

The development of irrigated agriculture in twentieth-century Spain: a case study of the Ebro basin*

by Vicente Pinilla

Abstract

This paper describes the transformation wrought by irrigated agriculture in the Ebro Basin (Spain's largest river system) during the twentieth century. Irrigation in this area is both relatively large in scale and has been the precursor of changes occurring later in the rest of Spain. We first consider the significant impact of hydrological policy on the expansion of irrigation. We continue by examining the process of intensification which took place throughout the twentieth century and the gradual shift towards specialization, closing this part of the paper with a discussion of the importance of technological change for output growth. Finally, we take account of some impacts of the expansion of irrigated agriculture on the natural environment and the conflict that has emerged in the last few decades over the building of new dams.

At the beginning of the twenty-first century farming represents a bare 2.4 per cent of Spain's gross domestic product and employs just 5.9 per cent of the labour force. Despite the considerable lag that it had to overcome when compared with the most advanced nations, Spain can be viewed as having achieved the status of a developed country since the beginning of the 1970s, with high per capita income and an economy in which industry and services have emerged as leading sectors.

In this context, it may seem surprising that the water question (management, use and infrastructure) should have been such a hot political issue over the last two decades. Whilst the recent conservative government had approved a National Hydrological Plan and secured its ratification by the Spanish parliament, one of the campaign promises of the current socialist

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prime minister was to suspend and then repeal this plan. This undertaking was quickly implemented by the incoming government. The socialist government of the early 1990s had proposed its own National Hydrological Plan, although it was never brought before parliament. The construction of costly infrastructure to transfer water from the Ebro River, Spain's largest river system, to the Mediterranean coast was the most hotly debated issue in both plans. Debate was strongly influenced by clashes between the territorial interests of the Autonomous Communities (political regions) that opposed the Ebro transfer (Aragon and Catalonia) and those that were in favour (Valencia, Murcia and Andalusia).

From an academic point of view, the most interesting aspect is the growing questioning of the 'classical' policies which aimed at increasing the supply of cheap water, and the emergence of a 'new water culture', which places stress on demand management, water saving measures, and advocates higher prices as an incentive for efficiency. When viewed from this perspective, it is assumed that policies aimed at increasing supply made sense throughout most of the twentieth century, to the extent that they solved either simultaneously or in parallel three key problems faced by underdeveloped, predominantly agricultural countries, with un-regulated rivers and limited deposits of fossil fuel, namely the provision of drinking water, the development of irrigation and the expansion of hydro-electric production. The change in the socio-economic context and the significant increase in the supply of water that had been made possible by the very high levels of hydrological regulation have resulted in a new paradigm being proposed, whose key elements are concern for sustainable development, the integrated management of water and territory and the management of water demand.¹

If water occupies such an important place in the current political and academic scene in Spain, this may be understood in terms of the importance of irrigation in the history of Spanish agriculture. Descriptions may be found elsewhere of Spain's hydrological management in Roman times, under Arab rule or even during the Enlightenment.² At the end of the nineteenth century, the 'Regenerationist' movement led by the prominent Aragonese thinker Joaquín Costa argued that the expansion of irrigation was the key to the modernization of Spanish agriculture and the attainment of productivity akin to British levels.³

The Ebro River Basin has played a key role in Spanish water policy and the development of the modern irrigation system since the end of the nineteenth century. This was not only

¹ P. Arrojo, 'Spanish national hydrological plan: reasons for its failure and arguments for the future', *Water International* 28 (2003), pp. 295–302; F. Aguilera, 'Hacia una nueva economía del agua: cuestiones fundamentales', in P. Arrojo and F. J. Martínez-Gil, *El agua a debate desde la Universidad. Hacia una nueva cultura del agua* (1999), pp. 49–66. A recent and very complete description of long term water management models in modern Spain is given in M. T. Pérez-Picazo and G. Lemeunier, 'Formation et mise en crise du modèle de gestion hydraulique espagnol de 1780 à 2000', *Économies et Sociétés* 37 (2000), pp. 71–98.

² See, for example, A. Gil-Olcina and A. Morales-Gil (eds), *Hitos históricos de los regadíos españoles* (1992), and

M. T. Pérez Picazo and G. Lemeunier, *Agua y modo de producción* (1990).

³ A pioneering analysis of Costa's work is to be found in G. J. G. Cheyne, *A bibliographical study of the writings of Joaquín Costa (1846–1911)* (1972). The most complete study of his agricultural thinking is C. Gómez Benito and A. Ortí, *Estudio crítico, reconstrucción y sistematización del Corpus agrario de Joaquín Costa* (1999). A recent view of hydrographic Regenerationism is provided in E. Swyngedouw, 'Modernity and Hybridity: Nature, Regeneracionismo, and the Production of the Spanish Waterscape, 1890–1930', *Annals of the Association of American Geographers*, 89 (1999), pp. 443–65.

because the area was Costa's native soil and the center of the Regenerationist movement. Both state intervention in the construction of new water infrastructure and the creation of a centralized system of governance and administration of the Spanish river systems began there. The change from purely public works to a mixed system involving private participation also began there at the end of the twentieth century. It is no wonder, then, that the Ebro Valley should be the key to understanding the development of irrigated agriculture in Spain over the last century. Today, as we find ourselves facing the rejection of policies based on the construction of ever more costly infrastructure to increase the supply of water, the lands of the Ebro have again taken a leading role in the move toward a new hydrological policy which stresses efficiency and water saving.⁴

Throughout the twentieth century, irrigation has played a key role in the process of agricultural transformation in Spain because it allowed new uses for the land and both facilitates and acted as an incentive to the adoption of technologies, providing a stepping stone from traditional to modern agricultural practice. As Hayami and Ruttan have pointed out, the development of water resources forms part of the bloc of biological and chemical innovations that have raised farm output and productivity, as well as allowing savings in the land factor.⁵ The expansion of irrigation has a close association with the growth of agro-industry, which has had a significant impact on economic development. Finally, the growth of irrigated agriculture has not been without effect on the rural environment, demography and economy.

I

The Ebro cuts right across the north-east of the Iberian Peninsula (Figure 1). With an area of 85,534 km², it is Spain's largest river basin, occupying 17 per cent of its territory. Although the River Ebro runs through nine Autonomous Communities (out of a total of seventeen), the most significant in terms of area are Navarre (10.8 per cent), La Rioja (5.9 per cent) and the Basque Country (3.1 per cent) on the Upper Ebro, Aragon (49.2 per cent) on the Middle Ebro, and Catalonia (18.3 per cent) on the Lower Ebro.⁶ At the end of the twentieth century, the area of irrigated farming land in the Ebro Basin totalled 729,000 hectares, representing over one fifth of the total irrigated land in the whole of Spain. Almost a quarter of all the cultivated land in the Ebro Basin is irrigated, which is higher than the figure for Spain as a whole in percentage terms.

Environmental conditions in large parts of Spain have historically set the bounds for farmers. Scarce and irregular rainfall, with seasonal drought, are the factors usually cited to explain the historical development of the country's agriculture.⁷ For example, it has been held that

⁴ P. Arrojo and E. Bernal, 'El regadío en el Valle del Ebro', in J. López and J. M. Naredo (eds.), *La gestión del agua de riego* (1997), pp. 139–82; Arrojo, 'Spanish national hydrological plan'.

