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ABSTRACT

This article analyzes the Ebro inter-basin transfer, which was the main project of the Spanish National Hydrological Plan. The Ebro transfer was prompted by pervasive pressures, scarcity, and degradation of southeastern basins in Spain. The heated policy debate on the Ebro transfer highlights the difficulties of achieving a sustainable management of water resources because of the conflicting interests of stakeholders and regions. Alternatives to the Ebro transfer show that acceptable outcomes combine demand and supply measures. Nevertheless, implementation could be difficult, requiring compensation to farmers; otherwise, an excessive burden on farmers would be met by social opposition, leading to the failure of the measures.

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INTRODUCTION

While never as important in shaping society as the hydraulic civilizations of the ancient Middle and Far East,[1] irrigation has been important in the Iberian Peninsula since ancient times. Significant waterworks were first introduced by the Carthaginians in the southeastern peninsula, and later waterworks were developed by the Romans for urban centers (e.g., in Tarraco, Emerita Augusta, Caesar Augusta), mineral extraction, and irrigation. The highest dam built during the Roman Empire was the 34 meter (m) Almonacid de la Cuba dam in the Ebro basin,[2] with a system of very old and complex canals supplying water to the irrigation fields of Campo de Belchite. In the Middle Ages, the Islamic Califato de Córdoba (929–1010) undertook substantial irrigation projects in Murcia, Valencia, and Granada to develop horticultural crops, sugar cane, and white mulberry trees to feed silkworm. Sugar cane was planted along the Mediterranean coast, from where it later passed to America during Spanish colonization. Muslim farmers from Granada contributed to the development of new irrigated areas along rivers such as the Guadalquivir, and their knowledge of irrigation techniques was passed down to subsequent generations of farmers.[3] The water court in Valencia (*Tribunal de las Aguas*) is an example of a water institution from the Middle Ages that has been settling water disputes among farmers for the last thousand years. After the sixteenth century, two major irrigation and transport projects undertaken were the Canal Imperial de Aragón and the Canal de Castilla, which were largely advanced in the eighteenth century.

During the nineteenth century, major water projects were partially financed by the private sector to provide urban supply facilities in Madrid (e.g., the Canal de Isabel II), Valencia, Gerona, and Cartagena, but the policy of private financing failed in agricultural irrigation projects. By the end of the nineteenth century, public involvement in irrigation projects was considered essential, based on the importance of

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1. *See generally* KARL A. WITTFOGEL, ORIENTAL DESPOTISM (1957) (a comparative study).

2. Other dams built during Roman times include the 22 m Proserpina dam (Mérida, Spain), and the 21 m Harbaqa (Palmyra, Siria) and Cornalvo (Badajoz, Spain) dams. *See* MIGUEL ARENILLAS PARRA, OBRAS HIDRÁULICAS ROMANAS EN HISPANIA (2002), http://traianus.rediris.es/textos/hidraulicas.htm.

3. *See generally* ANDREW M. WATSON, INNOVACIONES EN LA AGRICULTURA EN LOS PRIMEROS TIEMPOS DEL MUNDO ISLÁMICO (Ana Marínez Vela trans., Universidad de Granada ed.1998) (discussing agriculture in the early Islamic world); CARMEN TRILLO, AGUA, TIERRA Y HOMBRES EN AL-ANDALUS (2004) (analyzing the social and economic structures in Muslim Spain).

water to promote economic growth in agrarian Spain while also improving farmers' social conditions. A century ago, Joaquín Costa[4] developed this philosophy and was heavily involved in gathering the social impetus to bring about the early irrigation projects of the Canal de Aragón y Cataluña and Riegos del Alto Aragón in the Ebro basin.[5] The key premise of this traditional supply approach was that water is a plentiful resource to be developed by public and private agents.[6]

During the twentieth century in Spain, hydrological planning was an important issue driven by this traditional supply approach. This resulted in a succession of planning efforts, which included the Gasset Plan of 1902, the National Plan of Hydrological Works in republican Spain,[7] the Development Plans of the industrialization period of the 1960s and 1970s, and the National Hydrological Plans of 1993[8] and 2001.[9]

The 1933 National Plan of Hydrological Works together with the Agrarian Reform Law of 1932 were important government initiatives of the Spanish Republic aimed at modernizing the Spanish agricultural sector. The Minister of Public Works, Indalecio Prieto, created the Center of Hydrographic Studies under the direction of Lorenzo-Pardo and charged it with the task of elaborating the National Plan of Hydrological Works. The objectives of the Plan were to increase the nation's wealth and farmers' income by expanding agricultural production and exports through a 1.75 million hectare (ha) increase in irrigated acreage. The Plan included 215 high priority dams, canals, and irrigation districts, 142 of which had been completed by the end of the twentieth century.[10]

The main project of the National Plan of Hydrological Works was the Tajo-Segura water transfer to southeastern Spain (Figure 1[11]), a project strongly criticized by Félix de los Ríos, director of the Ebro basin

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4. JOAQUÍN COSTA, POLÍTICA HIDRAÚLICA: (MISIÓN SOCIAL DE LOS RIEGOS EN ESPAÑA) (1911), *available at* http://www.cervantesvirtual.com/servlet/SirveObras/00258309899772630757857/); JOAQUÍN COSTA, LA TIERRA Y LA CUESTIÓN SOCIAL (1912), *available at* http://www.eumed.net/cursecon/textos/costa/index.htm.

5. JUAN A. BOLEA-FORADADA, LOS RIEGOS DE ARAGÓN (Grupo Parlamentario Aragonés Regionalista de las Cortes de Aragón eds. 1986).

6. José Carles & Marta García, *La Coherencia de las Instituciones y los Modelos de Uso del Agua*, *in* LOS INSTRUMENTOS ECONÓMICOS EN LA GESTIÓN DEL AGUA EN LA AGRICULTURA 115, 117 (José Albiac ed., 2003).

7. MANUEL LORENZO-PARDO, PLAN NACIONAL DE OBRAS HIDRÁULICAS (1933).

8. DIRECCIÓN GENERAL DE OBRAS HIDRÁULICAS, MINISTERIO DE OBRAS PÚBLICAS Y TRANSPORTES, ANTEPROYECTO DE LEY DELPLAN HIDROLÓGICO NACIONAL (1993).

9. MINISTERIO DE MEDIO AMBIENTE, PLAN HIDROLÓGICO NACIONAL: ANÁLISIS DE LOS SISTEMAS HIDRÁULICOS (2000); MINISTERIO DE MEDIO AMBIENTE, PLAN HIDROLÓGICO NACIONAL: ANÁLISIS ECONÓMICOS (2000) [hereinafter ANÁLISIS ECONÓMICOS].

10. Miguel Arenillas Parra, *El Plan Nacional de Obras Hidráulicas Sesenta Años Después*, *in* PLAN NACIONAL DE OBRAS HIDRÁULICAS CVII, CXI (Juan de Zumárraga ed., 1993).

11. LORENZO-PARDO, *supra* note 7.

authority in 1933, who proposed the Ebro water transfer to southeastern Spain as an alternative (Figure 2[12]). In hindsight, de los Ríos was correct in criticizing the Tajo-Segura water transfer because the 1933 Plan's estimated 760 cubic hectometers (hm^3) of water available for diversion in the upper Tajo was seriously overestimated.[13]

The de los Ríos proposal is the origin of the Ebro water transfer, and this proposal resurfaced in the Second Economic and Social Development Plan of 1968. The Development Plan considered two major inter-basin water transfer projects: the Tajo-Segura project and the Ebro-Júcar-Segura project, but ultimately only the Tajo-Segura transfer was built during the 1970s. Miscalculation of water availability in the Tajo-Segura water transfer and the huge expansion of irrigation in southeastern Spain due to pervasive aquifer depletion led to the recent proposals of water transfers from the Ebro during the past decade in both the 1993 and 2001 National Hydrological Plans.

The National Hydrological Plan of 1993 was intended to interconnect all the main basins of the Iberian Peninsula with huge investments in waterworks.[14] The amount of transferred water was nearly 4,000 hm^3, with exports from the North, Duero, Tajo, and Ebro donating basins, and imports by the Ebro, Tajo, Guadiana, Guadalquivir, internal Cataluña, Júcar, Segura, and Sur receiving basins.[15] The extent of investments required to interconnect all the basins and the large volume of transfers caused controversy and were met with distrust by social and political groups and by territories. There were also serious legal obstacles because the Plan had less legal force than the Water Law of 1985, yet it proposed many modifications to the Water Law. A consulting body, the National Water Council, demanded a review of the planned expansion of irrigated acreage (600,000 ha) and the planned increases in water demands by each sector.

Finally, the Spanish Parliament decided in 1994 that the National Hydrological Plan had to include estimates and conditions for the inter-

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12. MINISTERIO DE OBRAS PÚBLICAS, PLAN GENERAL DE OBRAS PÚBLICAS. TOMO II OBRAS HIDRAÚLICAS (1940).

13. This was demonstrated when the Tajo-Segura transfer was finally built in the 1970s with a capacity of 1,000 hm^3 because, since 1978, when the Tajo-Segura transfer became operational, the average volume of water transferred each year has been only 330 hm^3.

14. The investments of the 1993 Plan (Ministerio de Obras Públicas y Transportes, Informe sobre el Plan Hidrológico Nacional, 1993) were 28 billion euros, and the investments of the 2001 Plan were 19 billion euros, of which 4.7 billion euros were earmarked to build the Ebro water transfer.

15. Water exports per basin (in hm^3) were North 200, Duero 1,050, Tajo 900, and Ebro 1,855; and water imports were Ebro 400, Tajo 850, Guadiana 170, Guadalquivir 100, internal Cataluña 475, Júcar 700, Segura 1,205, and Sur 105.

basin transfers, alternatives to the proposed water transfers, and budget assessments for the transfer projects. The Plan also had to be coordinated with a new National Irrigation Plan and with measures for water treatment, water savings, and water reutilization. Two additional hurdles were added when (1) the Senate introduced the requirement that all hydrological basin plans had to be approved before the National Hydrologic Plan was passed, and (2) all the representatives in the National Water Council rejected the Plan. Ultimately, these social and political factors triggered the collapse of the National Hydrological Plan of 1993.[16]

From an academic perspective, Federico Aguilera-Klink[17] was the first author in Spain to use economic arguments to challenge the traditional supply expansion approach by discussing the National Hydrological Plan of 1993 in a series of articles with Arturo González-Romero and Santiago Rubio.[18] González-Romero and Rubio had assumed that the costs of supplying and using water within basins were zero, and that the only relevant costs were those of transporting water between basins; therefore, profits from water arbitrage among basins would force water trades through inter-basin transfers. In response to Aguilera-Klink's comments, Rubio and González[19] conceded that there could be an increasing cost curve of water in each basin, generating positive water prices in "surplus" basins. They also acknowledged that to evaluate the change in social welfare from water transfers, information was needed regarding water supply and demand equilibrium prices for each basin, and these prices had to be compared with the costs of imported water.

