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The Rise and Fall of the Ebro Water Transfer†

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 water management, 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 and requires compensation to farmers, otherwise an excessive burden on farmers would be met by social opposition leading to the failure of measures.

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INTRODUCTION

While never as important in shaping society as the hydraulic civilizations of ancient Middle and Far East, described by Wittfogel,[1] irrigation has been important in the Iberian peninsula from 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 (Tarraco, Emerita Augusta, Caesar Augusta), mineral extraction and irrigation. The highest dam ever built throughout the whole of the Roman empire was the 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. 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 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 (Canal de Isabel II), Valencia, Gerona and Cartagena, but the policy of private financing failed in agricultural irrigation

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[1] K. Wittfogel, Oriental Despotism: A Comparative Study of Total Power (1957).

[2] M. Arenillas indicates that the highest dams were the 34 m Almonacid dam, the 22 m Proserpina dam (Mérida, Spain), and the 21 m Harbaqa (Palmyra, Siria) and Cornalvo (Badajoz, Spain) dams. M. Arenillas, Obras hidraúlicas romanas en Hispania, Paper presented at the I Congreso sobre las Obras Públicas Romanas, Mérida, Spain (2002). Available at http://traianus.rediris.es/textos/hidraulicas.htm

projects. By the end of the nineteenth century, public involvement in irrigation projects was considered essential, based on the importance of water to promote economic growth in agrarian Spain, while also improving farmers' social conditions. A century ago, Costa[3] elaborated on 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. The key premise of this traditional supply approach was that water is a plentiful resource to be developed by public and private agents.[4]

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,[5] the Development Plans of the industrialization period of the nineteen sixties and seventies, and the National Hydrological Plans of 1993[6] and of 2001.[7,8]

Figure 1 about here

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 ha increase in

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[3] J. Costa, Política Hidraúlica: Misión Social de los Riegos en España (1911); J. Costa, La Tierra y la Cuestión Social (1912).

[4] J. Carles & M. 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 (J. Albiac ed., 2003).

[5] M. Lorenzo-Pardo, Plan Nacional de Obras Hidráulicas. Tomo I Exposición General (1933).

[6] Ministerio de Obras Públicas y Transportes, Plan Hidrológico Nacional. Memoria y Anteproyecto de Ley (1993).

[7] Ministerio de Medio Ambiente, Plan Hidrológico Nacional. Análisis de los Sistemas Hidráulicos (2000).

[8] Ministerio de Medio Ambiente, Plan Hidrológico Nacional. Análisis Económicos (2000).

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.[9]

The main project of the National Plan of Hydrological Works was the Tajo-Segura water transfer to Southeastern Spain (Figure 1), a project strongly criticized by Félix de los Ríos, director of the Ebro basin authority in 1933, who proposed the Ebro water transfer to Southeastern Spain as an alternative (Figure 2). Retrospectively, De los Ríos was right in criticizing the Tajo-Segura water transfer, because the 1933 Plan's estimated 760 hm^3 of water available for diversion in the upper Tajo was seriously overestimated.[10]

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 finally only the Tajo-Segura transfer was built during the nineteen seventies. Miscalculation of water availability in the Tajo-Segura water transfer, and the huge expansion of irrigation in Southeastern Spain based on pervasive aquifer depletion, led to the recent proposals of water transfers from the Ebro during the past decade, in both National Hydrological Plans of 1993 and 2001.

Figure 2 about here

The National Hydrological Plan of 1993 was intended to interconnect all main basins of the Iberian peninsula, with huge investments in waterworks.[11] The amount of transferred water was close to 4,000 hm^3, with exports from the North, Duero, Tajo and

[9] M. Arenillas, *El Plan Nacional de Obras Hidráulicas sesenta años después*, in Plan Nacional de Obras Hidráulicas (J. Zumárraga ed., 1993).

[10] This was demonstrated when the Tajo-Segura transfer was finally built in the nineteen seventies 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.

[11] The investments of the 1993 Plan (Ministerio de Obras Públicas y Transportes, Informe sobre el Plan Hidrológico Nacional, 1993), were 3600 billion current 1993 pesetas, and the investments of the 2001 Plan were 19 billion euros or 3200 billion current 2000 pesetas, of which 4.7 billion euro were earmarked to build the Ebro water transfer.

Ebro donating basins, and imports by the Ebro, Tajo, Guadiana, Guadalquivir, internal Cataluña, Júcar, Segura and Sur receiving basins.[12] The size of the investments 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 was an instrumental law, but introduced many modifications to the Water Law of 1985, which was the basic law to be followed. A consultative 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 sector.

Finally, the Spanish Parliament decided in 1994 that the National Hydrological Plan had to include estimates and conditions for inter-basin transfers, it should also present alternatives to proposed water transfers, and some budget assessments of the transfer projects. The Plan also had to be linked to a new National Irrigation Plan, and to measures for water treatment, water savings and reutilization. Two additional hurdles were added when the Senate introduced the requirement that all hydrological basin plans had to be approved before the National Hydrologic Plan was passed, and when all users representatives in the National Water Council rejected the Plan. All these social and political factors triggered the collapse of the National Hydrological Plan of 1993.[13]

From an academic perspective, Aguilera-Klink[14] was the first author in Spain to use economic arguments to challenge the traditional supply expansion approach, by discussing

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[12] 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.

[13] Ministerio de Medio Ambiente, Libro blanco del agua en España (2000).

