, and the number of farm operators has decreased quite significantly. As a result of these processes, farm labour productivity has increased by at least 50% between 1999 and 2006 in virtually all provinces, but more sharply in the interior regions than in the Mediterranean regions. How these trends fit with the facts represented in Figure 5. In this case, the livestock sector explains the major ‘macro’ productivity gains shown at the provincial level, added to the productivity gains in the olive and wine sectors. The fact that the intensive livestock sector has become in the last 10 years among the largest in the EU explains the importance of crops like corn and alfalfa, as shown in Table 2.

Another fact that attests for the increasing capitalisation is the amount of outstanding debt of the whole farm sector. Farmers' outstanding debt has grown to 21 billion euro in 2006, from 15.8 in 2004. In 2006, outstanding debt was equivalent to the sector's net income, whereas in 2004, it was 55%.



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T ... onditions and their opportunities to do so, depend in part on management skill and available technologies (NRC, 1996). Irrigation technology and management in Spain has increased water and land productivity slightly (Garrido and Iglesias, 2007). This is especially important with many valuable Mediterranean crops that are harvested earlier than in the rest of Europe. The evidence supporting the beneficial effects of innovative irrigation management and technology is overwhelming (Georgopoulou et al. 2001). Water savings of 30 to 40% without yield reduction, achieved by improving the management of the application schedules have been reported (Causape et al. 2004; Luquet et al. 2005). Technology shifts both on-farm and within district levels shows that significant water conservation provides economic returns (Peterson and Ding 2005; Cetin et al. 2004). In most cases, the control of key management factors, such as soil moisture along the phenological stages, is sufficient to reach consumption reductions. In many cases the most efficient irrigation schedule is not the one that yields the maximum production (Shani et al. 2004). The change in irrigation technology has been dramatic in typical Mediterranean crops (Olives and vineyards) (Figure 6). Drip technologies, well adapted to these two crops, have become the most common in Spain in 2005, reaching 1.3 million hectares.

Deficit irrigation is becoming a hot scientific topic. The only large project, out of 15 projects for all sciences funded by the Consolider national program, focusing on agriculture is centered on ‘deficit irrigation’. The number of papers published by Spanish authors in journals like ‘Agricultural Water Management’ and ‘Journal of Agricultural Engineering and Management’ has trippled in the last decade. Spain is number 6 in world rankings in the agricultural sciences (13 in Geology, 11 in Chemistry, 15 in Engineering, among others). Finally, the Association of irrigation engineering companies just created a technological platform, which will be node for funding and participation in R+D European projects.

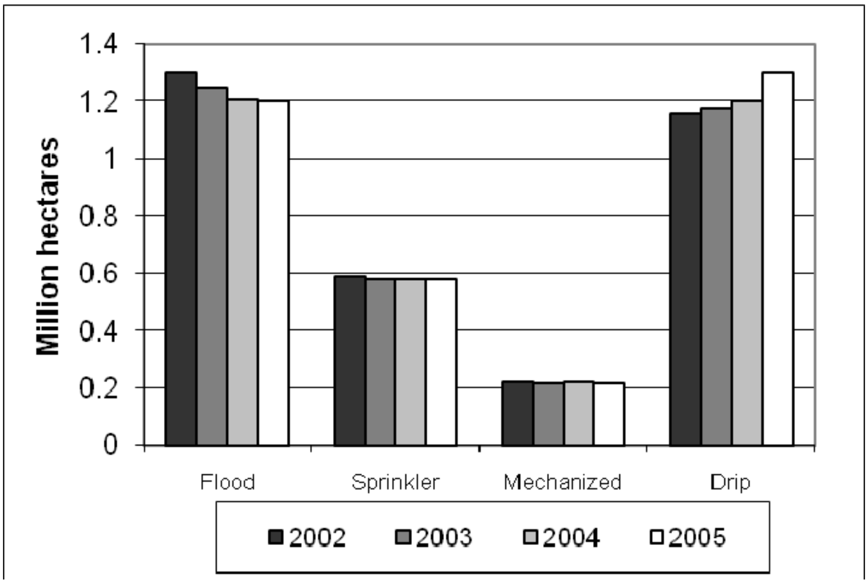

Figure 6 Irrigation technology

3.4 Common Agricultural Policy of the EU

Garrido and Varela (2008) and Varela (2008) explain the intimate connection between the Common Agricultural Policy (CAP) and the pattern of water uses in Spain. At least a dozen journal articles have shown the profound impact of the modalities of farm support delivered by the EU to growers (Garrido and Calatrava, 2008). Decoupled direct payments began in 2003, giving more freedom to farmers to grow the crops that market signals stimulate. Crops, like cotton, sugar beet and tobacco are being abandoned, and replaced by other crops.