The degradation of water resources in the semi-arid coastal areas of the Segura and Sur basins deteriorated further during the 1990s. A heavy increase in water demand from the highly profitable fruit and vegetable sector, which included substantial greenhouse acreage,[20]

16. MINISTERIO DE MEDIO AMBIENTE, LIBRO BLANCO DEL AGUA EN ESPAÑA 592–93 (2000).

17. Federico Aguilera-Klink, *El problema de la planificación hidrológica: una perspectiva diferente*, 2 REVISTA DE ECONOMÍA APLICADA 209 (1993).

18. Arturo González-Romero & Santiago J. Rubio, *El problema de la planificación hidrológica: una aplicación al caso español*, 1 REVISTA DE ECONOMÍA APLICADA 33 (1993).

19. Santiago J. Rubio & Arturo González-Romero, *El problema de la planificación hidrológica: un argumento económico a favor de los trasvases*, 2 REVISTA DE ECONOMÍA APLICADA 217 (1993).

20. Remote sensing information indicates that irrigation acreage has more than tripled in the Segura basin from 1970 to 1995, as measured by A. Quintanilla Ródenas et al., *Aproximación al estudio de la evolución temporal de la superficie en regadío de la cuenca del río Segura mediante técnicas de teledetección y SIG*, *in* TELEDETECCIÓN 39, 43–45 (Jose L. Casanova & Julia Sanz eds., 1997). In the Sur basin, greenhouse production started after 1970 and

resulted in acute water scarcity and aquifer overdraft. Most of the water demand increase was met by additional individual pumping by farmers from aquifers that were not controlled by the water administration. The government's solution was to undertake a new water planning effort, this time based on a unique inter-basin transfer bringing water from the Ebro to the Júcar, Segura, and Sur basins.

This article analyzes this last Ebro inter-basin transfer proposal, which was the main project of the National Hydrological Plan of 2001. The transfer was designed to solve the severe degradation of southeastern Júcar, Segura, and Sur basins by transferring 820 hm^3 from the Ebro basin a distance of up to 750 km.[21] The analysis considers the key tasks raised by Aguilera-Klink a decade ago and focuses on the costs of alternatives to the Ebro transfer and the response of demand to water prices. These important tasks were ignored by the Spanish water authority administration in the design of the Ebro water transfer project.

The Ebro transfer faced strong opposition from water resource experts, environmental and social organizations, and the Aragón and Cataluña states located in the Ebro basin.[22] The primary argument against the transfer was that the traditional approach of augmenting supply to deal with water scarcity was obsolete and that new water management policy initiatives were needed. These policy initiatives had to be based on reasonable management measures, such as water pricing, revision of water concessions, abstraction limits on surface and subsurface waters, development of regulated water markets, new supply technologies (e.g., desalination), water quality protection, and reuse and regeneration of water resources.

Another blow to the Ebro transfer was the reluctance of the European Union (EU) to provide funding for the project because of its shaky economic and environmental foundation. The Ebro transfer was at

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acreage has expanded to around 30,000 ha (Table 1). Remote sensing images comparing Campo Dalías greenhouses between 1974 and 2000 are presented in U.N. ENV'T PROGRAM, ONE PLANET, MANY PEOPLE: ATLAS OF OUR CHANGING ENVIRONMENT 200-01 (2005), *available at* www.na.unep.net/OnePlanetManyPeople/AtlasDownload/UNEP_Atlas/Atlas_3-5-Cropland_Screen.pdf.

21. An additional volume of 200 hm^3 was planned to be sent 180 km north to Barcelona (Figure 3).

22. Economic and environmental arguments on the transfer can be found at www.mma.es/agua/informes.htm, with the opinions of a large number of experts. A comprehensive assessment of the degradation of the Ebro Delta and the fluvial and marine ecosystems as a result of the inter-basin transfer can be found in CARLES IBAÑEZ & NARCÍS PRAT, *The Environmental Impact of the Spanish National Hydrological Plan on the Lower Ebro River and Delta*, 19 INT'L J. WATER RESOURCES DEV. 485 (2003), and in NARCÍS PRAT & CARLES IBAÑEZ, AVALUACIÓ CRÍTICA DEL PLAN HIDROLÒGIC NACIONAL I PROPOSTA PER A UNA GESTIÓ SOSTENIBLE DE L'AIGUA DEL BAIX EBRE (2003).

odds with the EU policies of the 2000 Water Framework Directive, which adopted a new water policy based on the management of demand, full recovery costs including environmental costs, and the establishment of standards on water flows, emission loads, and ambient pollution levels. The directive promotes the use of economic tools instead of increasing the availability of water resources in order to avoid mismanagement and reduce environmental degradation. Pursuant to the directive, the economic cost of water must be considered as an indicator of water scarcity, and at least a reasonable part of water costs should be recovered from users.

Finally, the Ebro water transfer was cancelled in 2005 by the new Spanish Parliament after the former government lost the 2004 elections. The current policy of the Spanish central government to solve the severe degradation of water resources in the southeastern basins is the AGUA project.[23] The AGUA project is designed to replace the Ebro transfer, and the main thrust of the project is to augment water supply with seawater desalination.

The Shortcomings of the Ebro Project

The documentation of the National Hydrological Plan of 2001[24] presents the economic and environmental analysis of the Ebro transfer project. Because the analysis adopted an engineering economics approach, following the traditional planning of the Spanish water administration, there were some critically important theoretical and empirical shortcomings in the economic analysis. Alternative levels of supply augmentation were not considered and the amount of water needed in the receiving area was taken as a fixed and given quantity. The basis for the municipal and industrial component of this quantity was explained by some projections of population and per capita water use, but no economic justification was provided for the remaining 561 hm^3 targeted for agriculture and intended to cover the elimination of aquifer overdraft (419 hm^3) and to guarantee supply reliability (142 hm^3). The

23. The official Spanish name for the Project is "Programa A.G.U.A." (Actuaciones para la Gestión y la Utilización del Agua).

24. *See* MINISTERIO DE MEDIO AMBIENTE, EVALUACIÓN AMBIENTAL ESTRATÉGICA DEL PLAN HIDROLÓGICO NACIONAL (2002); *see also* SOCIEDAD ESTATAL TRASAGUA INFRAESTRUCTURAS DEL TRASVASE, S.A. & MINISTERIO DE MEDIO AMBIENTE, MEMORIA DEL PROYECTO DE LAS TRANSFERENCIAS AUTORIZADAS POR EL ARTÍCULO 13 DE LA LEY 10/2001 DE 5 DE JULIO (PLAN HIDROLÓGICO NACIONAL) Y SU ESTUDIO DE IMPACTO AMBIENTAL (2003); *see generally* MINISTERIO DE MEDIO AMBIENTE, *supra* note 9 (citing to both the hydraulic system and the economic analysis documents).

analytical foundation for the determination of these specific quantities is flimsy and unconvincing.

The majority of the water transferred would go to agricultural uses, with the agricultural benefits calculated as the average value product of the water, estimated at 0.75 €/m³. However, the correct benefit measure of the incremental water supply in the receiving areas is the marginal value of water, in order to calculate the profit loss that is avoided by importing transferred water. By using the average value of water, the project makes two heroic assumptions: that profits are exclusively a return to water and that the average value is constant and not declining with the amount of water. Because of the possibility of changing the crop mixes and the varying land quality, the marginal profit loss from reducing water is likely to be well below this 0.75 €/m³ average value of water.

The type of analysis used in the Ebro project, known as an "ability to pay analysis," has been found in the United States to be highly unreliable for predicting demand for project water and consistently overstates this demand.[25] The shortfalls in demand forced project managers to charge prices to agricultural users that were well below the estimated ability to pay both in the Central Valley Project in California and, most recently, in the Central Arizona Project.[26] Because farmers' actual willingness to pay turned out to be substantially less than the estimates of their ability to pay, these and many other federal water projects have consistently failed to recover their costs. In the United States over the past century, the federal government spent 21.8 billion dollars on 133 water projects in the western states, of which 7.1 billion dollars was allocated to be paid by irrigation users; at present, less than one billion dollars of this cost has been repaid.

There are two further omissions in the economic analysis of the Ebro project. One is the failure to allow for the uncertainty in estimating future costs and benefits of project water, especially in the agricultural sector, which is vulnerable to potential future changes in EU agricultural and trade policies, changes in the continued availability of inexpensive foreign labor, and changes in energy prices. There is also no allowance for the potential future effects of climate change. The second omission of

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25. *See, e.g.*, RICHARD W. WAHL, MARKETS FOR FEDERAL WATER: SUBSIDIES, PROPERTY RIGHTS AND THE BUREAU OF RECLAMATION (1989); Paul N. Wilson, *Economic Discovery in Federally Supported Irrigation Districts: A Tribute to William E. Martin and Friends*, 22 J. AGRIC. & RESOURCE ECON. 61 (1997).

26. W. Michael Hanemann, *The Central Arizona Project* (Univ. of Cal. Berkeley, Dep't of Agric. & Resource Econ. & Pol'y, Working Paper No. 937, 2002), *available at* http://are.berkeley.edu/%7Ehanemann/cap.pdf.

the economic analysis is the lack of an explicit economic evaluation of the project's environmental impacts, both negative and positive. The project includes a small charge (0.03 €/m^3) to compensate for the negative environmental impacts within the Ebro basin, but this amount is arbitrary and not based on any systematic assessment of the environmental impacts and their non-market valuation. Experience worldwide indicates that the improvement of environmental conditions can generate significant economic benefits associated with recreation, eco-tourism, and the non-use value of ecosystem protection, which could outweigh the benefits from agricultural or even urban water use.[27]

The analysis presented below addresses some of the shortcomings in the economic analysis of the Ebro transfer project. The focus is on the agricultural benefits in order to examine both the water demand response in the southeastern basins and the marginal value of water in each county of these basins. Several demand and supply water policy alternatives to the Ebro transfer are examined and a very important issue in order to evaluate the water policy alternatives is the response of irrigation to water prices. The findings show that compromise solutions incorporating both water supply and demand management measures should be considered. These compromise solutions combine the reduction of water demand and the increase of water supply through desalination. The reduction in water demand could be achieved by water pricing or by water markets coupled with rationing the resource.