[14] F. Aguilera-Klink, *El problema de la planificación hidrológica: una perspectiva diferente*, 2 Revista de Economía Aplicada (1993).

the National Hydrological Plan of 1993 with González and Rubio.[15] González 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 comments, Rubio and González[16] accepted 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 is needed on water supply and demand equilibrium prices for each basin, and these prices must 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 1990's. A heavy increase in water demand from the highly profitable fruit and vegetable sector, which included a substantial greenhouse acreage,[17] resulted in acute water scarcity and aquifer overdraft. Most of the water demand increase was met by additional individual pumping by farmers from aquifers, which were not controlled by the water administration. The government's solution was to undertake a new water planning effort, based this time on a unique inter-basin transfer, bringing water from the Ebro to the Júcar, Segura and Sur basins.

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[15] A. González-Romero & S. Rubio, *El problema de la planificación hidrológica: una aplicación al caso español*, 1 Revista de Economía Aplicada (1993).

[16] S. Rubio & A. González-Romero, *El problema de la planificación hidrológica: un argumento económico a favor de los trasvases*. 2 Revista de Economía Aplicada (1993).

[17] Remote sensing information indicates that irrigation acreage has more than tripled in the Segura basin from 1970 to 1995, as measured by A. Quintanilla, S. Castaño, J. García, E. Navarro, J. Montesinos, *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: Usos y Aplicaciones (J. Casanova & J. Sanz eds., 1997). In the Sur basin, greenhouse production started after 1970 and acreage has expanded to around 30.000 ha (see Table 1). Remote sensing images comparing Campo Dalías greenhouses between 1974 and 2000, are presented in United Nations Environment Program, One Planet, Many People: Atlas of Our Changing Environment (2005). Available at www.na.unep.net/OnePlanetManyPeople/AtlasDownload/UNEP_Atlas/Atlas_3-5-Cropland_Screen.pdf on pages 200 and 201.

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 a distance of up to 750 km.[18] The analysis follows 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 met with strong opposition from water resource experts, environmental and social organizations, and the Aragón and Cataluña regions located in the Ebro basin.[19] The main argument against the transfer was that the traditional approach of augmenting supply to deal with water scarcity is obsolete, and new water management policy initiatives are needed. These policy initiatives should 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 such as desalination, water quality protection, and reuse and regeneration of water resources.

Another blow to the Ebro transfer was the reluctance of the European Union to provide European funding for the project, because of its shaky economic and environmental foundation. The Ebro transfer was at odds with the European Union policies of the 2000 Water Framework Directive, which adopts a new water policy based on the management of demand, full recovery costs including environmental costs, and

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[18] And additional volume of 200 hm^3 was planned to be sent 180 km north to Barcelona (Figure 3).

[19] 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 C. Ibañez & N. Prat, *The Environmental Impact of the Spanish National Hydrological Plan on the Lower Ebro River and Delta*, 19 International Journal of Water Resources Development (2003), and in N. Prat & C. Ibañez, Avaluació crítica del Pla Hidrològic Nacional i proposta per a una gestió sostenible de l'aigua del baix Ebre (2003).

setting up standards on water flows and on emissions 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. 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 has been 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. The AGUA project has been designed to substitute 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,[20] 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 remainder 561 hm^3, which was targeted for agriculture

[20] Ministerio de Medio Ambiente, Evaluación Ambiental Estratégica del Plan Hidrológico Nacional. Documento de Síntesis (2002); Trasagua, Proyecto de las Transferencias Autorizadas por el Artículo 13 de la Ley 10/2001 de 5 de Julio (Plan Hidrológico Nacional) y Estudio de Impacto Ambiental (2003); Ministerio de Medio Ambiente, *supra* notes 7 and 8.

and intended to cover the elimination of aquifer overdraft (419 hm^3) and to guarantee supply reliability (142 hm^3). The analytical foundation for the determination of these specific quantities is flimsy and unconvincing.

The majority of the water transferred would go to agricultural uses, and the agricultural benefits are calculated as the average value product of the water, which is estimated at 0.75 €/m^3. 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: 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 mix and the varying land quality, the marginal profit loss from reducing water is likely to be well below this 0.75 €/m^3 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.[21] The shortfalls in demand have forced project managers to charge prices to agricultural users which were well below the estimated ability to pay both in the Central Valley Project in California and, most recently, in the Central Arizona Project.[22] Because farmers' real 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 US over the past century, the federal government spent 21.8 billion dollars on 133 water projects in the

[21] R. Wahl, Markets for Federal Water: Subsidies, Property Rights and the Bureau of Reclamation (1989); P. Wilson, *Economic Discovery in Federally Supported Irrigation Districts: A Tribute to William E. Martin and Friends*, 22 Journal of Agricultural and Resource Economics (1997).

[22] M. Hanemann, The Central Arizona Project, Working Paper No. 937 (2002), available at http://are.berkeley.edu/%7Ehanemann/cap.pdf.

Western states, of which 7.1 billion dollars was allocated to be paid by irrigation users; at present, less than 1 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 the European Union agricultural and trade policies, changes in the continued availability of inexpensive foreign labor, and changes in energy prices. There is no allowance either for the potential future effects of climate change. The second omission 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. The 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.[23]

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

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[23] In the Mono Lake Decision, 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 habitat for wildlife. Non-use values associated with habitat protection being the main components of environmental benefits. See T. Wegge, M. Hanemann & J. Loomis, *Comparing Benefits and Costs of Water Resource Allocation Policies for California's Mono Basin* in Advances in the Economics of Environmental Resources Volume 1: Marginal Cost Rate Design and Wholesale Water Markets (D. Hall ed., 1996).

findings show that compromise solutions, incorporating both water supply and demand management measures should be considered. These 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 given in the final section.