⁵ Y. Hayami and V. Ruttan, *Agricultural development: an international perspective* (1971), p. 164.

⁶ Data from P. Ibarra, F. Pérez, I. Rabanaque and

V. Rodrigo, "El medio natural en la Cuenca del Ebro", in Pinilla (ed.), *Gestión*.

⁷ M. González de Molina, 'Condicionamientos ambientales del crecimiento agrario español', in J. Pujol, M. González de Molina, L. Fernández, D. Gallego and R. Garrabou, *El pozo de todos los males. Sobre el atraso en la agricultura española contemporánea* (2001), pp. 43–94.

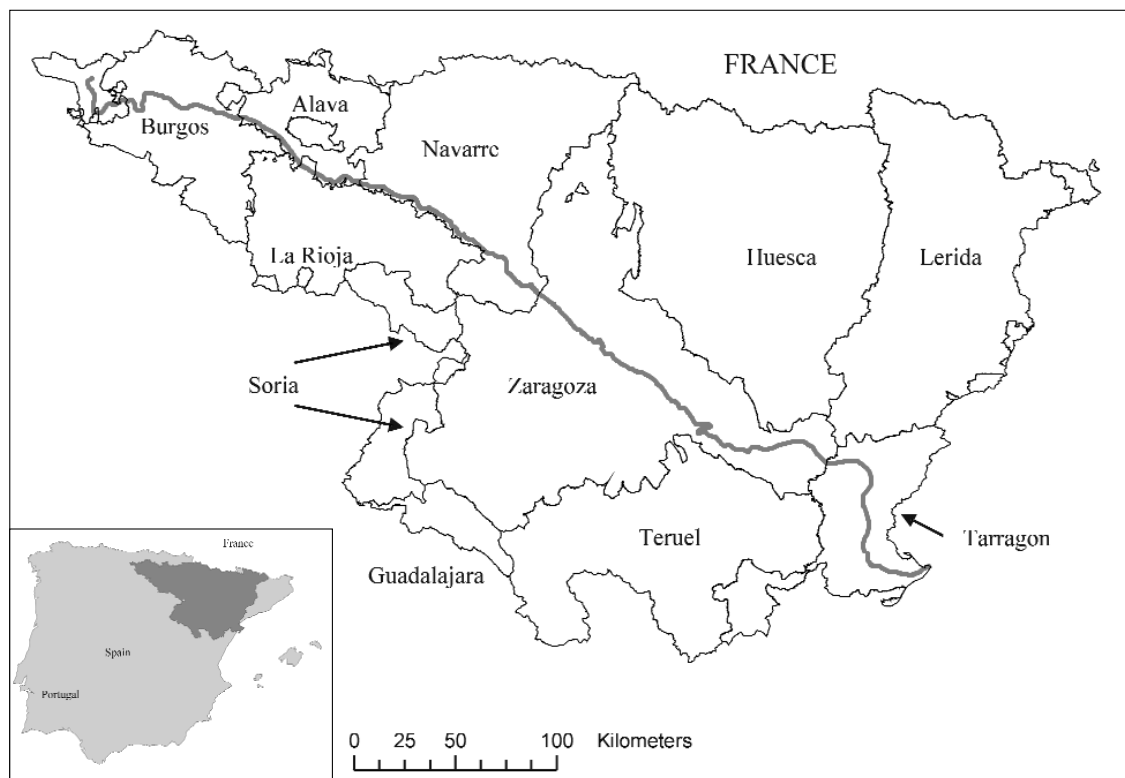


FIGURE 1. The Ebro Basin (provinces). The inset shows the location of the Ebro Basin.

disadvantageous climatic conditions were the main reason why Spain was unable to adopt the technical changes that defined the agrarian revolution in England.⁸

Natural limitations on agriculture are no less severe in the Ebro Basin than in other areas, and in many cases they are actually more severe. Annual precipitation varies significantly. Whilst maximum levels of rainfall are recorded in the highest mountain ranges such as the Pyrenees or the Cantabrian-Basque chain, with an annual average than more than 1500 mm, these levels fall steadily until they reach their minimum in the central areas of the Ebro depression, many of which receive an annual average of just 400 mm. As a result, these latter areas, which offer the best topographical conditions for the development of agricultural activities, are some of the driest areas of Spain, together with the Mediterranean coastal areas of Valencia, Alicante, Murcia and Almeria. However, and as is usual with climates of the Mediterranean type, the problem is not only the scarcity of rainfall, but also its quite dramatic inter-annual irregularity, which implies frequent extremely dry, or indeed drought, years. An added problem is that this rainfall is distributed very irregularly over the year, with maximum levels in

⁸ R. Garrabou, 'Revolución o revoluciones agrarias en el siglo XIX: su difusión en el mundo mediterráneo', in *Agriculturas mediterráneas y mundo campesino* (1994), pp. 93–110; G. Tortella, 'Patterns of economic retardation and recovery in south-western Europe in the nineteenth and twentieth centuries', *ECHR* 47 (1994), pp. 1–21.

the spring and autumn and minimum levels in the summer, a season in which the water requirements for some crops are higher than can be met from the available precipitation.⁹

The need to overcome, or at least ameliorate these conditions, has resulted in a very long tradition of harnessing the river system to irrigate arid land.¹⁰ Numerous small-scale hydraulic infrastructures, especially irrigation canals, dikes and water wheels, have been built along the Ebro river and its tributaries, transforming the flatter fields with the highest agricultural potential. In a few isolated cases, such as the Canal Imperial de Aragón (1776–90), a quantum leap was made possible by large-scale works providing the capacity to irrigate considerable areas. The main aim of these efforts to expand the irrigated area was to ensure a harvest rather than raise productivity or change the use of the land.¹¹

The profound changes occurring in the Spanish economy in the first half of the nineteenth century pointed the economy in the direction of capitalist development. In the farm sector, this was a time of transformation driven by what has come to be called the liberal agrarian reform, in the sense that it was introduced by a regime that was ideologically liberal and followed economically liberal policies, including the sale of church and publicly owned lands and the abolition of the feudal regime.¹² The shift from unirrigated to irrigated farming provided a perfect fit with the liberal programme, which sought to expand farm output by raising the productivity of the land. Under the classic liberal programme, which tended to limit state intervention in the economy, it was to be private investors who would undertake the works necessary for irrigation.¹³

As a result, scant progress was made with irrigation throughout most of the nineteenth century. This snail's pace development was a consequence of the progressively larger scale and increasing cost of the necessary infrastructure, resulting in higher initial funding requirements and longer depreciation periods. In a under-developed country like Spain, where the shortage of capital seriously hampered the development of agriculture, this made it difficult to set in

⁹ Ibarra, Pérez, Rabanaque and Rodrigo, 'El medio natural'.