The article is structured as follows: first, the analytical setting is presented, with a description of the methodology and the technical and economic data used and including information on water rights and water trading in the area. This is followed with the results of the simulation of water demand management alternatives and water supply expansion alternatives. The conclusions of the research are presented in the final section.

27. In the Mono Lake decision in California, the diversion from Mono Lake was reduced by two thirds, despite the loss of hydropower and water supply to Los Angeles, in order to protect wildlife habitat. This is an example of non-use values associated with habitat protection as being the main components of environmental benefits. *See* Thomas Wegge, W. Michael Hanemann & John Loomis, *Comparing Benefits and Costs of Water Resource Allocation Policies for California's Mono Basin*, *in* 1 ADVANCES IN THE ECONOMICS OF ENVIRONMENTAL RESOURCES 11, 14-21 (Darwin C. Hall ed., 1996).

Table 1. Acreage, Water Use, and Revenue in Southeastern Basins (2001)

Basins	Total	Cereals, alfalfa, and sunflower	Fruit trees	Open air vegetables	Greenhouse vegetables
Júcar					
Acreage (1,000 ha)	212.7	18.5	173.6	19.5	1.1
Irrigation water (hm³)	1,450	242	1,081	121	6
Revenue (million €)	1,196	39	957	167	33
Segura					
Acreage (1,000 ha)	154.8	7.2	115.9	26.8	4.9
Irrigation water (hm³)	863	49	710	82	22
Revenue (million €)	1,070	5	558	264	243
Sur					
Acreage (1,000 ha)	54.5	1.1	18.7	6.5	28.1
Irrigation water (hm³)	232	10	96	24	102
Revenue (million €)	1,124	1	67	87	969

ALTERNATIVES TO THE EBRO PROJECT

The alternatives to the Ebro project are evaluated with a linear programming model that incorporates a large quantity of technical and economic information specified at the county level. The model is used to simulate several water supply and demand policy scenarios.[28] The model covers the southeastern counties of the Iberian Peninsula that receive water from the Ebro transfer (Figure 3[29]). There are 22 counties in the Comunidad Valenciana, six counties in the Comunidad de Murcia, and seven counties in Almería. The year of reference for all technical and economic data is 2001, and the baseline data on acreage, water use, and revenue are presented in Table 1.

28. Details of the model building, parameter estimation, and simulation results are presented in José Albiac et al., *Evaluating Alternatives to the Spanish National Hydrological Plan* (CITA-DGA Working Paper No. 04/04, 2004); José Albiac Murillo et al., *El uso agrario del agua en las comarcas de Levante y del Sureste y el trasvase del Ebro*, 196 REVISTA ESPAÑOLA DE ESTUDIOS AGROSOCIALES Y PESQUEROS 95 (2002); José Albiac et al., *The Economic Unsustainability of the Spanish National Hydrological Plan*, 19 INT'L J. WATER RESOURCES DEV. 437 (2003); Grupo de Economía del Medio Ambiente y recursos Naturales, Plan Hidrológico Nacional, www.unizar.es/econatura/phn.htm (last visited Oct. 9, 2006) (archiving the databases of the study).

29. For the latest water transfer path, see SOCIEDAD ESTATAL TRASAGUA INFRAESTRUCTURAS DEL TRASVASE, S.A. & MINISTERIO DE MEDIO AMBIENTE, *supra* note 24.

Crop cost data come from the Government of Murcia,[30] the Ministry of Agriculture,[31] and other monographic studies. Quasi-rent or net income for each crop is calculated by subtracting direct costs, machinery and paid labor, and indirect costs and depreciation from gross revenue. Other coefficients are calculated from official statistical sources, such as municipal crop acreage or yield data, or elaborated from more than one source, as in the case of water availability by county, which is estimated from meteorological data and technical data from research institutes in Valencia, Murcia, and Andalucía. Water consumption for each crop is obtained by multiplying the water requirement per hectare by the acreage covered by the crop in the county.[32]

The objective function maximizes quasi-rent of irrigated cultivation activities, where the county is the decision unit. The constraints represent land, water, and labor resource availability. Irrigation acreage is defined for each type of crop and irrigation technology, and crops include fruits, vegetables, and cereals and alfalfa. Substitution among vegetables is allowed in the vegetable acreage, and substitution among cereals and alfalfa is allowed in the cereal acreage, but the fruit-tree acreage is held constant for each species.[33] The linear program for each county includes around 80 crop activities and 60 resource constraints. Resource constraints include 22 soil constraints and monthly water and labor constraints.

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30. AMOPA, GOBIERNO DE MURCIA, ESTUDIO GENERAL DE LA ESTRUCTURA Y BALANCE AGRONÓMICO Y ECONÓMICO DE LAS EXPLOTACIONES AGRÍCOLAS DE LA REGIÓN DE MURCIA (2000).

31. MINISTERIO DE AGRICULTURA, PESCA Y ALIMENTACIÓN, ANÁLISIS DE LA ECONOMÍA DE LOS SISTEMAS DE PRODUCCIÓN: RESULTADOS TÉCNICO-ECONÓMICOS DE EXPLOTACIONES HORTOFRUTÍCOLAS DE LA COMUNIDAD VALENCIANA EN 2001 (2002).

32. Gross water requirement of a crop is equal to net water requirement divided by the irrigation system efficiency (0.6 for surface irrigation and 0.9 for drip irrigation), and net water requirement is equal to the crop evapotranspiration less precipitation. Crop evapotranspiration is calculated from county meteorological data and crop coefficients K_c. *See* ANTONIO MARTÍNEZ COB ET AL., EVAPOTRANSPIRACIÓN Y NECESIDADES DE RIEGO DE LOS PRINCIPALES CULTIVOS EN LAS COMARCAS DE ARAGÓN (1998). *See also* RICHARD G. ALLEN ET AL., CROP EVAPOTRANSPIRATION—GUIDELINES FOR COMPUTING CROP WATER REQUIREMENTS (1998) (providing the U.N. Food and Agriculture Organization recommendations upon which the calculation is based).

33. *See, e.g.*, Bruce A. McCarl, *Cropping Activities in Agricultural Sector Models: A Methodological Proposal*, 64 AM. J. AGRIC. ECON. 768 (1982) (suggesting a procedure to solve the aggregation problem). *See also* Hayri Önal & Bruce A. McCarl, *Aggregation of Heterogeneous Firms in Mathematical Programming Models*, 16 EUR. J. AGRIC. ECON. 499 (1989); Hayri Önal & Bruce A. McCarl, *Exact Aggregation in Mathematical Programming Sector Models*, 39 CAN. J. AGRIC. ECON. 319 (1991).

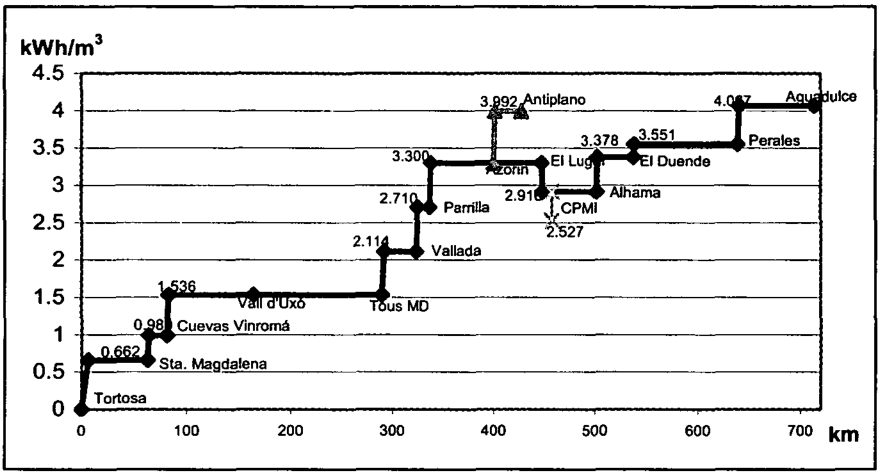

Table 2. Energy Consumption of the Ebro Transfer at Each Destination

The costs of the Ebro project at each delivery location have been calculated by Uche.[34] The energy costs of pumping are an important cost component of the transfer project, and the specific energy consumption at each section is closely related to the elevation of the channel (Table 2). The investment costs of the transfer project have been calculated by applying the methodology used in the project,[35] although some discrepancies have been detected and included in the costs. Table 3 shows the costs of diverted Ebro water by county. Costs of diverted water are lower than seawater desalination (0.52 €/m³) up to Costera and Vall d'Albaida counties, but desalination costs beyond these counties are lower than transfer costs, and transfer costs in Almería double desalination costs.

Water Rights and Informal Water Trading in Southeastern Basins

One of the alternatives being considered to solve water scarcity in the area is water trading, and the assessment of the present situation of water rights and water exchanges is important for developing regulated water markets. This section describes Spanish water law and

34. Javier Uche Marcuello, *Anejo 2. Análisis de los costes del Proyecto de Transferencias, in Alegaciones al Proyecto de Transferencias Autorizadas por la Ley del Plan Hidrológico Nacional y Estudio de Impacto Ambiental* (J. Albiac ed., CITA-DGA Working Paper 03/03, 2003).
35. ANÁLISIS ECONÓMICOS, *supra* note 9.

explains water rights and the informal water trading presently taking place in the southeastern basins.

The basic law regulating water management in Spain is the 1985 Water Act,[36] which was partly amended in 1999.[37] Both acts were consolidated in 2001[38] and this legislation has been adapted to the Water Framework Directive of the European Union.[39] In addition to these laws, water management is also affected by related legislation for the regulation of public works, water pollution, or wastewater treatment.

The key principle of the 1985 Water Act is that all continental water, either surface or ground water, is of the public domain, with some exceptions for ground water. There are no water rights in the strict sense but rather temporary public concessions that grant the holder the right to use a given amount of water. These concessions can be cancelled and reallocated to other users by the basin authority in the event of inadequate or unjustified use of water. This rarely occurs in practice, however.

The Spanish Water Act grants an important role to public administration. Each basin authority (known in each basin as the *Confederación Hidrográfica*) is the main administrative body responsible for water management at the basin level. They are responsible for the elaboration and monitoring of the basin hydrological plan, the administration and control of the water public domain, and all water uses. The *Confederaciones Hidrográficas* are in charge of projects, construction works, and the management of public hydraulic works, which may be financed by the central or state governments, local councils, or even private entities. The basin hydrological plans are integrated in the National Hydrological Plan approved by the central government. According to the Spanish Water Act, the objectives of hydrological planning are to satisfy all water demands, to attain an equilibrated and harmonious water sector, and to further regional development. This is achieved by increasing resource availability and maintaining water quality and by rational and sustainable usage.