Table 1 about here

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, and details of the model building, parameter estimation, and simulation results are presented in Albiac et al.[24] The model covers the Southeastern counties of the Iberian peninsula that receive water from the Ebro transfer (Figure 3). There are 22 counties in the Comunidad Valenciana, 6 counties in the Comunidad de Murcia, and 7 counties in Almería.

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[24] J. Albiac, M. Hanemann, J. Calatrava, J. Tapia, A. Meyer & J. Uche, Evaluating Alternatives to the Spanish National Hydrological Plan, CITA-DGA Working Paper No. 04/4 (2004); J. Albiac, E. Calvo & J. Tapia, *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 (2002); J. Albiac, J. Uche, A.Valero, L. Serra, A. Meyer & J. Tapia, *The Economic Unsustainability of the Spanish National Hydrological Plan*, 19 International Journal of Water Resources Development (2003). The databases of the study are available at www.unizar.es/econatura/phn.htm.

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.

Figure 3 about here

Crop cost data come from the Government of Murcia,[25] the Ministry of Agriculture,[26] 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.[27]

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

[25] AMOPA-Gobierno de Murcia, Estudio General de la Estructura y Balance Agronómico y Económico de las Explotaciones Agrícolas de la Región de Murcia (2000).

[26] 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).

[27] 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, following the procedure of A. Martínez-Cob, J. Faci & A. Bercero, Evapotranspiración y necesidades de riego de los principales cultivos en las comarcas de Aragón (1998). This procedure is based in the FAO recommendations by R. Allen, L. Pereira, D. Raes & M. Smith, *Crop evapotranspiration. Guidelines for computing crop water requirements*, 56 Irrigation and Drainage Paper (1998).

the cereal acreage, but the fruit-tree acreage is held constant for each species.[28] 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.

Table 2 about here

The costs of the Ebro project at each delivery location have been calculated by Uche.[29] 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,[30] 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 €/m^3) 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

[28] The aggregation problem has been solved using the procedure suggested in B. McCarl, *Cropping Activities in Agricultural Sector Models: A Methodological Proposal*, 64 American Journal of Agricultural Economics (1982); H. Önal & B. McCarl, *Aggregation of Heterogeneous Firms in Mathematical Programming Models*, 16 European Journal of Agricultural Economics (1989); and H. Önal & B. McCarl, *Exact Aggregation in Mathematical Programming Sector Models*, 39 Canadian Journal of Agricultural Economics (1991).

[29] J. Uche, *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 03/3, 2003).

[30] Ministerio de Medio Ambiente, *supra* note 8.

laws, and explains water rights and the informal water trading taking place at present in the Southeastern basins.

The basic law regulating water management in Spain is the 1985 Water Act[31] that was partly amended in 1999.[32] Both acts were put together in 2001,[33] and this legislation has been adapted to the European Union's Water Framework Directive.[34] 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 groundwater, is of the public domain with some exceptions for groundwater. 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 (Confederación Hidrográfica) is the main administrative body, largely responsible for water management at 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 for all water uses. They are in charge of projects, construction works and 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

[31] Water Act 29 (1985).

[32] Water Reform Act 46 (1999).

[33] Consolidated Water Act 1 (2001).

[34] Water Act 62 (2003).

sector, and to further regional development. This is achieved by increasing resource availability, 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. The 1985 Water Act establishes (article 73) 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 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 responsible for resource allocation through public concessions, while water users' associations are responsible for the management of secondary infrastructures and allocation of water among members.

Regarding the water pricing policy, the water legislation (articles 112 to 114 of the 1985 Water Act) establishes four levies that are collected by the basin authority.[35] The first is a levy on users occupying or making use of the public hydraulic domain, charging 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

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[35] A. Garrido & J. Calatrava, *Recent and future trends in water charging and water markets*, in Water Policy in Spain (R. Llamas & A. Garrido eds., 2005).

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. The second makes 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 restrictions, such as holding previously 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 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 groundwater 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 currently close to 1.0 million ha.[36] 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 groundwater were given the choice of either keeping their rights or exchanging them for temporal water concessions. Obviously the vast majority, that is over 80 percent of right holders, have maintained their private rights.[37]

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 groundwater is managed by local companies rather than individuals. In the Júcar and Segura basins, groundwater accounts for almost half of the irrigation water, most of it supplied by privately-owned water rights.[38] The 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 groundwater. In the Sur basin, private water rights are widespread in the province of Almería, because groundwater

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[36] 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).

[37] R. Llamas, J. Fornés, N. Hernández-Mora & L. Martínez, Aguas subterráneas: retos y oportunidades (2001).

[38] J. Carles, M. García & L. Avellá, *Aspectos económicos y sociales de la utilización de las aguas subterráneas en la Comunidad Valenciana*, in La economía del agua subterránea y su gestión colectiva (N. Hernández-Mora & R. Llamas eds., 2001).

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 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.[39]

Public water concessions to irrigation user associations are linked to the land as a rule. Private water rights, in contrast, 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 groundwater.

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 0.10-0.40 €/m^3 with an average around 0.15 €/m^3, although prices increase during periods of water scarcity. Groundwater 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 transaction, 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

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[39] J. Sumpsi, A. Garrido, M. Blanco, C. Ortega & E. Iglesias, Economía y política de gestión del agua en la agricultura (1998).

the water. To obtain additional water, farmers buy agricultural land sometimes as far as 100 kilometers upstream, and use the water in downstream farms, where water is scarcer and more valuable.[40] 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.[41] The reason is that farmers prefer the status quo, relying as indicated above on public management of water at 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 don't really need the water.