Furthermore, as Varela (2008) explains in detail, the CAP is increasingly applying the concept of conditionality, which means that the eligibility to farm subsidies is conditioned on farming with ‘best farming practices’. The CAP ‘Health Check’ placed ‘improving water management’ among the top priorities for the post-2013 EU farm policy. The implications of these changes are now beginning to be evident (Garrido and Varela, 2008).

3.5 National policy

Irrigation in Spain has been managed collectively since the 15th Century. The irrigators’ communities follow a common management regime that enhances cooperation and the common good. Irrigators communities translate national policy into workable programs that take into account the social and environmental particularities of each area. Since 2000, National policy focuses on improving efficiency of irrigation systems with an increasing emphasis on controlling salinity and erosion damage. Over half of the irrigation communities have already undertaken major changes to work towards the national goals. It is envisioned that these changes continue over the next decade, with the additional challenge of implementing a more realistic cost of water.

4 Emerging driving factors

4.1 Rehabilitation of traditional irrigation districts

From the supply point of view, National policy from the beginning of the 21st century focuses on rehabilitation of existing irrigation systems. The Spanish Government embarked in 2000 on a massive project to rehabilitate the entire irrigated area dated from the turn of the 19th century. With total budget now reaching €6 billion, 1.4 million hectares were completely refurbished and planned virtually from scratch in the period 2000-2008 (Barbero, 2005). In most cases, farmers have been requested to pay up to 50% of the cost, although were given preferential treatment to give it back in 50-year loans. As public policy, this project enjoyed bi-partisan approval and was run smoothly and continuously along two government periods. The program was revitalised with the new 'Priory Plan (*Plan de choque*)' 2007-2009 with 2.4 billion euros and targeting 868.000 hectares. So far, the programme initiated in 2000 has met 100% of its objectives.

4.2 Cost of water and water trade

Farmers have always enjoyed preferential access to cheap and subsidized access to water resources (Garrido and Llamas, 2008). With the enforcement of the EU Water Framework Directive (WFD), the Spanish and some regional governments, including the Catalan, have opted to exempt the farming sector from implementing water tariffs respectful with the principles of the WFD. While WFD's Article 5 establishes that each Member State should carry out for all its river basins (1) an analysis of its characteristics; (2) a review of the impact of human activity on the status of surface waters and on groundwater, and (3) an economic analysis of water use (MMA, 2007). This represents massive study for the whole country, and a completely new approach to the inherited criterions with which water statistics were collected and recorded. Spain submitted its report and was given a good mark by the EC (72 points, rank 6th out of 27 member States; EC, 2007). The findings of these reports cannot be sufficiently stressed. They pertain to the evaluation of cost-recovery rates in the agricultural sector – very close to 100%, simply because the costs are evaluated with inadequate amortization rates of the infrastructure.

Although the Water Law reform opened the era of water markets was enacted in 1999, the first experiences took almost seven years to occur. The Law opened two routes to enable right-holders to lease out their rights either to the basin authorities or to another user. The simplest way just takes an agreement of two right-holders and their decision to file a permission to formally exchange the right. The basin agency has 30 days to respond and, unless major technical, environmental or third-party difficulties are encountered, the petition will be granted. Very few, albeit significant, exchanges have been reported.

Consider the case of a big commercial farm in Almería (Southeast) that purchases rice fields in the marshes of the Guadalquivir basin, 300km away from Almeria in a different basin. As a water right-holder, it files a request to transfer its water rights linked to the rice paddies to Almeria, using an inter-basin water transfer that connects the headwaters of the Guadalquivir with another basin (the Negratin-Almanzora aqueduct). This sale was approved despite the potential third-party effects of water resouces that, in the absence of the transfer, would have flowed to the Atlantic ocean along the Guadalquivir river along 300km.