Another important feature of the Spanish water legislation is the key role given to water users, especially to those in agriculture. Article 73 of the 1985 Water Act establishes that users relying on water from a single common concession must create a water users association, or *comunidad de regantes* for agricultural users. Agricultural water users associations have their own equity and legal status and are ruled by

36. Ley de Aguas (B.O.E. 1985, 189, 243) (Spain).
37. Ley de modificación de la Ley de Aguas (B.O.E. 1999, 298) (Spain).
38. Ley de Aguas (B.O.E. 2001, 176) (Spain).
39. Council Directive 2000/60, EU Water Framework Directive, 2000 O.J. (L 327) (EC).

statutes approved by the users' assembly and the basin authority. They are self-financed from the levies paid by their members. These associations are in charge of the main issues relating to irrigation water use, such as organizing irrigation turns, controlling water allocation and consumption, collecting water fees, investing in the modernization of irrigation systems, and exchanging or leasing water with other users. The Spanish legislation therefore establishes a certain level of decentralization in water management. The basin authority is in charge of the main waterworks in the basin and is responsible for resource allocation through public concessions, while water users associations are responsible for the management of secondary infrastructures and the allocation of water among members.

Regarding the water pricing policy, Articles 112 to 114 of the 1985 Water Act establish four levies that are collected by the basin authority.[40] The first is a levy on users occupying or making use of the public hydraulic domain, charging for the use of land and river beds. The second levy is a discharge fee on authorized effluents released into water bodies belonging to the public domain. These two fees aim to protect and improve the state of the public hydraulic domain. The third levy, known as the "regulation fee," is paid by all beneficiaries of public waterworks that regulate runoffs and waterways. The fourth fee is the "water use tariff" on water consumption, paid by users that benefit from specific infrastructures. Both the "regulation levy" and the "water use tariff" aim to cover public operation and maintenance costs and part of the public investment costs.

Individual users pay fees directly to the basin authority. Farmers in water users associations pay the "regulation levy" and the "water use tariff" through their irrigation district, plus an additional tariff to cover costs of the irrigation district itself. Water users associations that abstract water directly without using public waterworks pay only the regulation levy.

The 1999 reform of the Water Act introduced the legal possibility of voluntary water exchanges, but with many restrictions. This reform acknowledged the limitations of the traditional supply-side policies by timidly encouraging temporary exchanges of water use rights. The public nature of water is upheld and only the right to use it is leased for a limited period of time. The Spanish water law envisions two ways to exchange public water concessions. The first is that concession holders may privately agree on specific terms for exchanging water use rights.

40. ALBERTO GARRIDO & JAVIER CALATRAVA, *Recent and Future Trends in Water Charging and Water Markets*, *in* WATER POLICY IN SPAIN (A. Garrido & M. Ramón Llamas eds., forthcoming 2007).

The second is that there are legislative provisions for launching "water exchange centers" (*bancos de agua*) that would be brokered by the basin authority to speed up transfers during shortages and to disseminate information regarding water transactions and prices. In both cases, the basin authority must approve water exchanges and take into account impacts on third parties. There are other stringent requirements, such as previously holding a public concession in order to participate in the market as a buyer. Water exchanges among different basins are also allowed, provided that water transfer facilities are in place and that exchanges are permitted by the National Hydrological Plan.

Up to 1985, most surface water resources were public as established in the Water Act of 1866, while the Water Act of 1879 recognized the ownership of ground water by private individuals or companies pumping the resource. The heavy public funding allocated for the development of surface water resources justified this dual legal treatment. During the twentieth century, development of collective irrigation systems based on public water works expanded irrigation from 1.0 to 2.5 million ha.

After 1960, there was a large escalation in groundwater extractions driven by the falling costs of pumping technologies in areas with profitable irrigated crops, groundwater irrigation being at present close to 1.0 million ha.[41] Prior to 1985, these private groundwater extractions were not controlled by the water administration, and the need for government control over groundwater resources led to the 1985 Water Act declaring all surface and subsurface water public domain. Holders of private rights over ground water were given the choice of either keeping their rights or exchanging them for temporal water concessions. Obviously the vast majority, over 80 percent of right holders, have maintained their private rights.[42]

Surface water in southeastern basins is allocated in the form of public concessions to local water agencies and irrigation user associations, while privately owned or public domain ground water is managed by local companies rather than individuals. In the Júcar and Segura basins, ground water accounts for almost half of the irrigation water, most of it supplied by privately owned water rights.[43] The

41. Water demand in the 1.0 million ha under groundwater irrigation is close to 5,000 hm^3, while water demand in the 2.5 million ha under surface irrigation is 19,000 hm^3. Almost half of the acreage under groundwater irrigation is located in the southeastern basins (Júcar, Segura, and Sur).

42. M. RAMÓN LLAMAS ET AL., AGUAS SUBTERRÁNEAS: RETOS Y OPORTUNIDADES (2001).

43. JOSÉ CARLES GENOVÉS, MARTA GARCÍA MOLLÁ & LLORENÇ AVELLÁ REUS, *Aspectos económicos y sociales de la utilización del agua subterránea en la Comunidad Valenciana*, *in* LA

development and management of private wells by irrigation companies is common in both basins, although in the Segura basin many irrigation districts have public entitlements over both surface and ground water. In the Sur basin, private water rights are widespread in the province of Almería because ground water prevails over surface water. These private water rights are owned by irrigation user associations, private companies, or cooperatives.

Informal water trading is quite common in southeastern basins, with spot exchanges predominating over occasional trading of water rights. Water exchanges usually take place at the local level, depending on water transportation facilities. Private companies, individual farmers, or landowners who own wells sell water regularly to individual irrigators, irrigation districts, industries, and urban water companies. Some irrigation districts in Alicante auction their water allotment to farmers, albeit with a limit on the amount of water for which an individual farmer is allowed to bid.[44]

Public water concessions to irrigation user associations are linked to the land as a rule. Private water rights, on the other hand, are normally based on participation of users in a private company and entitle users to a certain amount of water regardless of how much land they own. The very limited trading of water rights that takes place in the basins involves private rights to ground water.

Informal water trading goes on between farmers belonging to the same irrigation district. This includes exchanges of water supplied by the district and water from private wells owned by irrigators in the district. In years of regular water supply, prices range between 0.10 and 0.40 €/m^3 with an average around 0.15 €/m^3, although prices increase during periods of water scarcity. Ground water is commonly priced higher than surface water. Average agricultural water tariffs by county, shown in Table 3, are somewhat below groundwater prices and water trading prices. Water exchanges also take place among farmers without any monetary transactions, based on customary trust among local farmers.

Many illegal so-called drought wells are used mainly in dry years. Some of them belong to irrigation districts, but many others belong to individual farmers or landowners who sell the water. To obtain additional water, farmers buy agricultural land sometimes as far as 100 kilometers upstream and use the water in downstream farms

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ECONOMÍA DEL AGUA SUBTERRÁNEA Y SU GESTIÓN COLECTIVA 153 (N. Hernández-Mora & R. Llamas eds., 2001).

44. JOSÉ MARIA SUMPSI ET AL., ECONOMÍA Y POLÍTICA DE GESTIÓN DEL AGUA EN LA AGRICULTURA (1998).

where water is scarcer and more valuable.[45] Environmental associations claim that these practices often conceal illegal water sales to either agricultural or urban users. They have also reported illegal water rights transactions between irrigation districts and urban developers and water companies.

The 1999 Water Law reform was aimed at facilitating water exchanges, but it has not spurred the creation of water markets or further water exchanges in southeastern basins where scarcity is widespread.[46] The reason behind this is that farmers prefer the status quo, relying as indicated above on public management of water at the basin level and decentralized management by water users associations in irrigation districts. Formal water markets, even public water banks, are met with profound distrust by farmers. Despite the fact that these areas could benefit significantly from establishing formal water markets among districts, the general belief is that they would spread corruption and result in water resources mismanagement. Farmers appear to disregard the market potential to improve welfare and distrust markets that might lead to the introduction of new or higher taxes on water or pollution once public monitoring of water exchanges comes into operation. Farmers are reluctant to admit their willingness to sell water because they fear that such a disclosure would suggest that they do not really need the water.

Water Management Scenarios

The model representing the irrigated agriculture in southeastern basins has been used to assess the effects of several water management alternatives. Two of these involve water demand management measures, another two involve measures to increase water supply, and the last is a combined management alternative. In the first scenario, a strategy is analyzed in which groundwater overdraft is forbidden and there are no transfers of water from external basins. In the second scenario, a price increase is considered to reach a price level that balances water demand with available water resources in southeastern basins.[47] This scenario

45. The areas of origin are usually the upper Segura and Vinalopó rivers, using the water in the middle and lower Vinalopó and Segura rivers, and in Campo de Cartagena county.

46. The main water supplier in the Segura basin (*Mancomunidad de Canales del Taibilla*) placed offers in spring 2004 to buy water rights from agricultural users, but so far no irrigation districts have accepted such bids. In 2004, the Segura basin authority also approved the creation of a public water exchange center.

47. Baseline 2001 water prices for each county have been estimated from several sources. *See, e.g.*, JOSÉ CARLES GENOVÉS, LORENZO AVELLÁ REUS & MARTA GARCÍA MOLLÁ,

follows the full recovery cost principle of the European Water Framework Directive of 2000. The third alternative involves seawater desalination. The fourth alternative is to expand water supply with transferred water from the Ebro project, with water subsidies to maintain the low water prices that farmers currently pay. The fifth alternative combines seawater desalination and water trading among counties, with a prohibition on aquifer overdraft. Water trades may take place along current conveying facilities of main rivers and canals, allowing for an additional supply of desalinated water. Desalinated water is only considered as an option in coastal counties that exhibit a very high marginal value of water, called "shadow price" in economic jargon.

Elimination of Groundwater Overdraft

Banning aquifer overdraft reduces the availability of water for agriculture, the effects of which are concentrated in the counties where the aquifers are located.[48] While in the Júcar and Segura basins the reduction of available water and cultivated acreage mainly affects low profit crops, in the Sur basin the reduction of water and cultivated acreage affects highly profitable crops, since there are few low profit crops to be abandoned (see Table 1). Losses are quite substantial in the Sur basin, where farmers' revenue and quasi-rent fall by almost 50 percent, while in Segura they decline by 20 percent and in Júcar by less than ten percent. More than 60 percent of losses in quasi-rent, that is 261 million € of 408 in losses, occur in the Sur basin due to the abandonment of highly profitable greenhouse crops.

The quantity of water from the Ebro transfer project targeted to solve groundwater overdraft in the Sur basin is only 58 hm^3; this is insufficient to offset the current overdraft, which amounts to 71 hm^3. The proposed Ebro transfers into the Júcar and Segura basins, by contrast, are much more generous. Therefore, the Ebro transfer will not solve the aquifer overdraft in Almería.