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[40] 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 the Campo de Cartagena county.

[41] 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.

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 in order to reach a price level that balances water demand with available water resources in Southeastern basins.[42] This scenario follows the full recovery cost principle of the Water Framework Directive. The third alternative is to expand water supply with transferred water from the Ebro project, linked to water subsidies to maintain the low water prices that farmers currently pay. The fourth 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 very high shadow prices of water.

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.[43] Whereas in the Júcar and Segura basins, the reduction in 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

[42] Baseline 2001 water prices for each county have been estimated from several sources. A major reliable source is J. Carles, L. Avellá & M. García, Precios, Costes y Uso del Agua en el Regadío Mediterráneo (1998), although it has not been followed in all instances.

[43] 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.

profit crops to be abandoned (Table 1). Losses are quite substantial in the Sur 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 10 percent. More than 60 percent of loss in quasi-rent, that is 261 million € of 408 in losses, occurs 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, in 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.

Increasing water prices. The increase in water prices for irrigation is a demand management instrument advocated by the new EU Water Framework Directive. Current agricultural water prices range between 0.06 and 0.18 €/m^3 in Southeastern counties (Table 3). Since these water prices are below their shadow prices or marginal value of water, there is a situation of 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 €/m^3.

Table 3 about here

A increase of 0.12 €/m^3 in water prices, reduces agricultural water demand by 509 hm^3, with a 3 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 a 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 voluntary accept this increase in water prices (Tables 4 and 5).

An increase of 0.18 €/m^3 in water prices reduces water demand by 605 hm^3, with a 4 percent decline in revenue and a 24 percent drop in quasi-rent. The decline in quasi-rent is more pronounced in Júcar and Segura basins, because 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 district level, and the water administration at 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 and effective control on 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,[44] which is less than the costs of transferred water in the counties south of Safor (Table 3). Effective water demand at desalination cost is 387 hm^3 in the coastal counties from Safor to Campo Dalías.[45] 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 408 hm^3 reduction in demand driven by the 0.12 €/m^3 water price increase. This gives a total of 795 hm^3, which is very close to 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 has been 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 0.06-0.21 €/m^3 range that farmers currently pay (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 (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, a volume that falls short of 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.

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[44] J. Uche *Anejo 1. Costes energéticos*, 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 No. 03/3, 2003).

[45] 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.

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 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 destined to 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 Southeast, amounts to 301 million € per year (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 US, the experience with the Central Arizona Project was that the urban users of the 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.[46] 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

[46] Ministerio de Medio Ambiente, *supra* note 8.

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 by us 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 NHP. The NHP estimates the quasi-rent losses from banning aquifer overdraft at 210 million €,[47] 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 (Table 5). Notably, more than 70 percent of losses occur in Almería, and the NHP assignment to Almería for groundwater overdraft, fails to cover the current overdraft.[48] 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

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

[48] 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.

pay the high price of diverted water,[49] 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 (-24,000) while, under the project, it would grow to 102,000 jobs (+26,000). It is difficult to see where this employment growth comes from since, according to the NHP, the fall in quasi-rent will be 210 million € when the aquifer overdraft is eliminated, which could in turn provoke a fall in 24,000 jobs, while the growth in quasi-rent from irrigation guarantee is 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 shaky and 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), when the correct measure would 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 mix, and because some rough measure of land quality and other spatial factors are included through crop yields and water input variability.

[49] 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 2). 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 (see figure 4).

Figure 4 about here

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, that is one that combines both demand and supply measures. This alternative combines banning groundwater overdraft, water trades among counties, and supply of 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 Turia, Júcar, Vinalopó, Segura, Guadalentín, Almanzora, Andarax, and the Segura tributaries Argos and Quipar. The main canals are the Júcar-Turia and Acequia Real canals that 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 (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,[50] so that the solution to water trade and desalination flows is found by maximizing welfare (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 (Tables 4 and 5). The reassignment of water among counties increases welfare by 88 million €, and the additional

[50] This is the area between water excess supply and excess demand functions in each county.

desalinated seawater supplied to Campo Dalías (49 hm^3) and Campo Níjar (11 hm^3) increases welfare by 237 million €, making a total welfare gain of 325 million €. This is simply the difference in quasi-rent when shifting from the overdraft ban (-408 mill. €) to the combined alternative (-83 mill. €).[51]

Figure 5 about here

RANKING OF WATER MANAGEMENT ALTERNATIVES

The results from each water management alternative 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 about here

Farmers' quasi-rent losses are obtained 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 €/m^3, and to 1,300 million € by increasing water prices by 0.18 €/m^3. 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

[51] These results can be implemented, because recently the Carboneras desalination plant has been completed 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, and 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 indicates that eventually the water price may increase reducing the subsidy, in case of a strong irrigation demand.

maintains current farmers' quasi-rent, but requires 300 million € in subsidies to maintain the low water prices currently paid by farmers.

Table 5 about here

A sharp reduction in water demand is achieved by raising irrigation water prices by between 0.12-0.18 €/m^3. The current 2,550 hm^3 of demand for irrigation water falls by 500-600 hm^3, but the costs to farmers in quasi-rent losses are also quite high in the range 300-400 million €. A ban on groundwater overdraft is the worst solution because the fall in water demand is only 400 hm^3, 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 hm^3 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. Hernández-Mora et al.[52] indicate that the key reasons for groundwater mismanagement are that rules are not enforced by basin authorities because of lack of resources and will,[53] and that public and private registers of subsurface water

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52 N. Hernández-Mora, L. Martínez & J. Fornés, *Intensive groundwater use in Spain*, in Intensive Use of Groundwater: Challenges and Opportunities (R. Llamas & E. Custodio eds., 2003).