In another case, an irrigation district in the Tagus basin leases out all its water rights to a set of users in the Segura basin, using again another inter-basin aqueduct (the Tagus-Segura aqueduct). The revenue generated for the farmers by the contract is larger than the value of the crop farmers would have produced in a normal year (Garrido, 2006). The agreement was especially profitable because of two reasons: first, the district was undergoing a rehabilitation project to reduce the extremely large water allotments, which were transferred in full in the sale; secondly, as the rehabilitation project was being implemented, farmers would have hardly been able to irrigate their fields during the season for which the rights were transferred. Farmers leased-out their full allotments from headwater resources that had been used for years very inefficiently to users located in another basin.

The last case involves a subtler exchange that entailed no water transfer at all, but the obligation to maintain the minimum levels of key reservoirs. These levels are statutorily connected to the management of the Tagus-Segura aqueduct, so that the amount of resources that can be transferred in each year is conditioned on the state of the reservoirs at given dates. Through the purchase of water rights of users serviced from them, the purchasers could effectively increase their rights to transfer resources across the basin, simply keeping the levels above the minimum thresholds.

These three large-scale transfers illustrate the type of exchanges that will be more frequently requested. In general, they serve the purpose of moving water from the South central plateau to the Southeast. For the moment, basin authorities and the Ministry of the Environment have been permissive in granting these transfer requests. But once the third-party impacts are identified and evaluated, they will perhaps become more difficult (see Colby, 1990, in her seminal work, on water trading and its institutional impediments as proxies of environmental taxes). Colby's thinking also fits with the fact that the government of Castilla-La Mancha, the main area-of-origin in most exchanges, is erecting institutional barriers to prevent users located in their territories from selling water to others in adjacent Autonomous Communities.

The second route to enable water exchanges is by means of the so-called water banks or exchange centres. Not strictly an office or agency, these centres are hosted, run and located in the basin agencies themselves. Garrido (2007a & 2007b) show that centres are much more efficient means to promote water exchanges, because all sorts of reasons, including transparency, control, avoidance of third-party effects and market activity and scope. And yet, the experience so far has been limited to the Jucar, Segura and Guadiana basins. In March 2008, the public offering for farmers willing to relinquish their rights just one season in the Jucar basin was set at 0.25 € per cubic meter.

4.3 Water scarcity and climate change

Under normal – non drought – conditions many areas of Spain face significant problems due to the unbalanced distribution of water resources, conflicts among users, and between regions. Recurrent drought episodes in the country lead to the intensification of these problems and ads to the complexity of water management. Drought events in Spain have been more frequent after 1970 (Iglesias et al., 2007) with economic and social damage increasing form year to year. In addition to the direct effects, drought episodes also contribute to the degradation of groundwater quality (Garrido and Iglesias, 2007) as a result of the overuse of aquifers. An important number of wetlands are affected by irrigation activities during drought and highlight that habitats' conservation and agriculture have irreconcilable interests when water scarcity is an issue.

Water scarcity and drought have multidimensional implications for society and therefore no single management action, legislation or policy can respond to all aspects and demand objectives. Spain is a leader in the development of legislation with different perspectives and levels of integration into the overall water management policy. The fact that water is managed at the basin level with clearly defined institutional responsibilities ensures that the implementation of drought legislation is potentially effective and the fact that public participation in water management is increasing rapidly. The basin planning bodies develop and use drought management plans that define a protocol for water allocation under scarcity conditions. Drought management plans incorporate: demand and supply analysis and projections, contingency and preparedness plans, and scenario analysis for drought. In an optimal situation, permanent monitoring provides indicators that can trigger specific drought management actions. These indicators ideally include: hydrological, socio-economic, and environmental aspects. Recent drought management plans include a set of measures grouped according to different severity levels. A commonly used ranking describes three levels of severity (i.e., can be named pre-alert, alert, and emergency). It is extremely important to also define the "normal" situation, since the plan is optimally developed at this stage. There are many examples that validate this framework over the past decades in Spain (Garrote et al., 2007), especially in the pre-alert and alert levels. In the emergency level, the main priority is to maintain drinking water supply and all structural and non-structural measures of high economic, social, or environmental cost are designed and taken in order to avoid water restrictions for urban demand.