The ban on groundwater overdraft should be combined with additional management measures, such as water trading between counties in the Sur, Segura, and Júcar basins in order to minimize losses to farmers. This alternative is examined at the end of this section.

PRECIOS, COSTES Y USO DEL AGUA EN EL REGADÍO MEDITERRÁNEO (1998) (a reliable source, although, it has not been followed in all instances).

48. This measure would be difficult to implement by the administration because many wells are not registered, the volume of abstractions is not known, and there is a considerable number of illegal wells.

Table 3. Water Demand and Prices in Southeastern Basins, by County

County	Water Use (hm³)	Prices of Water (€/m³)			Value of water (€/m³)		
		Current	Costs of water from Ebro transfer	Seawater desalination	Average revenue	Average quasi-rent	Marginal value of water (shadow price)
Baix Maestrat	29	0.09	0.20		1.80	0.81	0.34
Plana Alta	45	0.09	0.23		1.44	0.67	0.42
Plana Baixa	120	0.09	0.29		1.23	0.58	0.56
Camp de Morvedre	48	0.09	0.30		0.95	0.46	0.34
Camp de Turia	127	0.09	0.31		0.98	0.45	0.40
Horta Nord	50	0.06	0.31		0.82	0.37	0.18
Valencia	25	0.06	0.32		0.58	0.26	0.13
Hoya de Bunyol	13	0.06	0.32		1.40	0.69	0.15
Horta Oest	39	0.06	0.32		0.80	0.38	0.16
Horta Sud	65	0.06	0.33		0.66	0.33	0.19
Ribera Alta	272	0.06	0.35		0.68	0.34	0.31
Ribera Baixa	227	0.06	0.35		0.32	0.18	0.13
Safor	99	0.06	0.46	0.52	0.83	0.40	0.37
Vall d'Albaida	12	0.06	0.46		1.42	0.58	0.14
Costera	30	0.06	0.46		1.01	0.49	0.25
Marina Alta	47	0.09	0.56	0.52	1.04	0.51	0.34
Marina Baixa	17	0.12	0.56	0.52	0.84	0.42	0.20
Alacantí	27	0.12	0.56	0.52	1.54	0.80	0.14
Alt Vinalopó	37	0.12	0.56		0.33	0.17	0.15
Vinalopó Mitja	65	0.15	0.56		1.10	0.67	0.20
Baix Vinalopó	55	0.12	0.57	0.52	0.63	0.30	0.13
Baix Segura	247	0.12	0.57	0.52	0.76	0.37	0.16
Noreste	57	0.12	0.72		0.93	0.53	0.21
Vega del Segura	273	0.12	0.57		0.75	0.42	0.24
Centro	20	0.06	0.57		0.86	0.44	0.18
Noroeste	40	0.06	0.57		0.89	0.43	0.11
Campo de Cartagena	64	0.12	0.61	0.52	3.12	1.40	0.19
Valle del Guadalentín	163	0.12	0.67	0.52	2.29	1.14	0.19
Bajo Almanzora	33	0.15	0.78	0.52	3.61	2.08	0.23
Alto Almanzora	34	0.06	0.92		0.65	0.29	0.08
Campo Tabernas	20	0.06	0.92		0.66	0.30	0.07
Río Nacimiento	11	0.06	1.05		0.72	0.29	0.13
Campo Níjar-Bajo Andarax	47	0.18	1.05	0.52	6.22	3.52	0.29
Alto Andarax	16	0.06	1.05		1.13	0.54	0.15
Campo Dalías	72	0.21	1.05	0.52	9.14	4.59	3.43

Increasing Water Prices

An increase in water prices for irrigation is a demand management instrument advocated by the EU Water Framework Directive. Current agricultural water prices range between 0.06 and 0.21 €/m³ in southeastern counties (see Table 3). Since these water prices are below the marginal value of water (or shadow price), the result is a rationed market where demand exceeds supply. Water scarcity could be reduced by increasing prices, and the price increases considered are 0.12 and 0.18 €/m³.

An increase of 0.12 €/m^3 in water prices reduces agricultural water demand by 509 hm^3, with a three percent fall in revenue and a 17 percent fall in quasi-rent due to the reduction in the acreage of cereal and woody crops, which are less profitable. The impact on quasi-rent is much greater in the Júcar and Segura basins, where crops are less profitable, than in Almería, where there is substantial greenhouse acreage. The 509 hm^3 reduction in water demand is close to the 561 hm^3 agricultural allotment from the Ebro water transfer project. The annual loss of 287 million € in quasi-rent is a measure of the compensation that could be offered as an incentive to farmers to voluntarily accept this increase in water prices (see Tables 4 and 5).

An increase of 0.18 €/m^3 in water prices reduces water demand by 605 hm^3, with a four percent decline in revenue and a 24 percent drop in quasi-rent. The decline in quasi-rent is more pronounced in the Júcar and Segura basins because of the reduction of less profitable cereal and woody crops. The 605 hm^3 contraction in water demand is not much less than the 820 hm^3 total of transferred water from the Ebro to the three basins for urban, industrial, and agricultural uses. The remaining excess demand could be covered by water trading between counties or by seawater desalination. The costs of this 0.18 €/m^3 price increase, which amounts to 405 million €, equal the farmers' quasi-rent losses. This would be the compensation required to ensure that farmers voluntarily accept the price increase.

The 0.12 €/m^3 or 0.18 €/m^3 water price increases, coupled with seawater desalination or water trading, solve the water shortage by balancing supply and demand while avoiding the huge investment required for the Ebro transfer. To implement this water pricing alternative, higher prices must be charged for both surface and subsurface water. Enforcement of higher prices would be straightforward for surface water, which is already controlled both by irrigation user associations at the district level and the water administration at the basin level. Enforcement would be quite difficult to implement on individual aquifer abstractions, however, because there are no irrigation water associations, nor does the basin authority have information on and effective control of aquifers.

Desalination

Desalination of seawater is a supply measure that can be used to complement water management measures such as water pricing or

water markets. The cost of desalination is 0.52 €/m^3,[49] which is less than the costs of transferred water in the counties south of Safor (see Table 3). Effective water demand at desalination cost (that is, water demand able to pay the 0.52 €/m^3 desalination price) is 387 hm^3 in the coastal counties from Safor to Campo Dalías.[50] Desalination increases supply and may contribute to balancing water demand and supply in southeastern basins. This balance could be achieved with 387 hm^3 supplied by desalination coupled with a 509 hm^3 reduction in demand driven by the 0.12 €/m^3 water price increase. This results in a total of 896 hm^3, which is above the Ebro water transfer allocation of 820 hm^3 for all uses.

Transferring Water from the Ebro

This is the Ebro project alternative featured in the National Hydrological Plan of 2001, which was cancelled by the Spanish Parliament in 2005. Diverted water would involve high costs depending on the distance from the Ebro river, with prices ranging between 0.20 €/m^3 and 1.05 €/m^3. These are well above the low prices in the 0.06 to 0.21 €/m^3 range that farmers currently pay (see Table 3) and at these prices the project water will only pay for itself in counties with highly profitable crops.

The volume of imported water that counties can absorb at the prices shown in Figure 2 is 761 hm^3 in Júcar, 294 hm^3 in Segura, and 132 hm^3 in Sur. These quantities contrast with the planned water transfer targets for agricultural and environmental use of 141 hm^3 in Júcar, 362 hm^3 in Segura, and 58 hm^3 in Sur (see Table 4). Thus, there is a significant inconsistency in the proposed transfer project for the Segura basin, which can absorb only 294 hm^3 of water for agricultural use at the water transfer price, compared with the 362 hm^3 for agricultural use allocated by the Ebro project. Farmers in Segura would not be willing to pay for a quantity of imported project water equal to the amount now being overdrawn, which means that overdrafting will persist.

The former central Spanish government asserted that farmers in the receiving basins would pay for Ebro water at the same price they are currently paying. Its intention, therefore, was to remove the inconsistency in transfer allocation targets by subsidizing the price of transferred water allocated to agriculture and charging higher prices to urban and industrial water users. These subsidies would ensure the

49. Javier Uche, *Anejo 1. Costes energéticos*, *in Alegaciones al Proyecto de Transferencias Autorizadas por la Ley del Plan Hidrológico Nacional y Estudio de Impacto Ambiental* 20 (José Albiac ed., CITA-DGA, Working Paper No. 03/3, 2003).

50. This demand amounts to 52 hm^3 in Baix Segura, 53 hm^3 in Campo de Cartagena, 110 hm^3 in Valle del Guadalentín, 43 hm^3 in Campo Níjar, and 69 hm^3 in Campo Dalías.

survival of the less profitable agricultural activities supported by the Common Agricultural Policy. Subsidizing diverted water for agricultural use would be costly for non-agricultural water users of Segura because the surcharge would come to 187 million €. Establishing the surcharge on present urban and industrial use in the Murcia region and on the future transfer allotment reserved for urban and industrial use implies a surcharge for this group of users of about 0.76 €/m^3, resulting in a final price of 1.62 €/m^3. The subsidy needed to maintain the whole 561 hm^3 of transferred water for agriculture at the present low water prices paid by farmers in the southeast amounts to 301 million € per year (see Table 5).

This option is frankly unjustifiable, either in terms of economics or equity, since non-profitable agricultural activities would be maintained in an unsustainable framework while the diverted water resources would degrade the ecological functioning of the donating basin. It may also prove politically unfeasible: in the United States, the experience with the Central Arizona Project was that the urban users of imported water rebelled when they were asked to subsidize excessively low prices for the agricultural users.

The economic analysis presented above differs in several fundamental ways from that conducted by the Spanish Ministry of Environment.[51] The documents of the National Hydrological Plan (NHP) consider the effects of the water transfer on agricultural quasi-rent, revenue, and employment in the irrigation areas of the southeastern receiving basins. As indicated above, the procedure used lacks rigor since it starts with a fixed volume of water to be transferred from the Ebro without justifying the quantity. This volume of water is then divided by a standard irrigation assignment per hectare, and in this way the affected acreage is calculated. Total quasi-rent is estimated by multiplying this acreage by a representative quasi-rent per hectare. This procedure is excessively simple and poorly supported and thus cannot be regarded as reliable.

The procedure used for the present study is more consistent with economic theory and more precise because it incorporates the acreage of each crop by county, meteorological information relevant for modeling irrigation water demand, agronomic data on yields and costs, and technical information about irrigation systems. Most importantly, the marginal value of water is calculated in each county of the receiving basins and water demand responds to changes in water prices.