53 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.

rights are largely incomplete. Llamas and Martínez[54] 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. An additional reasons is that basin authorities may modify the water prices charged to collective irrigation systems using surface water, but 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. The example is the shadow price of water in Campo Dalías, where prices would need to escalate from 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 there are informal water transactions, 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 effective irrigation demand if water is not subsidized and farmers have to face the 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 effective demand amounting to 111 hm^3. Other

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[54] R. Llamas & P. Martínez, *Intensive Groundwater Use: Silent Revolution and Potential Source of Social Conflicts*, 131 ASCE Journal of Water Resources Planning and Management (2005).

clear 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 0.09-0.18 €/m^3. Since pumping costs are considerably below 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 sums up 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 public funds are invested in desalination plants, but then 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 very populated.[55] At the same time it lost support in Aragón and the Ebro delta regions located

[55] Some authors claim that the real aim of the Ebro transfer was to guarantee further urban development of the Spanish Mediterranean coast, 35 per cent of which was already urbanized in the year 2000, as indicated by the European Environmental 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 in 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.

in the donating basin, where both population and votes are sparser. 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 only because the AGUA project will alleviate the water scarcity problem, but also because as a result of the European Union enlargement, Spain will no longer be eligible for EU funding after 2008.

CONCLUSIONS

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 this 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 created strong opposition to the transfer from water resource experts, environmental and social organizations.

The study focuses on the shortcomings of the Ebro project, and the evaluation of several alternative water policies to solve 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 1 to 3.5 million hectares. The Ebro project was grounded on a purely 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 product 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 misses the demand response to water prices, by ignoring that farmers may change crop mixes and 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 are examined, the analysis 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; and the supply measures are the Ebro transfer project and seawater desalination. The introduction of water markets is also 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 Jucar and Segura basins, where water shadow prices are low, is to ban aquifer overdraft rather than increasing 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.

However, implementation of demand management measures in agriculture is not easy; because a ban on aquifer overdraft would be difficult after long-standing water resource mismanagement in the area, and water pricing or water markets will be met by farmers' opposition. 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 are achieved through compromise solutions, in which 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. The Ebro project in comparison 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 seems a good alternative, since greenhouse production is a very dynamic sector potentially able to 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 are not curbed.

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 now 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 also non-point sources, including pesticide and nutrients from agricultural and urban runoff. Any chosen alternative will not work without the enforcement by the water authority of effective rules protecting water resources.

The effort to meet this challenge will surely involve re-allocating 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 types of measures such as the control of non-point pollution, the recovery or artificial construction of wetlands for nutrient removal, habitat restoration, etc. The experience in the US 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 point 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.

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 (hm^3)	1,450	242	1,081	121	6
Revenue (million €)	1,196	39	957	167	33
Segura					
Acreage (1,000 ha)	154.9	8.1	107.7	34.2	4.9
Irrigation water (hm^3)	863	62	654	125	22
Revenue (million €)	1,070	6	485	336	243
Sur					
Acreage (1,000 ha)	54.5	1.1	18.7	6.5	28.1
Irrigation water (hm^3)	232	10	96	24	102
Revenue (million €)	1,124	1	67	87	969

Table 2. Energy consumption of the Ebro transfer at each destination.

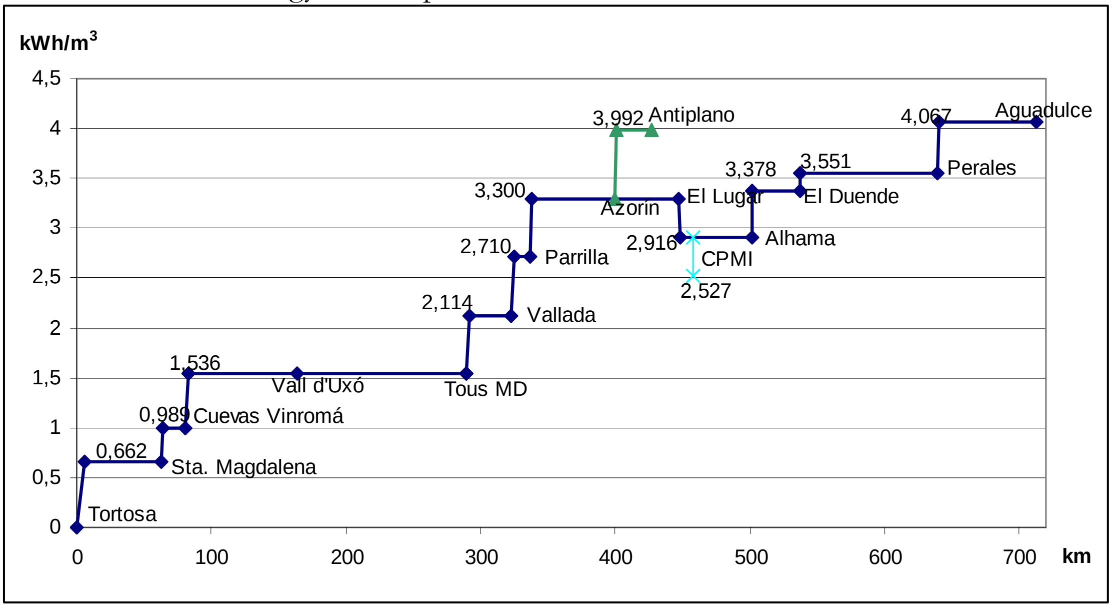


Table 3. Water demand and prices in Southeastern basins, by county.