¹⁰ Various recently published papers have sought to relate the development of irrigation to the limitations imposed by the natural environment in various parts of the Ebro basin. See the following papers in R. Garrabou and J. M. Naredo (eds.), *El agua en los sistemas agrarios. Una perspectiva histórica* (1999); for Navarra, J. M. Lana, 'Desequilibrios hídricos y transformaciones del regadío en la Navarra seca', pp. 365–90; for Aragón, P. Ibarra and V. Pinilla, 'Regadío y transformaciones agrarias en Aragón, 1880–1990', pp. 391–426; and for Catalonia, R. Garrabou, E. Tello, E. Sagner and J. Boixadera, 'El agua como factor limitante en los sistemas agrarios de Cataluña (siglos XIX y XX)', pp. 199–224 and E. Vicedo, J. Boixadera and J. R. Olarieta, 'Sistema hidráulico, organización de los riegos y usos del agua en la huerta de Lleida', pp. 225–54.

¹¹ For a discussion of the Canal Imperial de Aragón and irrigation in general in a pre-industrial

Mediterranean economy, see G. Pérez, *Agua, agricultura y sociedad en el siglo XVIII. El Canal Imperial de Aragón, 1766–1808* (1984).

¹² The classic study of the liberal agrarian reform in Spain is A. García-Sanz, 'Crisis de la agricultura tradicional y revolución liberal (1800–1850)', in A. García-Sanz and R. Garrabou, *Historia agraria de la España contemporánea, I, Cambio social y nuevas formas de propiedad (1800–1850)* (1985), pp. 8–99.

¹³ See J. Maluquer de Motes, 'La despatrimonialización del agua: movilización de un recurso natural', *Revista de Historia Económica*, 1, (1983), pp. 79–96, J. Melgarejo, 'De la política hidráulica a la planificación hidrológica. Un siglo de intervención del Estado', in C. Barciela and I. López, *El agua en la historia de España* (2000), pp. 275–324, and J. J. Mateu, 'Política hidráulica e intervención estatal en España (1880–1936): una visión interdisciplinaria', *Revista Española de Estudios Agrosociales y Pesqueros*, 197 (2002), pp. 35–61.

motion a programme of hydrological infrastructure construction based entirely on private investment.¹⁴ Perhaps the most significant exception to the general approach was the drilling of wells in the Valencia region to extract water for the expansion of orange growing.

The majority of the development projects proposed came to nothing. The exclusion of the state from developments in water infrastructure is perfectly consistent with the standard pattern of liberal agrarian policy, which was concerned with steering institutional change to foster the creation of the conditions appropriate for productive development but with respect for private property and reliance on the operation of the market to assign resources.¹⁵ If the liberal agrarian reform established the basis for the expansion of production in the case of land, private initiative failed to generate similar outcomes in the case of water for the reasons discussed above.

This situation is illustrated by the results achieved in the Ebro Basin in the nineteenth century. The main initiatives arising in this period focused basically on the construction of irrigation canals and crystallized in a number of large-scale works in the Lower Ebro (provinces of Lerida and Tarragon). There was less success, however, in other areas such as the province of Huesca, where numerous projects were also proposed. Scarcely any dams – the most complex and costly infrastructure – were built. In an overall evaluation of the development of irrigation in this context, we find that the main achievements were the irrigation of land in the province of Tarragona using water from the canal built along the right bank of the Ebro Delta, and in Lerida through the main Urgell canal. In the latter case, progress was quite considerable with an increase of 15,000 hectares in the area under irrigation between 1860 and 1880.¹⁶

Considering the agro-climatic conditions described above and the failure to develop irrigation as a means of raising farm productivity, we need hardly wonder at the strength with which the Regenerationist movement led by Joaquín Costa emerged in the Ebro Valley and Aragon in the last quarter of the nineteenth century.¹⁷ Since private initiative had proved unable to do much with the opportunities offered by the privatization of water, the Regenerationists openly demanded state support, while irrigation was viewed as the panacea for the grave problems affecting rural areas and, especially, for the poverty reigning in some parts. Costa's ideas broke with the tradition of economic liberalism and instead granted the state a role in encouraging the economic development of the country. Owing to the end-of-century farm depression, the call for state intervention was received in a much more receptive context and the idea that it was the state's responsibility to increase in the supply of water for irrigation became widely accepted.

¹⁴ For a discussion of the key role of capital shortage in Spanish agricultural development, see V. Pinilla, 'Sobre agricultura y crecimiento económico en España, 1800–1935', *Historia Agraria*, 34 (2004), pp. 137–62.

¹⁵ R. Garrabou, 'Crecimiento agrario, atraso y marco institucional', in Pujol, González de Molina, Fernández, Gallego and Garrabou, *El pozo*, pp. 215–51.

¹⁶ J. M. Ramón, 'L'agricultura de regadiu a la Catalunya comperànica: els canals d'Urgell, 1860–1960' (Unpublished Ph.D. thesis, Universitat Pompeu Fabra, 1994), p. 381.

¹⁷ For the hydrological policy of Joaquín Costa, see

A. Ortí, *En torno a Costa (Populismo agrario y regeneración democrática en la crisis del liberalismo español)*, (1996); E. Fernández-Clemente, *Estudios sobre Joaquín Costa* (1989), pp. 190–215; C. Gómez Benito and A. Ortí, *La fundación de la Cámara Agrícola del Alto Aragón en el proyecto de desarrollo agrario nacional de Joaquín Costa* (1992). Similarities between the hydraulic debates in Spain and the United States at the end of the nineteenth century have been stressed by J. L. Ramos, 'Paralelismos entre los debates hidráulicos de España y Estados Unidos a finales del siglo XIX', *Historia Agraria*, 32 (2004), pp. 85–112.

Following this turnaround in economic policy, and in view of the agricultural potential of some areas after the change to irrigation and related improvements (e.g. levelling and soil improvements), the Ebro Valley swiftly became a test bed for the new water policy. The starting point was the state's decision to complete the works on the Aragón and Catalonia Canal. This represented an acceptance of the failure of privately-sponsored hydrological works and the beginning of state-sponsored development, which has continued almost to the present day. The continuation of this policy was marked in 1915 when the government adopted the Upper Aragon Irrigation Plan, which had originally been designed by private initiative in 1913 and implied a very significant investment. Another key episode in the state's growing intervention in the Ebro Basin was the construction of a canal along the left bank of the Delta in Tarragona. A further turning point moment was the formation of the *Confederación Hidrográfica del Ebro* (1926), which was the first attempt to achieve integrated management of the whole of a River Basin, including not only the design of irrigation plans but also the management of other water uses, such as urban water supply and hydroelectric generation.¹⁸ The experiment was subsequently extended to the whole of Spain. The *Confederación Hidrográfica del Ebro* definitively established the principle of the state direction of irrigation infrastructure.

The new hydrological policy adopted during the first decades of the twentieth century implied that the state would assume responsibility for a significant part of the financing of the large-scale hydrological works (dams and main and secondary canals), whilst the farmers would bear the cost of levelling the agricultural plots, channeling the water within them and establishing the connections between the irrigation ditches and their plots. Given that the water was made available to the farmers at an extremely low cost, the main investment they had to make was in improving the farms themselves, which led to important returns due to the increase in the production that came with the change to irrigation-based farming. In many cases, the slowness of the farmers in changing the range of crops they grew was mainly determined by their inexperience with irrigated crops, together with the limited interest shown by the state in offering the technical training which would accelerate such changes.