There are several striking differences when comparing the results of the present study with those of the NHP. The NHP estimates

51. *See* ANÁLISIS ECONÓMICOS, *supra* note 9.

the quasi-rent losses from banning aquifer overdraft at 210 million €,[52] while the loss of quasi-rent in this study has been valued at 408 million €, which is distributed between losses of 46 million in Júcar, 101 million in Segura, and 261 million in Almería (see Table 5). Notably, more than 70 percent of losses occur in Almería, and yet the NHP assignment to Almería for groundwater overdraft fails to cover the current overdraft.[53] Clearly, this water transfer has no economic justification based on southeastern agriculture because Almería is the zone where the elimination of groundwater overdraft has the greatest economic impact and, despite being easily able to pay the high price of diverted water,[54] it does not receive a sufficient share to eliminate overdraft.

Regarding the impact on employment, the NHP points out that there are 76,000 agricultural jobs in the Segura basin and asserts that, without the water transfer project, employment would fall to 52,000 (a reduction of 24,000 jobs), while under the project it would grow to 102,000 jobs (an additional 26,000 jobs). It is difficult to see where this employment growth would come from since, according to the NHP, the fall in quasi-rent would be 210 million € when the aquifer overdraft is eliminated, which could in turn provoke a fall of 24,000 in jobs, while the growth in quasi-rent from irrigation guarantee reckoned to be 12 million €, and it is doubtful that this increase would generate 26,000 jobs.

In our analysis, the number of jobs in the Segura basin is estimated at 88,600, which approaches the figure of 76,000 estimated by the NHP. This present study evaluates the loss in employment due to the overdraft ban in the counties of Murcia and Alicante in the Segura basin at 12,200 jobs, which is half the loss of 24,000 indicated in the NHP.

Summing up, the NHP measures the benefits of the project on the basis of estimates of avoided losses in quasi-rent and employment, but the procedure used to estimate those losses is very questionable and is not consistent with accepted economic practice. Losses for the entire receiving area are estimated in a crude manner without allowing for any spatial variation between basins, provinces, or counties. Most importantly, quasi-rent losses are calculated by using a single average value product of water (0.75 €/m^3), whereas the correct measure should

52. The NHP states that lack of enhanced reliability of agricultural water supply causes additional quasi-rent losses amounting to 12 million €.

53. Overdraft in Almería is 71 hm^3 and Almería receives only 58 hm^3. Segura receives 362 hm^3 for agriculture, 142 hm^3 more than the groundwater overdraft in the basin and 68 hm^3 more than the effective demand for water at the price charged for imported water.

54. Current shadow prices of water are 3.43 €/m^3 in Campo Dalías, 0.29 €/m^3 in Campo Níjar, and 0.23 €/m^3 in Bajo Almanzora (Table 3). When groundwater overdraft is forbidden, shadow prices rise to 5.21 €/m^3 in Campo Dalías, 4.19 €/m^3 in Campo Níjar, and 0.56 €/m^3 in Bajo Almanzora (Figure 4).

be the *marginal* value of water from additional water supplies. In our analysis, water demand in each county responds to water prices because farmers may change crop mixes and because some rough measure of land quality and other spatial factors are included through crop yields and water input variability.

A Workable Combined Alternative to the Ebro Transfer

Finally, we consider an alternative more suitable than either an aquifer overdraft ban or an increase in water prices, one that combines both demand and supply measures. This alternative combines banning groundwater overdraft, trading water among counties, and supplying desalinated seawater to selected coastal counties.

Existing conveying facilities are used for water trading between counties along main rivers and canals according to shadow prices of water in each county. Figure 4 shows these conveying facilities and the shadow prices of water by county when groundwater overdraft is forbidden. The main rivers in the three basins are the Turia, Júcar, Vinalopó, Segura, Guadalentín, Almanzora, and Andarax, and the Segura tributaries Argos and Quipar. The main canals are the Júcar-Turia and Acequia Real canals, which run south to north in the Júcar basin, and the Canal Margen Izquierda, Canal de Crevillente, Canal Campo de Cartagena, and Canal Margen Derecha in the Segura basin. The water shadow prices in each county are calculated under prohibition of groundwater overdraft and these shadow prices indicate that water transfers may take place along the Vinalopó, Segura (including the Argos and Quipar tributaries), Guadalentín, Almanzora, and Andarax rivers, and along the Canal Margen Izquierda and Canal Campo de Cartagena (see Figure 4). Seawater desalination is considered only for Campo Dalías and Campo Níjar counties, which exhibit the highest water shadow prices of all coastal counties.

The welfare gain from water trading and desalination is measured by the economic surplus[55] so that the solution of water trading and desalination flows is found by maximizing welfare (see Figure 5). Results from the combined scenario show a significant reduction of 362 hm^3 in water use and moderate losses of 83 million € in quasi-rent (see Tables 4 and 5). The reassignment of water among counties increases welfare by 88 million € and the additional desalinated seawater supplied to Campo Dalías (49 hm^3) and Campo Níjar (11 hm^3) increases welfare by 237 million €, with a total welfare gain of 325 million €. This is simply

55. This represents the area between water excess supply and excess demand functions in each county.

the difference in quasi-rent when shifting from the overdraft ban (-408 mill. €) to the combined alternative (-83 mill. €).[56]

RANKING THE WATER MANAGEMENT ALTERNATIVES

The results from each of the water management alternatives are summarized in Tables 4 and 5. Table 4 presents water demand scenarios under each alternative and the water allocation of the Ebro project. Table 5 shows farmers' quasi-rent losses under each alternative and, hence, the subsidies needed in order to maintain farmers' quasi-rent.

Table 4. Water Demand Scenarios in Southeastern Basins and Ebro Project Allocation (hm^3)

	Júcar Basin	Segura Basin	Sur Basin	Total Southeast
Current Water Demand	1,450	863	232	2,545
Water Demand Reduction for Agricultural Use...				
...through a groundwater overdraft ban	139	213	70	422
...through a 0.12 €/m^3 water price increase	313	142	54	509
...through a 0.18 €/m^3 water price increase	350	181	74	605
...through the combined alternatives (overdraft ban, water markets, desalination)	139	213	10	362
Ebro Project Allocation				
All uses	300	420	100	820
Agricultural and environmental use	141	362	58	561
Urban and industrial use	159	58	42	259
Effective Demand of Water for Agricultural Use...				
...at transferred water prices (0.20 to 1.05 €/m^3)	761	294	132	1,187

56. These results can be implemented because of the recent completion of the Carboneras desalination plant in Campo Níjar county. The capacity of the Carboneras plant is 42 hm^3, of which 15 are for urban use and 27 for agricultural use; another desalination plant is planned in Campo Dalías. In Campo Níjar county, overdraft amounts to 25 hm^3 and effective demand at desalination prices is 42 hm^3. But local water experts indicate that farmers are reluctant to buy the whole 27 hm^3 of desalinated water from Carboneras at the high desalination price. This problem may be worked out if the projected "water highway" conveying facility linking Campo Níjar and Campo Dalías is built, since in Campo Dalías the overdraft is 40 hm^3 and the effective demand is 69 hm^3. However, the water authority intends to solve the problem in Campo Níjar by subsidizing the price of desalinated water, charging farmers a reduced price of 0.30 €/m^3 instead of the 0.52 full price. The water administration has suggested that eventually the water price may be increased, reducing the subsidy in case of a strong irrigation demand.

Farmers' quasi-rent losses are calculated by comparing each alternative with the current situation. Quasi-rent is above 1,700 million € under the present baseline scenario, which is reduced to around 1,400 million € by increasing water prices by 0.12 €/m³ and to 1,300 million € by increasing water prices by 0.18 €/m³. Banning groundwater overdraft reduces quasi-rent to 1,300 million €. Under the combined alternative, quasi-rent exceeds 1,600 million €, which is higher than under any other measure. The Ebro transfer project maintains current farmers' quasi-rent but requires 300 million € in subsidies to maintain the low water prices currently paid by farmers.

Table 5. Quasi-Rent Losses under Alternative Scenarios and Subsidies (Million € Per Year)

	Júcar Basin	Segura Basin	Sur Basin	Total Southeast
Current Quasi-rent	586	536	589	1,711
Quasi-rent Losses to Farmers...				
... through a groundwater overdraft ban	46	101	261	408
... through a 0.12 €/m³ water price increase	166	94	27	287
... through a 0.18 €/m³ water price increase	232	136	37	405
... through the combined alternative (overdraft ban, water markets, desalination)	39	49	-5	83
Subsidies Needed by the Ebro Project...				
... to cover gap between costs of transferred water (0.20 to 1.05 €/m³) and present low water prices	54	187	60	301

A sharp reduction in water demand is achieved by raising irrigation water prices by between 0.12 and 0.18 €/m³. The current 2,550 hm³ of demand for irrigation water falls by 500 to 600 hm³, but the costs to farmers in quasi-rent losses are also quite high in the range of 300 to 400 million €. A ban on groundwater overdraft is the worst solution because the fall in water demand is only 400 hm³, considerably less than the reduction achieved by increasing prices, while costs to farmers are higher than under the water pricing alternatives. The combined alternative of an overdraft ban, water markets, and desalination reduces irrigation demand by almost 400 hm³ at a much lower cost of less than 100 million € in terms of farmers' quasi-rent. The combined alternative ensures an end to aquifer overdraft, improves upon any other demand management measure, and is more suitable than the Ebro transfer project.

Some caveats are in order with respect to the difficulties of implementing demand management measures. Decades of water resource mismanagement in the southeastern basins of the Iberian

Peninsula have created pervasive pressures on water resources and a severe degradation problem. The measure of banning aquifer overdraft would be very difficult to achieve, since there is at present no effective control on the number of wells or the volume of abstractions. Various authors[57] have indicated that the key reasons for groundwater mismanagement are that rules are not enforced by basin authorities because of a lack of resources and will[58] and that public and private registers of subsurface water rights are largely incomplete. Other authors[59] strongly support groundwater use, although they recognize that its chaotic development may lead to depletion, quality degradation, and negative effects on ecosystems. As a common pool resource, aquifers present significant managerial challenges.

Water pricing measures are also difficult to implement because farmers will oppose price increases. Additionally, although basin authorities can modify the water prices charged to collective irrigation systems using surface water, they have no control over the costs faced by individual farmers pumping from aquifers. Even if water pricing could be implemented on individual abstractions, price increases will not reduce demand in irrigation areas based on very profitable greenhouse production. An example of this is the shadow price of water in Campo Dalías, where prices would need to escalate from the current 0.21 €/m^3 to over 3 €/m^3 in order to curb demand.