In spite of the many positive aspects of recent drought management plans, these need to continue to evolve and further include some key climate change considerations, ecological issues, and overall long term issues related to sustainable development. Information on possible longer-term climate forecasts and/or development of plausible scenarios has not yet been incorporated into any specific action plans. Furthermore, neither the current legislation nor the envisioned implementation of the EU Water Framework Directive, provide explicit regulations about how to calculate the ecological discharge during in drought situations, this important question is being left to the discretion and responsibility of the various basin authorities. It is surprising that international initiatives such as The United Nations Convention to Combat Desertification (UNCCD, 2000) that provides the global framework for implementing drought mitigation strategies, or the United Nations International Strategy for Disaster Reduction (UNISDR, 2002) that establishes a protocol for drought risk analysis, are not taken into account by local drought management plans.

Climate change projections for the region derived from global climate model driven by socio-economic scenarios (Iglesias et al., 2008) result in an increase of temperature (1.5C to 3.6C in the 2050s) and precipitation decreases in most of the territory (about 10 to 20% decreases, depending on the season in the 2050s). Climate change projections also indicate an increased likelihood of droughts (Kerr, 2005) and variability of precipitation – in time, space, and intensity – that would directly influence water resources availability. The combination of long-term change (e.g., warmer average temperatures) and greater extremes (e.g., droughts) can have decisive impacts on water demand, limiting further ecosystem services. Under all climate change scenarios, water supplies decrease and irrigation demand increase in Spain (Iglesias et al., 2007; Iglesias et al., 2008). The adaptation capacity of Spain irrigated agriculture to climate change is challenged in particular, as climate change comes in conjunction with high development pressure in the most productive areas and sub-optimal agricultural systems in areas that do not offer economic alternatives to the rural population. Evidence for limits to adaptation of socio-economic and agricultural systems in Spain can be documented in recent history. For example, water reserves were not able to cope with sustained droughts since the late 1990's to the present day and are causing many irrigation dependent agricultural systems to cease production. The partial inability of a range of stakeholders to reconcile interests of the agricultural and urban sectors, is leading to the perception by most people that drought and climate change are among the most prominent problems in Spanish society. Furthermore, the weak cooperation among different institutions, and the fragmented roles of the State, the administrative regions and the river basin authorities, often results in conflicts and impediments for implementation of existing legislation and management actions, and limits the adaptive capacity of the Spanish irrigation sector with uncertain demand and supply.

4.4 Societal values

The evolution of water use for agriculture reflects changes in the societal values are is guided by the economic and political drivers. The political pressures arising from water scarcity and social change resulted in the transition of Spanish water management regime towards conservation-oriented policies. The transition was initially resisted by irrigation farmers who were beneficiaries of the status quo but these farmers have been gradually adapting to efficient management. In spite of the profound transformation of the sector, most people outside the agricultural population perceive that the dedication of a substantial amount of water supplies to irrigation as inequitable and inefficient. This is especially true in areas that compete with urban or environmental water. A recent survey in Castilla-Leon (Gomez-Limon, 2006) shows that urban dwellers value irrigated agriculture by &&& and consider a top priority to maintain the population of the rural areas. The views of Castillians is not shared in regions where the farm sector is less important, or their territories less vulnerable to depopulation and aging.

A main challenge for further improving water management is to further translate some of the cost of water to the farmer. Currently farmers in most regions benefit from low tariffs that barely reflect the cost of operation and maintenance. The idea deeply ingrained and shared by the public and government agencies is that farmers use excessive water since water is too cheap for them. The irrigators' main association 'FENACORE' has been voicing the positive role of maintaining irrigated farms in the rural areas. It has also promoted the adoption of water management systems in the main irrigation districts, even to the extent of creating new software to run their engineering and administration systems. However, the view of irrigators by other actors is predominantly negative. The 'Fundación Nueva Cultura del Agua' (FNCA, www.fnca.es) is the main think tank in water issues Spain during the last years. FNCA issued a corporate letter highlighting the risks associated with joining the Environmental and Agricultural Ministries in April 2008, and signalling the danger of focusing specifically on particular water interests. The evolution of the Spanish irrigation system depends on the ability of the private and public sectors to evolve towards a unified interest and the careful evaluation of the consequences of alternative conservation policies.

5 A critical assessment of future irrigation dynamics in Spain

Irrigation is Spain is in a time of transition. The ability to project future irrigation dynamics depends on the understanding of the formal relationships between the determinants of change and the responses to change. This is complex. Here we evaluate the main categories of factors that influence irrigation (i.e., availability of water, economic change, and changes resulting from concerns about environmental protection) and the responses within the irrigation enterprises, the science and technology sector, and the institutions (Table 3). The critical assessment of the resulting interactions is evaluated taking into account the dynamics and determinants of irrigation in Spain.