The growing importance of the state as the main source of finance for the hydrological works can be appreciated from the decade on decade increase in the percentage of dams constructed with state finance. Thus, whilst this corresponded to less than 25 per cent in the years prior to 1920, it reached levels of more than 80 per cent in each of the subsequent decades of the twentieth century, save for 1950–59. Indeed, in four decades, 1920–29 and 1960–89, precisely the years when the biggest works were being constructed, all the dams built were erected by the state.¹⁹

State intervention initially focused on the construction of irrigation canals, but these, whilst making the extension of irrigated farming possible, could not guarantee a regular supply of water. The main limitation of this type of hydrological work came in the form of insecurity of water supply in dry years or insufficiency of supply in normal years to sustain certain types

¹⁸ For a discussion of the creation of the Confederación Hidrográfica del Ebro and its early activities, see M. L. Frutos, 'Las confederaciones sindicales hidrográficas', in A. Gil and A. Morales (eds), *Planificación hidráulica en España* (1995), pp. 181–256. An analysis of

the activities of this institution throughout the twentieth century is provided in E. Fernández Clemente, 'La Confederación Hidrográfica del Ebro: la institución y su capital humano', in Pinilla (ed.), *Gestión*.

¹⁹ Ibarra and Pinilla, 'Regadío', p. 408.

of crops. Because of this limitation, these canals often did not allow any transformation in land use, but only an increase in farm output. For this reason, regulation works would play a key role from the second decade of the twentieth century onwards, although state involvement was still at this time very limited. The dams built by the hydroelectric utilities, which in some cases allowed mixed use (irrigation and electricity generation), to some extent led the field, linked as they were to the electrification of the Basque Country and Catalonia, the main industrial areas of Spain, by drawing on the water resources of the Pyrenees. In the third decade of the twentieth century, however, the state was already dominant in the construction of dams, and it is in this context that the *Confederación Hidrográfica del Ebro* was formed. The 1920s, and especially the years after 1926, marked a turning point, as the speed at which the state constructed a range of hydrological infrastructures came to determine the possibility of developing irrigated farming in the Ebro Basin.²⁰ In any event, by 1916 Ebro irrigation represented a third of the total for Spain, and its importance had already been consolidated before the Civil War of 1936–39 as the construction of hydrological works gathered pace in the early 1930s, the period in which the area's major irrigation systems were defined.

A comparison of the achievements of water policy in the Ebro Basin compared to Spain as a whole reveals the scale of the regulating works, basically dams, undertaken right up to the Civil War of 1936–39 (Table 1). A disproportionate part of construction nationally was carried out in the Ebro Basin with the result that the volume of water stored in reservoirs for use in irrigation increased from 17.4 per cent of the total for Spain in 1900 to a maximum of 54 per cent in the late 1920s. The completion of major works in other river systems, particularly along the Guadalquivir, reduced this relative share to 30 per cent in the 1930s, but this was still a very high percentage for Spain as a whole. The relative importance of dam construction in the Ebro Basin in comparison with the rest of Spain, together with the building of canals in the nineteenth and the first third of the twentieth century would strengthen the undisputed leading role of the area in the development of water policy over the whole period. Thus, during the First World War, the irrigated land in the Ebro Basin accounted for almost one third of the total for Spain (Table 2).

In the years following the Civil War, water policy formed an important part of the Franco dictatorship's (1939–75) farm policy. This was based on earlier irrigation plans, which required the construction of ever larger dams. The greatest increase in the regulating capacity for irrigation took place between the mid-1950s and the end of the 1960s. A key event here was the state's decision to undertake the work required directly, going a step further with a policy which, as we have seen, had emerged at the beginning of the twentieth century.²¹ Water policy was, however, also based on the implementation of far-reaching plans to transform some areas by means of what was called 'integral colonization', which meant not only irrigating the land but the movement of people into development areas as colonists. The implementation of this policy was managed by the *Instituto Nacional de Colonización*, founded in 1949 and dissolved in

²⁰ An overview of twentieth-century hydrological infrastructure construction in Spain is given in E. Fernández-Clemente, *Un siglo de obras hidráulicas en España. De la utopía de Joaquín Costa a la intervención del Estado* (2000). For the general framework, see

A. Herranz, *La dotación de infraestructuras en España, 1844–1935* (2004).

²¹ C. Barciela, M. I. López and J. Melgarejo, 'La intervención del Estado en la agricultura durante el siglo XX', *Ayer* 21 (1996), pp. 51–96.

TABLE 1. Capacity of dams built to store water for irrigation (classified by river basins)

	North	Douro	Tagus	Gua- diana	Guadalq uivir	South	Segura	Jucar	Ebro	Pyrenees	Spain
(a) in cubic hectometers											
until 1900	0.0	0.0	10.0	12.0	0.0	0.5	28.1	17.4	14.3	0.0	82.2
1901–1910	0.0	0.0	0.0	0.0	0.0	0.2	54.9	0.0	8.1	0.0	63.2
1911–1920	0.0	0.0	3.1	0.7	65.4	0.0	0.0	26.9	237.1	0.0	333.2
1921–1930	0.0	79.9	0.0	0.0	99.1	0.0	6.7	0.0	157.0	4.9	347.5
1931–1940	0.0	108.1	211.5	0.0	425.0	0.0	204.8	0.0	155.0	0.8	1,105.2
1941–1950	2.5	255.0	1.7	0.0	905.0	74.1	0.0	0.6	553.5	0.0	1,792.4
1951–1960	341.5	957.1	1,202.0	1,632.7	534.5	0.0	474.7	1,415.6	747.9	0.0	7,305.9
1961–1970	22.8	809.4	2,593.2	1,647.5	2,182.0	87.0	36.7	132.8	618.6	474.6	8,604.6
1971–1980	0.0	3.9	239.6	100.0	350.4	346.5	251.3	1,041.2	598.4	0.0	2,931.4
1981–1990	0.0	0.8	141.3	3,789.0	1,023.7	569.1	0.0	12.8	179.3	2.4	5,718.4
TOTAL	366.8	2,214.1	4,402.4	7,181.9	5,585.1	1,077.4	1,057.2	2,647.2	3,269.2	482.6	28,283.9
(b) per cent of total for Spain for each period											
until 1900	0.0	0.0	12.1	14.6	0.0	0.6	34.1	21.2	17.4	0.0	100.0
1901–1910	0.0	0.0	0.0	0.0	0.0	0.3	86.9	0.0	12.8	0.0	100.0
1911–1920	0.0	0.0	0.9	0.2	19.6	0.0	0.0	8.1	71.2	0.0	100.0
1921–1930	0.0	23.0	0.0	0.0	28.5	0.0	1.9	0.0	45.2	1.4	100.0
1931–1940	0.0	9.8	19.1	0.0	38.5	0.0	18.5	0.0	14.0	0.1	100.0
1941–1950	0.1	14.2	0.1	0.0	50.5	4.1	0.0	0.0	30.9	0.0	100.0
1951–1960	4.7	13.1	16.5	22.3	7.3	0.0	6.5	19.4	10.2	0.0	100.0
1961–1970	0.3	9.4	30.1	19.1	25.4	1.0	0.4	1.5	7.2	5.5	100.0
1971–1980	0.0	0.1	8.2	3.4	12.0	11.8	8.6	35.5	20.4	0.0	100.0
1981–1990	0.0	0.0	2.5	66.3	17.9	10.0	0.0	0.2	3.1	0.0	100.0
TOTAL	1.3	7.8	15.6	25.4	19.7	3.8	3.7	9.4	11.6	1.7	100.0

Source: author's calculations from data presented in Dirección General de Obras Hidráulicas, *Inventario de presas españolas* (1992).