As indicated, the creation of water markets is also a difficult task. Although informal water transactions occur, the possibility of formal water markets introduced by the 1999 Water Law reform has not spurred any significant trading in the last six years due to the farmers' mistrust of formal water markets.

Augmenting water supply by publicly financed desalination is much more straightforward. The problem arises with the lack of irrigation demand if water is not subsidized and farmers have to face high desalination prices. The potential of desalination is given by the effective demand for desalinated seawater, which reaches a volume of almost 400 hm^3 in coastal counties from Safor to Campo Dalías, at the 0.52 €/m^3 cost of desalinated seawater. The obvious locations for desalination plants are Campo Dalías and Campo Níjar, with a combined

57. *See, e.g.*, N. Hernández-Mora, L. Martínez & J. Fornés, *Intensive Groundwater Use in Spain*, *in* INTENSIVE USE OF GROUNDWATER: CHALLENGES AND OPPORTUNITIES 387 (Ramón Llamas & Emilio Custodio eds., 2003).

58. Programs to install water quality control stations were started ten years ago by basin authorities in Spain, but the Segura basin, with the worst water quality problems, is one of the few basins where these stations are not yet operational.

59. *See, e.g.*, R. Llamas & P. Martínez, *Intensive Groundwater Use: Silent Revolution and Potential Source of Social Conflicts*, 131 ASCE J. WATER RESOURCES PLAN. & MGMT. 337 (2005).

effective demand amounting to 111 hm^3. Other obvious locations for desalination plants to supply water to greenhouses are Campo de Cartagena and Valle de Guadalentín counties.

What prevents this effective demand from materializing is that farmers are extracting water from aquifers at pumping costs of around 0.09 to 0.18 €/m^3. Since pumping costs are considerably below those for desalination, farmers will not buy desalinated water. Public investments in desalination plants become reasonable only under a strict enforcement by the water authority of an aquifer overdraft ban that would force farmers to buy desalinated water.

This last point demonstrates the problem facing the new AGUA project, which is supposed to replace the Ebro transfer. The AGUA project involves investing 1,200 million € to achieve a desalination capacity of 600 hm^3, including around 300 hm^3 for irrigation between Campo Dalías and Marina Alta coastal counties. As indicated above, effective demand in these counties could hypothetically amount to 400 hm^3, but implementation of the AGUA project requires the strict enforcement of an aquifer overdraft prohibition, which is a daunting challenge for the water authority. The risk of the AGUA project is that, after public funds are invested in desalination plants, the irrigation demand does not materialize.

The debate continues on the Ebro transfer project and the AGUA project in Spain. The former central government used the Ebro transfer project to gain political support and votes in the receiving water transfer regions of Valencia and Murcia, which are highly populated.[60] At the same time, it lost support in Aragón and the Ebro delta regions located in the donating basin, where both population and votes are quite low. The 2004 elections brought a new central government that cancelled the Ebro project, replacing it with the AGUA project. The regions of Valencia and Murcia, where there is continued demand for the Ebro transfer, await a change of government in the next parliamentary elections of 2008. Reinstatement of the Ebro project is highly unlikely, however, not

60. Some authors claim that the real aim of the Ebro transfer was to guarantee further urban development of the Spanish Mediterranean coast, 35 percent of which was already urbanized in the year 2000, as indicated by the European Environment Agency, Corine land cover database 2000 (2005). Two recent developments support this claim, one is the half-million houses planned between Mazarrón and Carboneras (100 km) along the new highway being built between Cartagena and Vera, in one of the last pieces of unspoiled Mediterranean coast. The other is the Fourtou Report just approved by the European Parliament, asking for a suspension of plans to build 150,000 houses on the Valencia coast. Coast damage from urban development is serious, and the European Commission is threatening Spain with bringing the Valencia urban development law to the Court of Justice of the European Union.

Figure 1. The Tajo-Segura Water Transfer Project in the Plan of 1933.

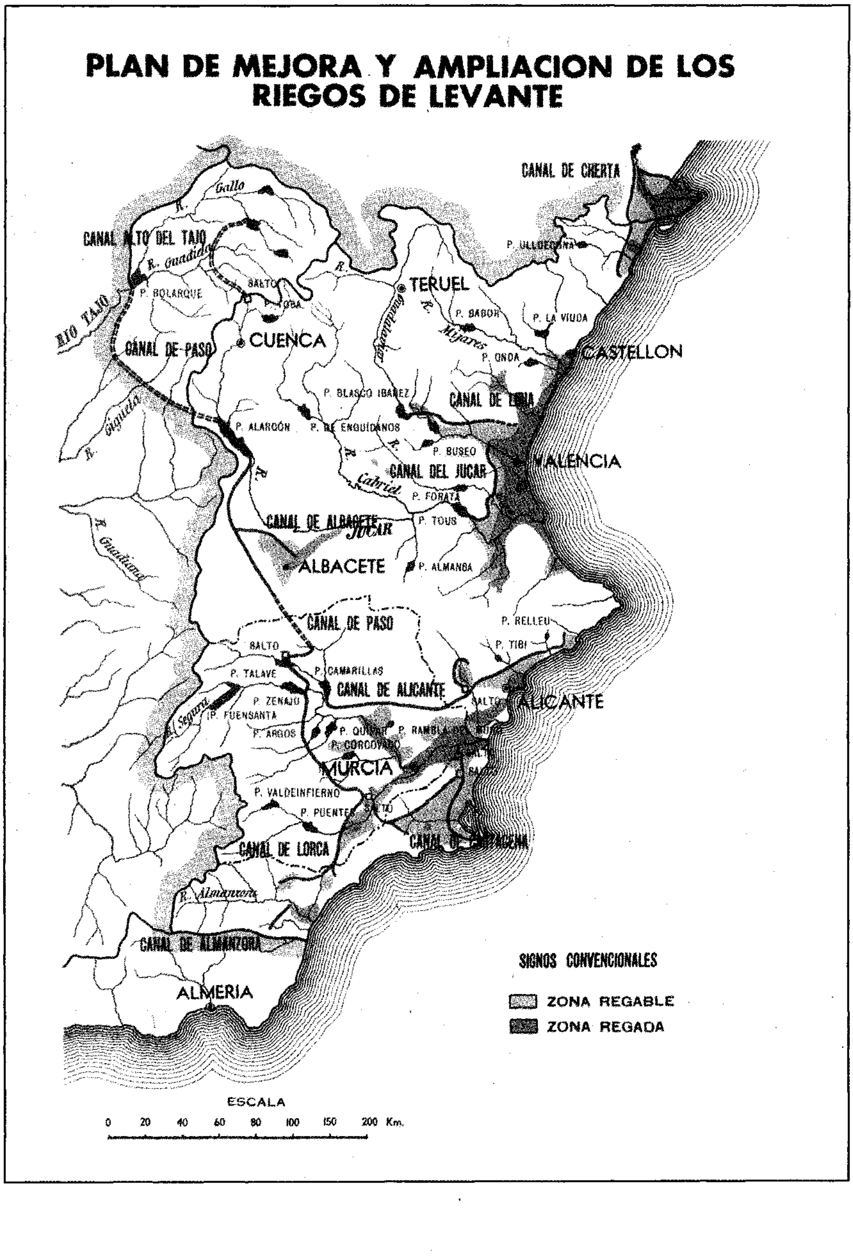


Figure 2. The Ebro-Segura Water Transfer Alternative by Felix de los Rios to the 1933 Plan.

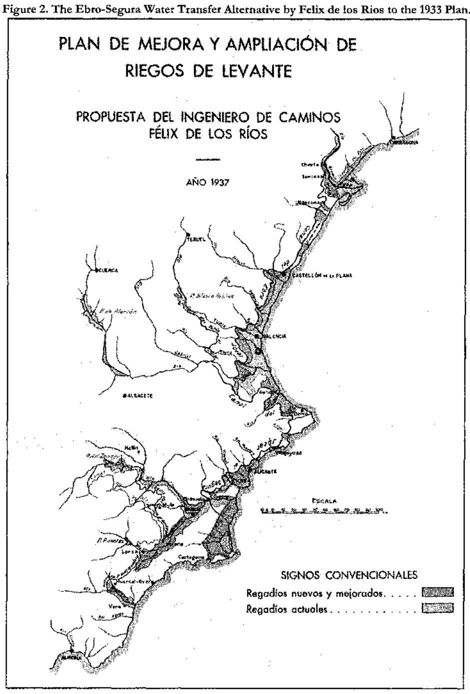


Figure 3. Map of the Water Transfer Path and Counties in the Receiving Basins.

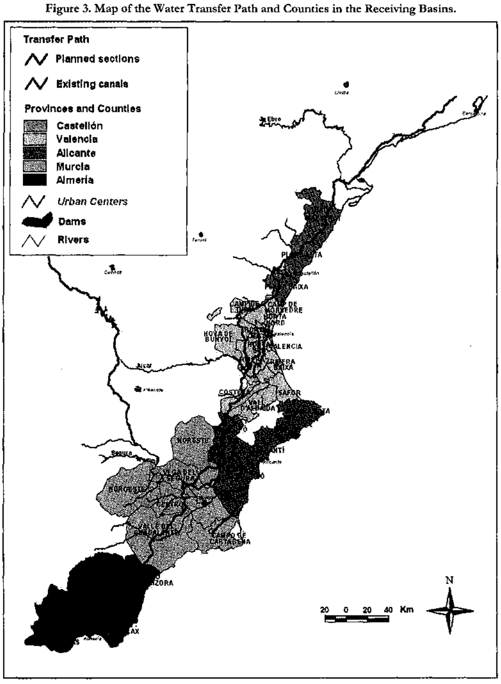


Figure 4. Main Canals and Rivers and Water Shadow Prices under Overdraft Prohibition.