Table 3 Forces of change and responses to irrigation in Spain

Responses / Forces of change	Irrigation enterprise	Science and technology community	Institutions
Availability of water	– Adopt improved technology, informal economic instruments	– Solutions to salinity damage – Monitoring systems – Strategies for adapting to climate change	– Deliver policies that respond to competition for water – Ensure participation to respond to changes in societal values
Economic forces	– Respond to the globalisation of the economy – Recognise the driving force of urbanisation	– Provide models and decision support systems – Develop scenarios	– Explore fiscal policy – Increase standards of irrigation efficiency
Environmental protection	– Respond to complex regulations	– Offer evidence on environmental impacts – Widen management alternatives	– Shifting roles of the government and supra-national regulation – Role of institutions as partners in management

5.1 Irrigation enterprise

Private enterprises face increasing competition among water users. It is unlikely the private farmers increase the irrigated land. Nevertheless, they are the primary beneficiaries of science and technology, thought potential improvements in the quality of irrigation water and management. Market-based transfers of water use will continue to evolve, especially for farms located near the urban areas. In particular, now that Barcelona is facing serious scarcity risks, very few commentators and academicians have noted the fundamental ‘buffer’ value that irrigation can deliver to the urban sector. With hardly any irrigated agriculture in the basin from which the Barcelona’s water supply originates, the 2nd largest city in Spain stands less prepared for droughts than other cities in more arid environments because of the irrigation sector. Garrido (2007a and 2007b) and Gómez-Ramos (2004) have shown the important ‘risk-reducing’ effects of optioning water rights. The institutional setting to promote this and similar arrangements is already in place.

The negotiations of the WTO imply an increase in the competition of irrigated products. Spanish irrigated enterprises can probably respond to the challenge due to their high level of capitalisation, but leaving at the margins the farms that are not well-financed.

5.2 Science and technology community

Technological innovation offers many ways in which irrigation can be more efficient. Models and decision support systems provide management scenarios of water allocation choices and instruments to solve conflict. Models may assist in planning for irrigation management, including ‘supplemental irrigation’ and water-conservation (Oweis et al. 2004; Pereira et al. 2002), and suggest that investing in more efficient irrigation technology is just one element of the set of responses that farmers can pursue to respond to more expensive water. Sometimes, fallowing the least efficient crops or moving to rainfed irrigation may be more beneficial than investing in new technologies. There is a wealth of literature that demonstrates that significant water conservation levels are accessible to millions of farmers in Spain. In orchard agriculture for instance, the benefits of drip irrigation may include: better olive survival, earlier crop production, greater yields, more efficient nutrient distribution, less plant stress, reduced yield variability, and improved crop quality (Cetin et al. 2004). Drip irrigation in olive trees can produce a Net Present Value of 3464 US$/ha after an initial investment of 2244 US$/ ha (Cetin et al. 2004).

5.3 Institutions

Irrigation will remain dependent on the institutions that influence the allocation of scarce water supplies among competing users. Institutions are driven by changing societal values and increased competitions for water. These values challenge: the cost of water for irrigation artificially low, and the environmental goals. Institutions are cooperating in the development of policies that represent the increased need for environmental protection and the adequate risk management under scarcity conditions, but it is certain that it will be necessary to shift some portion of water for irrigation to other uses.

5.4 The significance of the Water footprint and 'virtual water trade'

The water footprint in Spain has been evaluated by a number of authors. A summary of the evaluations is shown in Table 4. Rodríguez (2008) has evaluated the water footprint of the Spanish agriculture with some detail. As we compare the results of Table 4, borrowed from Rodríguez et al. (2008) with those reported in Table 3, it becomes clear that there are potential economic gains to be made by substituting less valuable crops. Note the importance of 'green water' in the cereals and olive sector. Novo (2008) looks at the role grain trades under the view of virtual water trade. In a dry year, Spain has a net import of water embedded in the grains 8,500 Mm3, which is about half all water use in the farm sector in a very dry year. In a wet year, net imports represent only 3,500 Mm3.