1971.²² Integral colonization involved the state financing the conversion to irrigation, in such a way that the former owners received a plot of land whose value was equivalent to the dry lands they had held. The surplus land, that not returned to its former owners, was divided into plots that were given to the new colonists, who were normally land-less labourers. They, in turn, paid the state a rent for a certain number of years, normally around twenty, at the end of which they obtained full title to the land. In a number of areas of newly irrigated land lying in the Ebro Valley, new population centers were also established, with the houses that had been constructed also being handed over to the colonists. The new colonizing policy was of enormous importance in the Ebro Valley with no less than 40 new centers being constructed with a population

²² C. Barciela and M. I. López, 'La política de colonización del franquismo: un complemento de la política de riegos', in Barciela and Melgarejo, *El agua*, pp. 323–63; for colonization in the Ebro Basin see A. Sabio, 'La colonización agraria en Aragón, 1940–1985', in Pinilla (ed.), *Gestión and V. Bretón, Tierra, Estado y Capitalismo. La transformación agraria del occidente catalán, 1940–1990* (2000).

TABLE 2. Area under irrigation, 1916

	<i>Hectares</i>	<i>per cent Spain</i>	<i>per cent Ebro Basin</i>
Alava	439	0.0	0.1
Navarre	34,402	2.5	7.8
Rioja	36,275	2.7	8.2
UPPER EBRO	71,116	5.2	16.1
Huesca	63,124	4.6	14.3
Teruel	39,679	2.9	9.0
Zaragoza	115,734	8.5	26.2
MIDDLE EBRO (ARAGON)	218,537	16.0	49.5
Lérida	116,852	8.6	26.5
Tarragona	34,622	2.5	7.8
LOWER EBRO (CATALONIA)	151,474	11.1	34.3
EBRO BASIN	441,127	32.3	100.0
TOTAL SPAIN	1,366,441	100.0	

Source: Junta Consultiva Agronómica, *Medios que se utilizan para suministrar el riego a las tierras. Distribución de los cultivos en la zona regable* (1918).

of 18,180 by 1981. Some 56,790 hectares of irrigated land were handed over to the new colonists, representing 29.5 per cent of the total area assigned to colonists under these schemes in Spain as a whole.²³

The Franco regime's farm policy put an end to the Republican agrarian reforms which involved the redistribution of land and substituted in its place a technical reform with irrigation as one of its pillars. Needless to say, this policy led to a major expansion in the area of irrigated land. The construction of dams to store water for use in irrigation reached its zenith between 1951 and 1970. In the Ebro Basin, the regulating capacity for irrigation in 1980 was five times that of 1940. As a consequence, the area of irrigated farmland grew sharply and by the 1980s it was a third greater than before the Civil War. Despite the significant quantitative increase in the area irrigated, however, the key feature was the improvement in the 'quality' of irrigation. Because there were not enough regulating dams on the headwaters of rivers before the Civil War, irrigation, as we noticed, could be largely intermittent. The expansion of the mid-twentieth century, however, allowed an improvement in the consistency of water supply, making most irrigation permanent, which not only meant an increase in harvests of traditional crops but also allowed farmers to change their crops because of the greater certainty that water would be available during the summer months. This improvement in both the quantity and security of the water supply allowed for important changes to be made in land use, with the introduction of crops with high water requirements.

²³ A. Villanueva and J. Leal, *La planificación del regadío y los pueblos de colonización. Historia y Evolución de la Colonización Agraria en España*, III, (1990). On the integral colonization of the Ebro Valley, see A. Sabio 'La colonización agraria en Aragón' and V. Bretón 'Regadío y colonización agraria en el occidente catalán', both in Pinilla (ed.), *Gestión*. Also see Bretón, *Tierra, Estado y Capitalismo*.

TABLE 3. Evolution of the area under irrigation in the Ebro basin, 1951–95

	1951–55	1956–60	1961–65	1966–70	1971–75	1976–80	1981–85	1986–90	1991–95
(a) Area under irrigation ('000 hectares)									
Alava	2.8	2.8	2.9	2.5	2.3	1.9	1.4	5.8	6.8
Navarre	66.8	66.2	66.6	66.6	66.4	65.6	66.5	67.5	74.5
La Rioja	40.5	39.8	40.5	43.0	46.6	47.4	47.6	47.1	44.4
UPPER EBRO	110.0	108.8	110.0	112.2	115.3	114.9	115.5	120.3	125.7
Huesca	84.7	86.1	104.1	122.9	137.2	152.3	163.6	177.5	180.8
Teruel	32.8	32.3	32.7	34.1	36.5	35.8	36.3	35.6	35.0
Zaragoza	128.4	128.6	138.9	147.8	160.5	161.5	167.5	173.6	182.5
MIDDLE EBRO (Aragon)	245.8	247.0	275.7	304.7	334.2	349.6	367.3	386.7	398.2
Lérida	138.4	139.5	143.9	154.6	150.6	152.6	145.8	139.1	138.2
Tarragona	44.2	43.7	51.5	57.6	53.9	55.6	59.2	65.2	67.2
LOWER EBRO (Catalonia)	182.6	183.2	195.4	212.2	204.5	208.1	205.1	204.4	205.4
Spain	1,656.3	1,770.6	1,957.9	2,175.3	2,532.1	2,739.5	2,939.9	3,132.7	3,188.7
(b) irrigated area as a percentage of total Spanish irrigated area									
Upper Ebro	6.6	6.1	5.6	5.2	4.6	4.2	3.9	3.8	3.9
Middle Ebro (Aragon)	14.8	13.9	14.1	14.0	13.2	12.8	12.5	12.3	12.5
Lower Ebro (Catalonia)	11.0	10.3	10.0	9.8	8.1	7.6	7.0	6.5	6.4
Ebro Basin	32.5	30.4	29.7	28.9	25.8	24.6	23.4	22.7	22.9
Spain	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
(c) irrigated area as percentage of total cultivated land									
Upper Ebro	15.1	16.3	15.7	15.9	16.4	17.4	18.2	19.1	20.5
Middle Ebro (Aragon)	16.7	16.3	16.5	18.0	17.7	18.5	19.3	20.6	22.1
Lower Ebro (Catalonia)	23.3	23.7	25.0	25.9	28.0	28.9	28.2	28.1	29.7
Ebro Basin	18.1	18.3	18.4	19.6	19.7	20.6	21.1	22.0	23.5
Spain	8.2	8.6	9.5	10.8	12.1	13.3	14.3	15.0	16.5

Source: Spanish Ministry of Agriculture, Fisheries and Food, *Anuarios de Estadística Agraria* (1951–90).