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

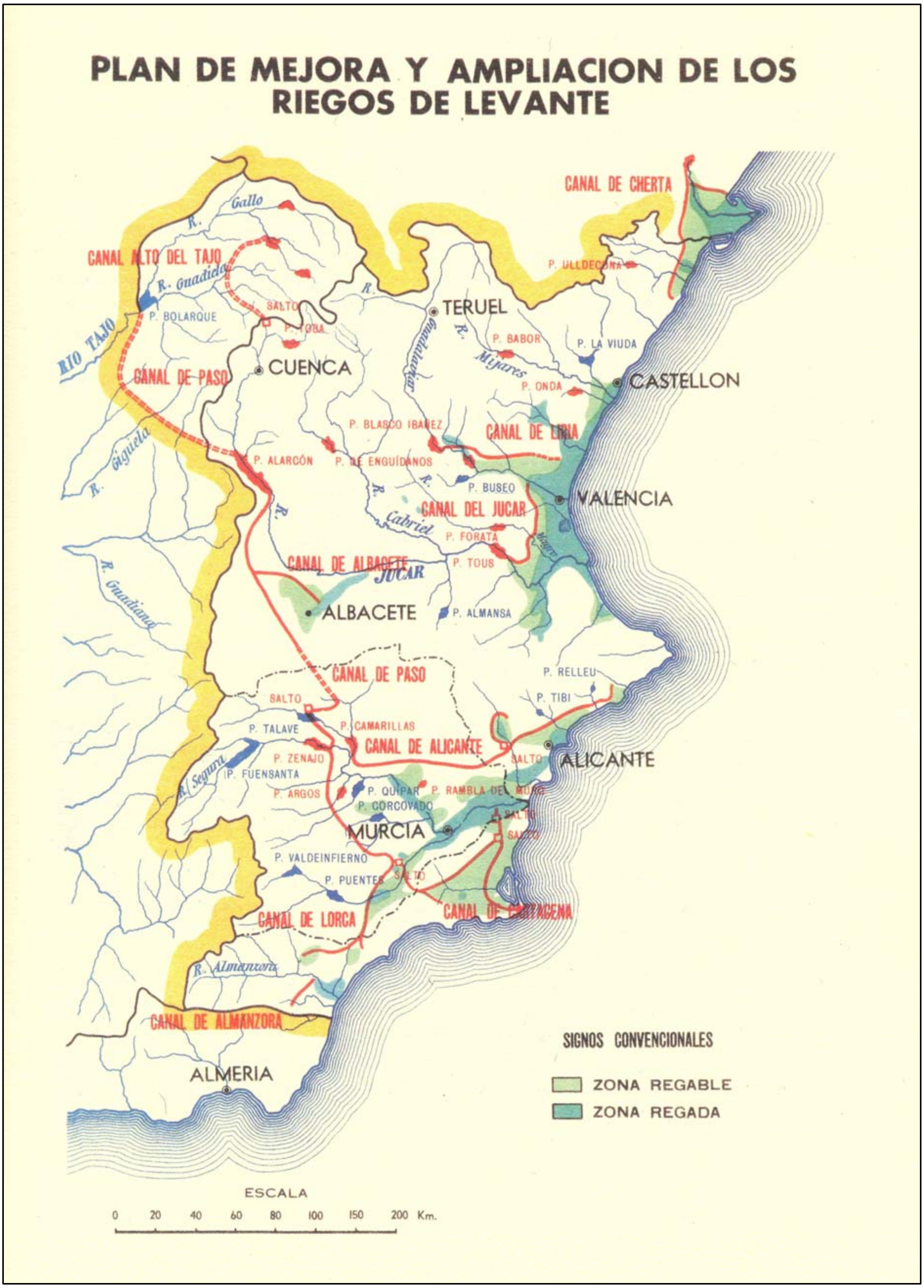
Table 4. Water demand scenarios in Southeastern basins and Ebro project allocation (hm^3).

	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 alternative (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

Table 5. Quasi-rent losses under alternative scenarios and subsidies (million € per year).