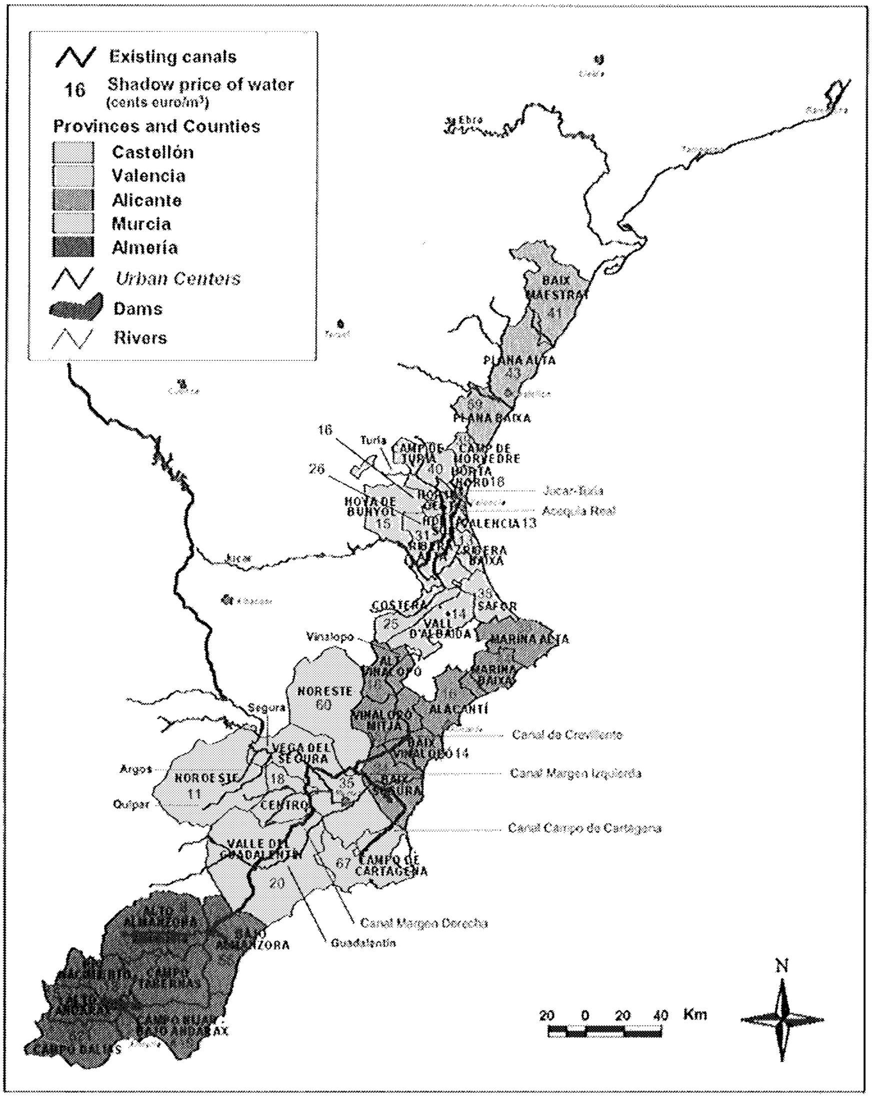
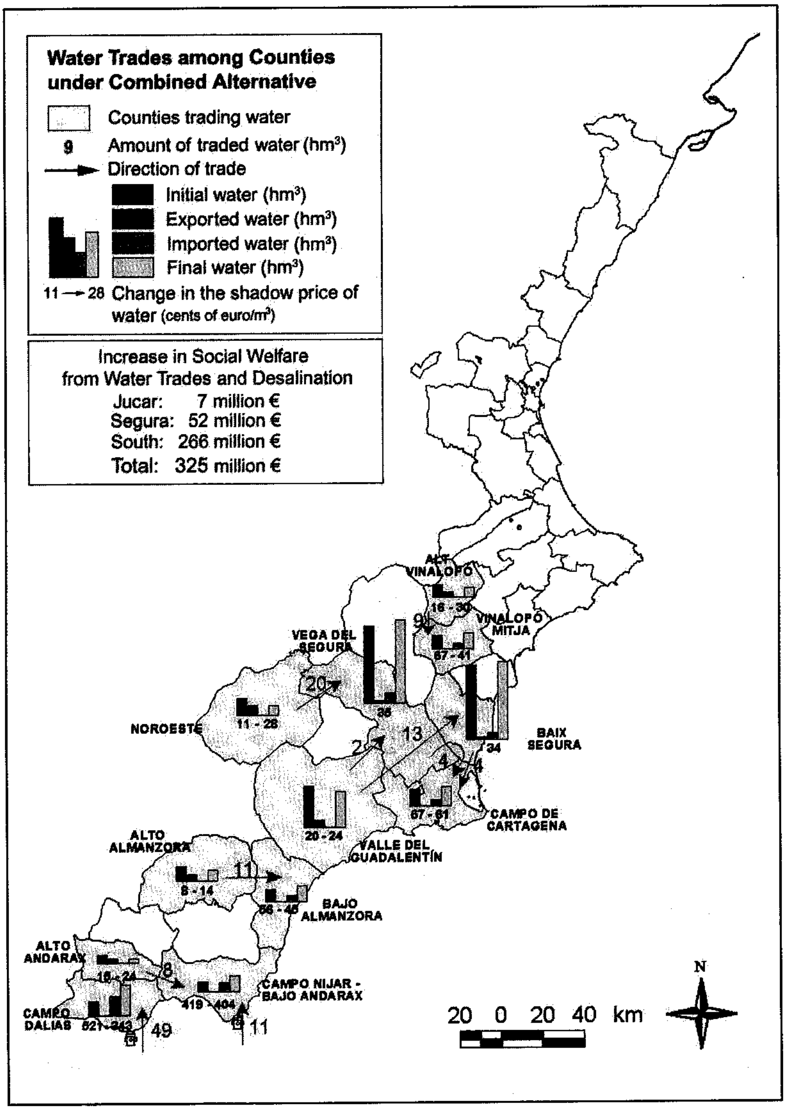


Figure 5. Water Exports and Imports by County under the Combined Alternative.



only because the AGUA project will alleviate the water scarcity problem, but also because, as a result of the EU enlargement, Spain will no longer be eligible for EU funding after 2008.

CONCLUSION

This study analyzes the economic rationale behind the Ebro inter-basin transfer, the main project of the Spanish National Hydrological Plan of 2001. The debate in Spain over the Ebro project has been very keen and has raised important issues related to water resources management. The debate deteriorated into squabbling between the main Spanish political parties and tough conflicts among the water donating and receiving territories. It also faced strong opposition from water resource experts and environmental and social organizations.

The study focuses on the shortcomings of the Ebro project and the evaluation of several alternative water policies for solving the water scarcity problem in southeastern Spain. The Ebro transfer project followed the long-established supply approach used in hydrological planning in Spain during the twentieth century, which expanded irrigation from one to 3.5 million hectares. The Ebro project was grounded on a pure engineering underpinning, traditional in Spanish water planning. Several important limitations of the project are that intermediate augmentations of supply are not considered, no economic justification is given for the water intended for agriculture, and agricultural benefits are not constant, as assumed in the project, but depend on the quantity of water transferred and the elasticity of demand for imported water in each agricultural activity and region.

The outdated "ability to pay" analysis used in evaluating the project is based on the average value of water. This single average value is used to estimate the avoided losses of quasi-rent and labor from building the project, instead of the methodologically correct marginal value of water. This approach disregards the demand response to water prices by ignoring that farmers may change crop mixes and by overlooking the spatial heterogeneity of investments in irrigation and the varying quality of land.

Several water management demand and supply alternatives to the Ebro project have been examined, focusing on the response of water demand to these alternatives and their effects on farmers' quasi-rent. The demand management measures are an aquifer overdraft ban and water pricing, while the supply measures are the Ebro transfer project and seawater desalination. The introduction of water markets has also been

examined, although the institutional water framework precludes the smooth development of water trading.

Results indicate that differentiated water management policies are best suited for each basin. In areas with high shadow prices of water, the overdraft ban alternative results in steep quasi-rent losses to farmers. Conversely, in areas with low shadow prices of water, the alternative of increasing water prices generates steep quasi-rent losses. Because reductions in demand could be achieved by controlling water abstractions or by water pricing, the measure of choice in the Júcar and Segura basins, where water shadow prices are low, is to ban aquifer overdraft rather than increase water prices. In the Sur basin, where water shadow prices are high, prohibition of aquifer overdraft should be coupled with augmenting water supply through desalination in order to avoid steep quasi-rent losses to farmers. Additionally, allowing water trading between counties may moderate the negative income effects of controlling water abstractions to prevent overdraft.

Implementation of demand management measures in agriculture is problematic, however, because a ban on aquifer overdraft would be difficult after longstanding water resource mismanagement in the area, and water pricing or water markets will be met by opposition from farmers. Losses to farmers should be compensated; otherwise an excessive burden on agricultural activities will be met by social opposition, causing the measures to fail.

The most advantageous outcomes can only be achieved through compromise solutions, where water demand and supply management measures are combined and adapted to each basin. Along these lines, the best alternative is a combination of measures including overdraft control, water markets, and desalination; this curbs demand by almost 400 hm^3 in southeastern basins at costs below 100 million € per year in terms of quasi-rent losses to farmers. In comparison, the Ebro project maintains farmers' quasi-rent but needs 300 million € per year in subsidies to bring the high costs of transferred water down to the level that farmers are paying now. These 300 million € in subsidies are only the market social costs of the Ebro project, and a correct assessment of the project costs and benefits requires an explicit economic valuation of the project's environmental impacts.

Seawater desalination is a quick and relatively low-cost water source for urban, industrial, and agricultural users in coastal counties. The construction of desalination plants for irrigation in the coastal counties south of Campo de Cartagena appears to be a good alternative since greenhouse production is a very dynamic sector that can pay for the water.

Seawater desalination under the AGUA project is the water policy alternative to the Ebro transfer chosen by the present government. The implementation of the AGUA project requires the enforcement of surface and subsurface water extraction limits, which is a daunting challenge for the water administration. The risk of the AGUA project is that, once public investments in desalination plants are completed, the irrigation demand may fail to materialize because current water extractions continue.

Finally, a striking feature of both the Ebro project of the former government and the AGUA project of the current administration is that both focus exclusively on water supply and not at all on environmental restoration. In the United States and other countries, any water project of this magnitude would include environmental restoration as one of the basic objectives. Future water plans need to take seriously the goal of environmental restoration and improvement in southeastern basins. In the Segura and Sur basins, the consequence of the large imbalance between water supply and demand is a serious water scarcity problem. Additionally, water quality is impaired by pollution both from point sources, including treated and semi-treated sewage and industrial wastes, and non-point sources, including pesticide and nutrients from agricultural and urban runoff. Any chosen alternative will not work without the enforcement of effective rules protecting water resources by the water authority.

The effort to meet this challenge will surely involve reallocating some water from off-stream use by agricultural, urban, and industrial users to environmental uses both in aquifers and streams, and also in the coastal wetlands. It will also involve other measures such as the control of non-point pollution, the recovery or artificial construction of wetlands for nutrient removal, and habitat restoration. The experience in the United States and elsewhere worldwide is that this type of environmental restoration and improvement can generate significant economic benefits associated with recreation, eco-tourism, and the non-use value of ecosystem protection, which may outweigh the benefits from agricultural and even urban water use. This is a key question in southeastern basins because of the importance of present and potential tourism activities that would be spoiled by water resources mismanagement and reckless urban development.