Comparison of the rate of construction of regulating infrastructures for irrigation purposes in the Ebro Basin and in the rest of Spain shows a clear pattern of declining importance in relative terms. If, at the end of the 1940s the Ebro dams still represented one third of total Spanish regulation capacity, this figure thereafter fell quickly despite the intensification of construction in the Ebro Valley. By the end of the 1990s, its capacity represented just 12 per cent of the national total. This can easily be explained the enormous works carried out in some of the other river basins such as the Guadiana or Tagus (Table 1).

The construction of regulating works is clearly reflected in the evolution of the area under irrigation. At the beginning of the 1950s, the area irrigated in the Ebro Valley was still almost one third of the total for Spain (Table 3). Nevertheless, the share of Spanish irrigation represented by the Ebro fell in the second half of the twentieth century. Between 1951 and 1995 the share lost was almost ten percentage points, from 32.5 per cent to 22.9 per cent, even though the area occupied by irrigated farming in the Ebro Valley actually increased by 35 per cent. This was



FIGURE 2. Aerial photographs of the irrigation district of Bardenas IV (Zaragoza): Before irrigation, 1957 (left) and after irrigation, 1981 (right)

not, then, due to any decline in irrigation in the Ebro Valley as compared to the rest of Spain. On the contrary, the data show that the percentage of irrigated to total farmland was notably higher in the Ebro Basin throughout the twentieth century. Although the gap has narrowed considerably, there remains a significant difference (Table 3). The explanation for the declining share of Ebro Valley irrigation in the total for Spain is, therefore, connected with the early, indeed pioneering, development of water policy in this region. Logically, the importance of the Ebro declined as the rest of Spain caught up. Even so, over one fifth of Spanish irrigation is still found in the lands along the River Ebro.

The scale of the irrigation works entailed, as may be imagined, large-scale landscape change, with the eradication of old field patterns and their replacement by linear field systems devised around the new irrigation canals. Some indication of the scale of these changes may be gathered from Figure 2, which shows the same area in Zaragoza in its unirrigated state and quarter of a century later, after the implementation of the programme of improvement.

II

The increase in the area under irrigation in Spain throughout the twentieth century was not the only factor behind the increasing importance of irrigation to farming. Its greatest impact has probably been the major change that has taken place in the use of irrigated land. Where irrigation had initially been used with the aim of ensuring more regular harvests of the same crops as were grown on unirrigated land, with productivity gains only as a secondary objective, the emphasis now shifted to the production of crops that could only be grown in a Mediterranean climate when more water was available than fell as rain. This change is associated with possibilities allowed by the number of hours of sunlight enjoyed by the Iberian Peninsula. There was a gradual shift from the crops traditionally grown on both irrigated and unirrigated

land, winter cereals, vines and olives, to those characteristic of irrigated land alone, fruit, vegetables, spring cereals such as maize and rice, forage plants and certain root vegetables and tubers, whose cultivation on unirrigated land is not viable in most of Spain. At a latter stage priority was given to the most intensive of these crops, such as fruit and vegetables.

In the early twentieth century, irrigated crops in the Ebro Basin differed very little from unirrigated crops. These were, however, progressively replaced by other more intensive crops. Initially, the main examples of this change were sugar beet in Zaragoza, vegetables in La Rioja, forage plants in Lerida and fruit (orchards) in Tarragona. The substitution of traditional crops was associated both with the problems caused by the agricultural depression at the end of the nineteenth century, which led to a significant fall in the price of cereals, and to agro-industrial incentives to switch to more intensive crops, not to mention changes in the demand for food products. This transformation in land use was accompanied by the development of industries (sugar refining, fruit and vegetable canning), which added value to basic farm produce and boosted incentives to switch crops, as well as the opportunity to grow intensive crops such as fruit and vegetables to supply city markets or for export.

The switch was well underway by the outbreak of the Civil War. Over half of the sugar produced in Spain came from the Ebro lands, especially the area around Zaragoza, while the main canning industry was located in La Rioja and the Province of Tarragona had become one of the leading Spanish exporters of farm produce.²⁴ Even so, most irrigated land was still given over to traditional crops. But after the Civil War, the Dictatorship instigated a policy of economic autarky, creating difficulties that not only slowed down intensification, but in some cases reversed the process, an outcome that would only be corrected in the 1950s.

In the second half of the twentieth century, the process of crop change leading to greater intensification in land use has gone ahead throughout the Ebro Basin, though at unequal speed and with differing results (Table 4). It is significant that in those provinces where the area under irrigation has grown fastest (such as Huesca and Zaragoza), this expansion has been compatible with the intensification of land use, with the result that typical irrigated crops had increased their share of total irrigated land by over 20 percentage points by the early 1990s. In Huesca it had more than doubled and in Zaragoza it had risen by almost 80 per cent. The expansion of the most intensive crops was even more spectacular, with a two-fold increase in relative share in Huesca and an six-fold increase in Zaragoza.²⁵

The same process of intensification is also evident in those provinces where the expansion of the irrigated area was less significant following the Civil War. In Teruel, the area of irrigated land given over to typical irrigated crops increased to over 50 per cent, while intensive crops tripled their area. Progress was even more spectacular in the Catalan part of the Ebro Basin, where various regulating works ensured higher volumes of water for the Lerida and Tarragona canals. In turn, this allowed the relative share of typical irrigated crops to increase by over

²⁴ D. Gallego, *La producción agraria de Alava, Navarra y La Rioja desde mediados del siglo XIX a 1935* (1986); J. M. Martínez-Carrión, 'Formación y desarrollo de la industria de conservas vegetales en España, 1850-1935', *Revista de Historia Económica*, 7 (1989), pp. 619-49; J. Pujol, *Les transformacions del sector agrari català entre*

la crisi finisecular i la Guerra Civil (unpublished Ph.D. thesis, Universitat Autònoma de Barcelona, 1988); V. Pinilla, *Entre la inercia y el cambio. El sector agrario aragonés, 1850-1935* (1995).

²⁵ Ibarra and Pinilla, 'Regadío'.