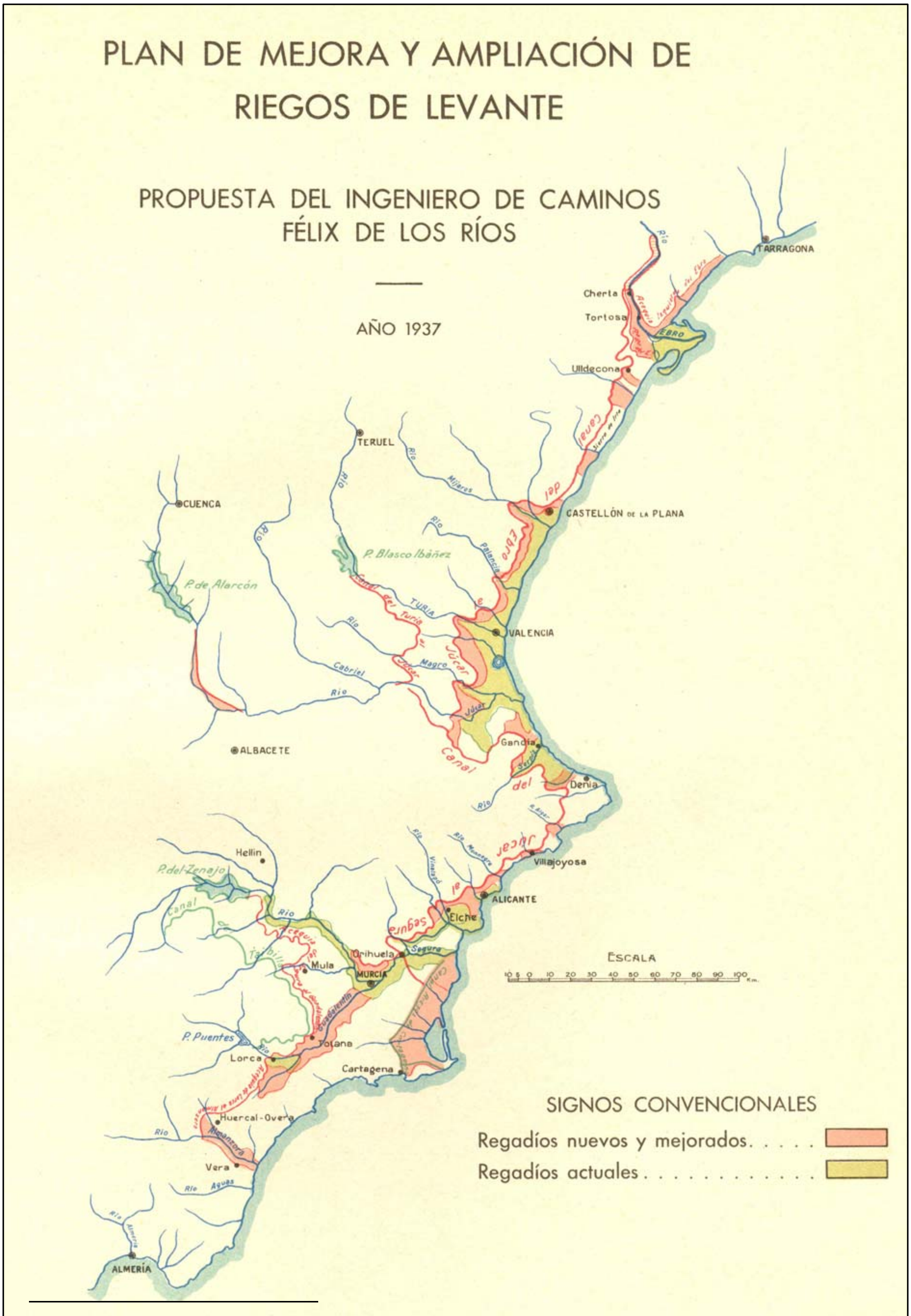
	Júcar basin	*Segura basin*	*Sur basin*	*Total Southeast*
Current Quasi-rent	586	536	589	1,711
Quasi-rent Losses to Farmers...				
... through a groundwater overdraft ban	46	101	261	408
... through a 0.12 €/m^3 water price increase	166	94	27	287
... through a 0.18 €/m^3 water price increase	232	136	37	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 €/m^3) and present low water prices	54	187	60	301

Figure 1. The Tajo-Segura water transfer project in the Plan of 1933.[56]



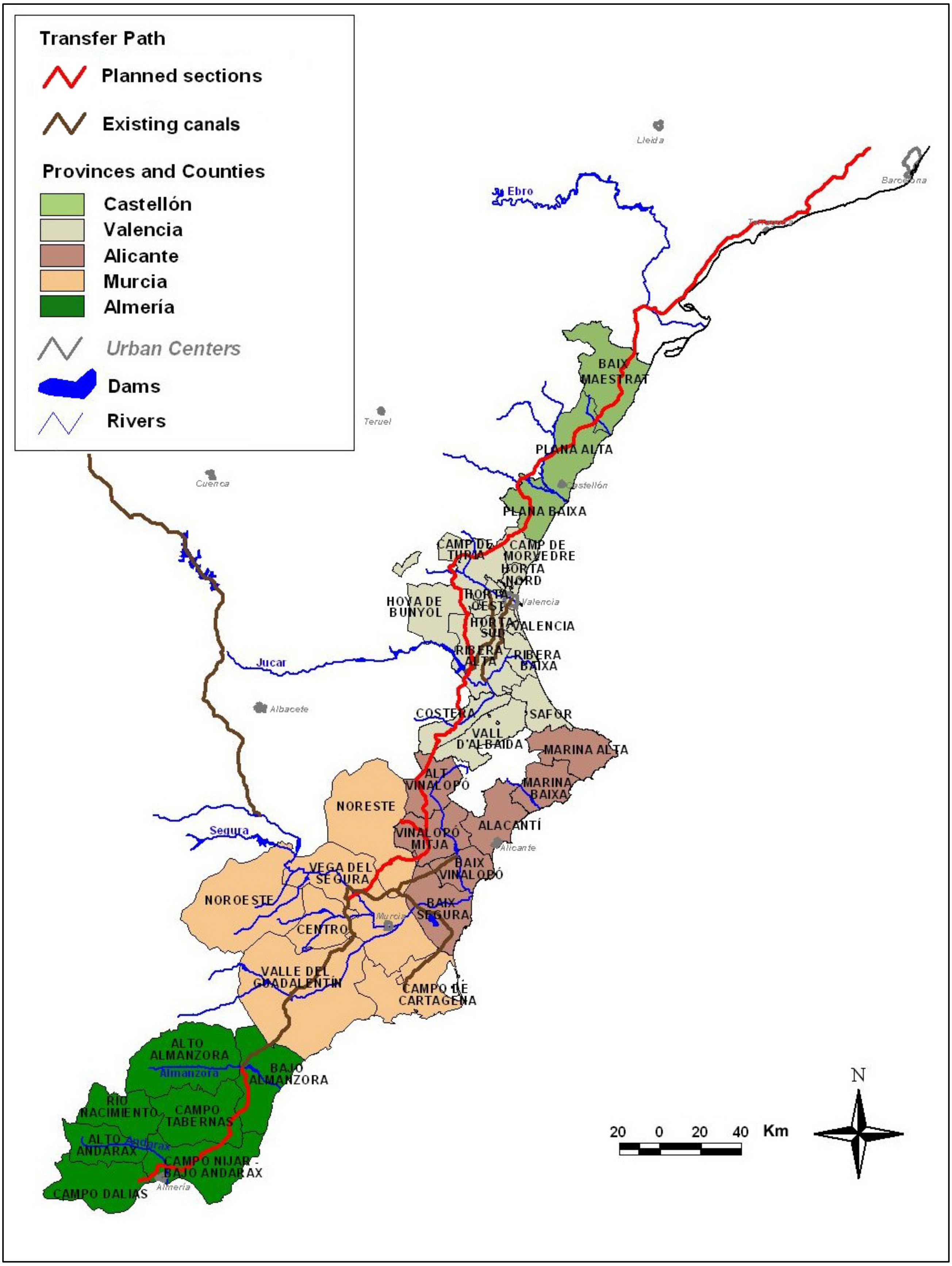
[56] M. Lorenzo-Pardo, *supra* note 5.