Table 4 Area, water consumption and the water footprint by groups of crops in year 2001

	Area (ha)		Water (Mm^3)		Imports of virtual water VW_i (Mm^3)	Exports of virtual water VeW_E (Mm^3)	Water Footprint (Mm^3)
	Rainfed	Irrigated	Green water	Blue Water			
Cereals	5,341,501	1,086,016	5,462	4,980	6,343	1,381	**15,406**
Industrial crops	742,358	380,957	530	2,557	10,957	2,537*	**11,507**
Vegetables	28,897	307,595	273	1,699	58	676	**1,354**
Citrus	4,773	295,187	318	1,861	115	1,259	**1,035**
Olive	1,981,826	309,560	2,263	1,154	773	1,375**	**2,816**
Fresh	82,626	203,069	1,163	126	294	315	**1,268**
Nuts	781,965	59,451	350	477	1,456	477	**1,806**
Vineyard	1,002,863	132,029	489	441	32	88	**873**
Forage crops	767,461	272,812	776	1,045	-	-	**1,821**
Potato	30,168	84,958	523	63	75	49	**611**
Other crops	542,610	77,908	1,224	869	601	16	**1,066**

Source: Rodríguez et al. (2008)

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6 Conclusions

Irrigation in Spain was created in the 13th Century and developed in the 20th Century; now Spain is transforming irrigation. In 2008, Spain irrigates almost two percent of the world irrigated area. The annual expansion of the Spanish irrigated land has fallen from an average of over two percent from the mid 1955 to 1999 to insignificant changes after 2000. This dramatic change in the evolution of irrigated areas has been accompanied by even more dramatic changes in management. The changes in management represent social values on the management of a common resource and the shifting emphasis on environmental protection. Nevertheless, the actors without direct experience and relations to the irrigation sector have not perceived these changes fully. Although further reforms are needed, especially in relation to the cost of water, the lessons learned from the evolution of irrigation in Spain may be relevant to other regions.

Silent transformation. A key lesson from Spain is that irrigation-based economies are transformed when social values change. The irrigated sector has been profoundly transformed in the last ten years. Human and physical capital transformation has evolved gradually and silently. The potential for becoming a useful partner has been neglected by a sharp adversarial view, which has blamed the irrigator sector for most water problems in Spain. This paper argues that the irrigation sector has done its homework, with the generous support of the government, and now plays two fundamental roles. First, in highly regulated basins, such as the Spanish ones, the farm sector operates as a buffer for other water use sectors. Under such conditions, liberalisation, by means of banks and exchange mechanisms, enhance this role of 'secondary water source' to other sectors as well as the environment. Second, the institutional and technical modernisation has had no parallel in other water sectors, and nor in water planning, in which there is never been a consensus.

Economics. The economics of water use in agriculture shows very slight growth in water and land productivity, with some marked regional variations. Farm prices have grown less than the rest of the economy's, and much less than farm input costs. And yet, Mediterranean crops, like olives, fruits and vegetables and vineyards, show healthy growth rates to expense of crops whose rationale was primarily the subsidies of the European Union farm programmes. Spain has a comparative advantage in specialty crops. The expansion of this market is expected to continue favouring the most competitive growers that generate returns similar to some urban landscape uses.

Role of markets. The profound transformation of the irrigation sector has had a solid scientific support and been market driven. Virtual water trade shows how trade with farm products has adapted to climate variation. In dry years, cereal imports represented in virtual water about the same amount to total blue water used in the entire irrigation sector. Farm trade has alleviated the pressure on scarce resources and has helped the farm economies to concentrate on the most profitable crops.

Communication. The scientific community, especially the social sciences, has failed to acknowledge the positive role of irrigation, and has taken an adversarial standpoint with respect to the agricultural sector. In our view, the farm sector and its Ministry failed to communicate the importance of agriculture, its positive impacts in the rural areas, and foremost, the massive transformation program to fully refurbish 1.4 million hectares.

Administration and management. Governance of irrigation in Spain is multi-level and it is combined with an interactive decision process. Nevertheless, the intellectual gap between the agricultural and environmental administrations since 1996 is responsible of the clear confrontation between environmentalists and irrigators. This deep confrontation is not supported by the increasing emphasis in managing demand rather than supply shared by the scientific community and the irrigation managers. In April 2008 the Environment and Agriculture Ministries were joined, providing an opportunity to pursue more integrated policies in a less adversarial mode. Regardless of the national politics, the commons management regime of the Spanish irrigation communities offers opportunities for successful adaptive management focussing on the sustainability of the irrigation systmes.

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