TABLE 4. Crop patterns for irrigated land in the Ebro basin provinces (per cent)

	1900	1910	1920	1930	1935	1950	1960	1970	1980	1990
ALAVA										
Irrigated and unirrigated crops	n.a.	n.a.	n.a.	n.a.	n.a.	63.9	68.3	43.1	0.9	0.5
Irrigated crops only	n.a.	n.a.	n.a.	n.a.	n.a.	36.1	31.7	56.9	99.1	99.5
NAVARRRE										
Irrigated and unirrigated crops	n.a.	75.2	n.a.	n.a.	72.4	67.0	59.2	43.5	38.5	39.8
Irrigated crops only	n.a.	24.8	n.a.	n.a.	27.6	33.0	40.8	56.5	61.5	60.2
Vegetables	n.a.	n.a.	n.a.	n.a.	n.a.	5.3	8.8	20.5	22.2	19.7
HUESCA										
Irrigated and unirrigated crops	53.7	55.0	75.2	73.1	74.0	74.2	58.4	68.6	55.2	54.4
Irrigated crops only	46.3	45.0	24.8	26.9	26.0	25.8	41.6	31.4	44.8	45.6
Forage plants	n.a.	21.0	11.2	12.3	13.1	7.2	10.2	10.5	18.4	12.7
TERUEL										
Irrigated and unirrigated crops	59.8	57.7	60.7	57.6	59.5	65.9	47.3	43.0	45.6	49.3
Irrigated crops only	40.2	42.3	39.3	42.4	40.5	34.1	52.7	57.0	54.4	50.7
ZARAGOZA										
Irrigated and unirrigated crops	78.5	65.3	50.5	50.1	52.9	62.7	56.7	45.6	41.5	38.2
Irrigated crops only	21.5	34.7	49.5	49.9	47.1	37.3	43.3	54.4	58.5	61.8
Maize	4.8	8.9	6.8	3.7	4.6	2.8	10.3	18.2	21.3	20.9
Sugar beet	5.1	7.6	22.9	20.9	14.3	15.8	10.9	4.3	1.0	0.1
LÉRIDA										
Irrigated and unirrigated crops	83.0	66.1	70.9	65.7	62.1	57.8	50.6	38.7	39.6	28.1
Irrigated crops only	17.1	33.9	29.1	34.3	37.9	42.2	49.4	61.3	60.4	71.9
Fruit	0.4	0.4	0.5	0.2	0.2	0.3	1.8	12.9	19.6	27.6
Forage plants	10.9	22.1	19.7	22.7	25.1	29.0	32.7	28.7	16.5	24.1
TARRAGON										
Irrigated and unirrigated crops	69.2	49.8	44.1	41.3	41.4	24.5	14.3	10.1	6.5	9.8
Irrigated crops only	30.8	50.2	56.0	58.7	58.6	75.6	85.7	89.9	93.5	90.3
Fruit	0.1	19.5	10.9	6.5	9.2	18.4	20.4	25.0	34.8	37.5
Spring cereals	20.6	20.0	30.3	25.9	29.1	34.7	38.1	36.4	31.2	31.2

Notes: Irrigated and unirrigated crops = winter cereals, legumes, vines and olives; Irrigated crops only = Maize, rice, tubers, industrial plants, forage plants, fruit and vegetables.

Sources: Alava and Navarre: Iriarte and Lana, 'La agricultura'; Huesca, Teruel and Zaragoza, Ibarra and Pinilla, 'Regadío'; Lérida and Tarragona, Ramon, 'La agricultura de regadío'.

fifteen percentage points in the latter case, representing 90 per cent of irrigated land use by the beginning of the 1990s. In Lerida, growth in the relative share given over to typical irrigated crops represented almost 30 percentage points, while intensive crops expanded from less than 6 per cent of total irrigation to over 30 per cent by the early 1990s.²⁶ Progress on the Upper

²⁶ Ramón, 'La agricultura de regadío'.

Ebro was also significant. Thus, in Alava, Navarre and La Rioja the area sown with typical irrigated crops grew by 68, 27 and around 20 percentage points respectively. In all of these cases, the growth in the relative share of intensive crops was also very significant, especially in Navarre and La Rioja.²⁷

III

If all of the Ebro lands have enjoyed considerable progress in the substitution of traditional by typical irrigated crops, or by intensive crops, diversity has remained a notable feature, with different areas specializing in very different crops.

This diversity in specialization was conditioned by a range of factors. The moment at which the change in crops began in each area and the options chosen have been decisive. On the one hand path dependence and on the other the evolution of demand threw up different alternatives depending on the prevailing situation. This evolution and changes in the demand for food products have also conditioned the various production options due to variations in relative prices. Ecological conditions and the availability of water have also had a decisive impact. Finally, the relationship between irrigated agriculture and the rest of the economy has also had a considerable influence on this trajectory, as a result of integration with agro-industry and the availability and cost of labour as determining factors for certain production options. The structure of ownership may also have played a significant role.

One example of specialization is the introduction of sugar beet which played a decisive role in the change of irrigated crops, especially in Zaragoza, some districts of Huesca, Navarre and Teruel. The adoption of sugar beet, which was clearly centered on Zaragoza, received a decisive boost at the end of the nineteenth century and, in the depths of the agricultural depression, from the state-financed Zaragoza Experimental Farm, which sought to foster the development of sugar factories and encouraged a model of irrigation in small and medium-sized owner occupier farms that was very intensive in both labour and capital.²⁸ The beet cycle began to run out of steam in the mid-1920s although actual decline did not set in until the 1960s. Thereafter, it disappeared almost completely from many irrigated areas along the Ebro as production shifted to other areas of Spain (the Duero Valley and Jerez) due to the higher returns obtained from the crop on these new lands.²⁹ Though sugar beet yielded very good results, exceptional even in Zaragoza, at the time of its decline farmers specializing in the crop found themselves at a relative disadvantage when they sought to switch to more intensive crops requiring specialist skills and agro-industrial inputs to boost expansion. Because of this, the available options tended to reaffirm those specializations that had begun to emerge from the beginning of the 1960s, especially maize, and even as far back as the turn of the century, such as forage plants. The main advantage here was the possibility of mechanization in areas where labour was relatively scarce due to the strong pull of urban and industrial employment in cities such as

²⁷ Iriarte and Lana, 'La agricultura'; Moreno, 'La Rioja'.

²⁸ L. Germán, 'Características del desarrollo del complejo remolachero-azucarero en España, 1882-2000', in C. Barciela and A. Di Vittorio (eds.), *Las industrias*

agroalimentarias en Italia y España durante los siglos XIX y XX (2003), pp. 335-56; Pinilla, *Entre la inercia*.

²⁹ F. Asín et al., *El cultivo de la remolacha y la industria azucarera en la economía aragonesa* (1981).

Barcelona, Bilbao, Valencia, Zaragoza and Pamplona, as well as the demand for feed from the expanding intensive livestock farming industry, since Spain suffered a chronic shortage of forage. Specialization of this kind was, however, interspersed by districts where crops were grown (especially fruit trees), which in the 1950s had still not spread significantly.

A different trend is evident in large parts of the Upper Ebro. In this area, there was a clear initial option for market gardening, associated with the local canning industry, which fed back into further specialization.³⁰ Potatoes also offered an alternative, because they were already established as a crop of the wettest unirrigated land, which favoured their continuation when the land was converted to irrigation. Market garden specialization of this kind was particularly evident in La Rioja, Alava and Navarre.³¹ While it was already strongly entrenched in Alava and La Rioja before the Civil War, in Navarre such specialization benefited from a combination of proximity to these areas and the sugar beet crisis, which would drive the switch to new crops in the province.