Figure 2. The Ebro-Segura water transfer alternative by Félix de los Ríos to the 1933 Plan.[57]



[57] Ministerio de Obras Públicas, Plan General de Obras Públicas. Tomo II Obras Hidraúlicas (1940).

Figure 3. Map of the water transfer path and counties in the receiving basins.[58]



[58] Trasagua, *supra* note 19, for the latest water transfer path.

Figure 4. Main canals and rivers, and water shadow prices under aquifer overdraft ban.

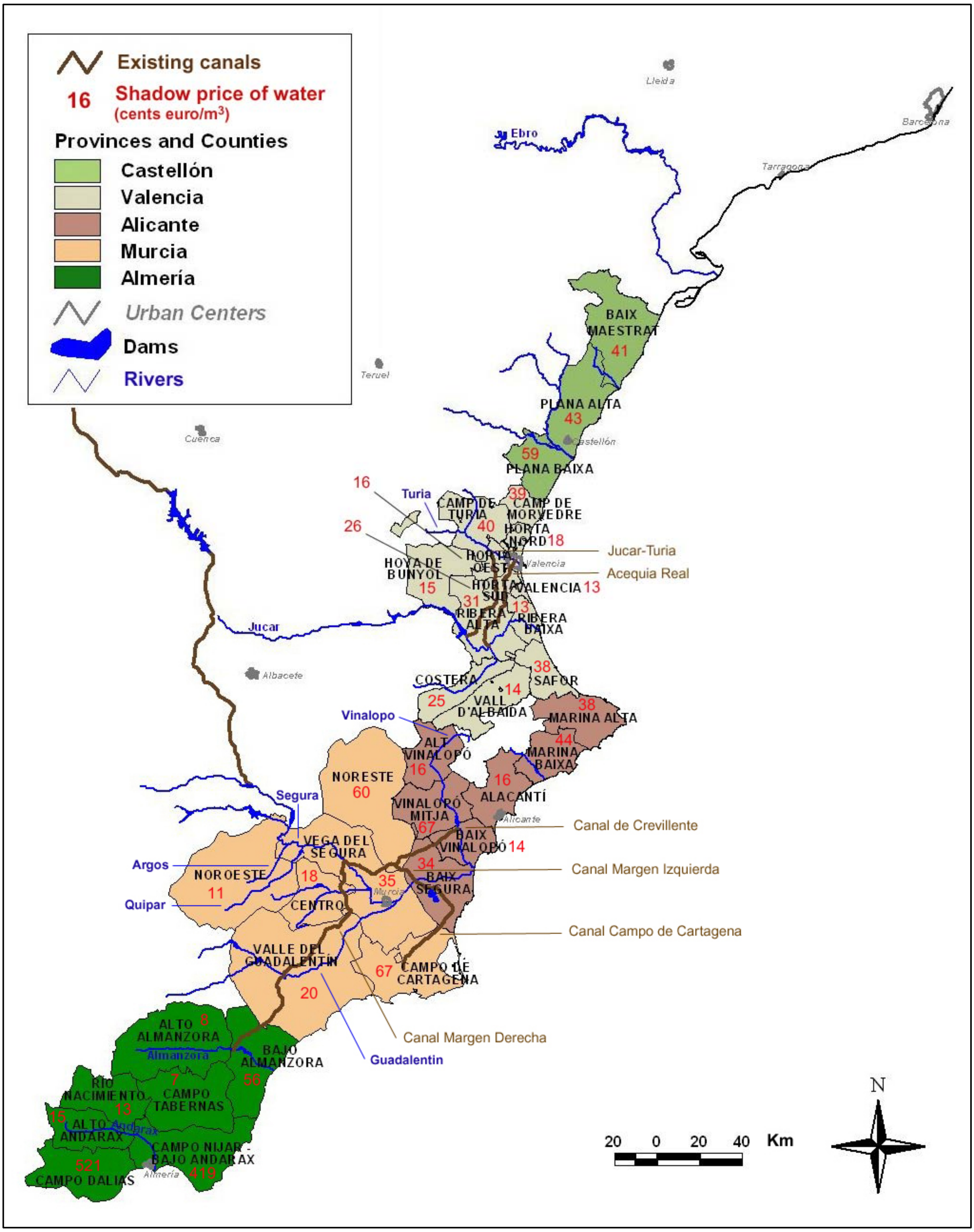


Figure 5. Water exports and imports by county under the combined alternative.