In the Catalan part of the Ebro, the provinces of Lerida and Tarragona today both have a specialization in fruit growing, which occupies 27 per cent and 37 per cent respectively of irrigated land. Nevertheless, the timing of the adoption of fruit growing differed considerably between the two provinces. Tarragona opted for orchards much earlier, and fruit trees already occupied a significant part of irrigated area in the province before the Civil War, although the leading crop was rice, which had a long tradition in the Ebro Delta, and still shares this position with fruit. From at least 1900, Tarragona specialized in almonds and oranges, and there has been relatively little change in this configuration over the twentieth century. Together with these two products, vegetables represent the third pillar of highly intensive irrigation specialization in Tarragona, based on the availability of water and abundant labour and capital. In Lerida, specialization in fruit took place rather later and, indeed, its share of irrigated land was marginal until the 1960s.³² Until that time, forage plants had been the predominant option for irrigation in Lerida, together with traditional crops. The increasing importance of fruit, accompanied by maize, only became possible with the completion of major regulating works in the 1950s and '60s which ensured the supply of water to irrigate orchards and provided the opportunity to break with the traditional crops. In addition to this basic requirement, changes in demand and the development of a strong canning industry around the city of Lerida provided a boost for specialization, which mainly centered on apples, pears and peaches.³³ In this instance, the trend was towards a combination of crops similar to the Aragonese in certain areas, which were highly mechanized and needed only limited labour, while orchards required not only technical change but also good distribution and an outlet through canning industries, as well as demanding intensive seasonal labour and offering the possibility of mechanization.

³⁰ J. R. Moreno, 'La Rioja: las otras caras del éxito', in L. Germán, E. Llopis, J. Maluquer and S. Zapata, *Historia económica regional de España, siglos XIX y XX* (2001), pp. 153–81.

³¹ Gallego, *La producción*.

³² Pujol, *Les transformacions*; Ramón, 'La agricultura

de regadío'.

³³ E. Lluch and R. Seró, *La regió fruitera de Lleida* (1970); J. M. Sabartés, 'La "Regió fruitera de Lleida" vint anys després', in F. López (ed.), *La Regió agrària de Lleida* (1993), pp. 177–207; Bretón, *Tierra*.

IV

The changes brought about by irrigated agriculture go much deeper than merely the substitution of traditional for other, more intensive, crops. Throughout the twentieth century there were profound changes in production methods, resulting in a shift from traditional farming, where sunlight was the main source of energy, to modern agricultural systems based on high levels of capitalization and which were enormously dependent on power generated by burning fossil fuels and inputs from other sectors. Thus, there has been a move away from agricultural methods that are well integrated with the environment, but at the same time relatively unproductive, to systems involving much more environmental pressure and inefficient energy use, but which provide far higher yields per unit of cultivated land and capital. In both physical and financial terms, one of the most striking results of this process has been the rapid growth in output, which has been much more pronounced in irrigated than unirrigated land. Both have seen a formidable process of technical change, in which new technologies have often been applied first in irrigated areas and then transferred to unirrigated areas.

This intensive use of new technologies in irrigated land is directly reflected in the rise in irrigated output per hectare, and the productivity gap with unirrigated farming. We may consider the case of Aragon, which, as we have seen, accounts for half of the area of the Ebro Basin, to examine the evolution of this gap. Thus, the difference in total farm output per hectare for unirrigated and irrigated land increased from 6.3 to 6.8 times between 1950 and 1990 (at 1975 constant prices). In absolute terms, the gap also widened considerably. In this case, the extra €161.60 earned per hectare on total irrigated farm output in 1950 had swelled €358.50 by 1990.³⁴ If the same calculation is performed at current prices, the better performance of typical irrigated produce further increases the difference. Thus, total output per irrigated hectare in 1950 was 4.5 times that of unirrigated land, but had risen to 5.5 times by 1990.³⁵

This widening of the gap in output per hectare between unirrigated and irrigated land has taken place in a period when both forms of agriculture have achieved very significant productivity gains. In the case of irrigated agriculture, output per hectare more than doubled between 1950 and 1990 (Table 5). As explained previously, the rapid growth in irrigated farm output is also explained by the expansion of the irrigated area and the reorientation of production toward those crops which command higher prices (i.e. typical irrigated crops in general, and especially the most intensive crops). However, the importance of these two factors varies in the different lands of the Ebro Basin.

The expansion of irrigation has logically provided a major boost for output in those areas where it has been most intense. In general, the expansion of irrigation in the Ebro Valley as a whole over the twentieth century may be put at almost 300,000 hectares, which in itself explains a large part of the increment in output. Furthermore, the improvement of irrigation, in particular to ensure regular water supplies during the more drought prone summer months, has allowed output to increase. Changes in crops have been another key factor. Better quality irrigation and above all demand-side factors such as higher incomes and changes in diet have

³⁴ Ibarra and Pinilla, 'Regadío', pp. 15–16.

³⁵ V. Pinilla, *Evolución histórica del regadío en Aragón en el siglo XX* (1996), mimeo.

TABLE 5. Change in area, output and output per hectare of irrigated land in the Ebro basin, 1950–90
(100=1950)

	<i>Alava</i>	<i>Navarre</i>	<i>Rioja</i>	<i>Huesca</i>	<i>Teruel</i>	<i>Zaragoza</i>	<i>Lerida</i>	<i>Tarragon</i>	<i>EBRO B</i>
Output 1990	1,590	308	384	624	214	387	371	178	348
Area 1990	691	127	154	270	106	171	125	127	160
Output/Hect. 1990	230	243	249	231	201	226	298	140	217

Source: As Table 4 and Moreno, 'La Rioja'.

progressively encouraged concentration on higher earning crops that can only be grown on irrigated land in a Mediterranean climate. This has also had a considerable impact on the rise in output measured in cash terms.

The result of faster growth in irrigated than unirrigated farm output has been a marked trend to concentrate production on irrigated land, and in the Ebro Valley this has meant that a minority of the total farmland has come to represent a very significant percentage of total output. The case of Aragon once again illustrates the situation. In 1990, irrigation represented only 21.7 per cent of cultivated farmland in the Region, but nevertheless accounted for 65.3 per cent of total farm output.

The relative contribution made by the expansion of irrigation and technical change to growth in irrigated farm output can be estimated using a simple formula which reflects the extent to which the increase in irrigated output is due to one of these causes or the interaction between them. On the one hand, it is possible that the increase in the area irrigated alone explains a parallel increase in output. On the other, the rise in output per hectare may also be significantly affected either by the impact of technical change or by the switch to higher earning crops, which would also imply a trend toward rising output. The formula applied is:

$$Y_n - Y_1 = P_1 \cdot (S_n - S_1) + S_1 \cdot (P_n - P_1) + (P_n - P_1) \cdot (S_n - S_1)$$

Where:

Y_n is total irrigated farm output in 1990 (at 1975 prices).

Y_1 is total irrigated farm output in 1950 (at 1975 prices).

S_n is the cultivated area under irrigation in 1990.

S_1 is the cultivated area under irrigation in 1950.

P_n is total output per hectare irrigated in 1990 (at 1975 prices).

P_1 is total output per hectare irrigated in 1950 (at 1975 prices).

The first term, $P_1 (S_n - S_1)$ represents growth in output due to changes in the area irrigated, assuming output per hectare remains constant. The second, $S_1 (P_n - P_1)$, represents changes in production where the area remains constant, reflecting changes in output per hectare. Finally, the third term, $(P_n - P_1) (S_n - S_1)$ represents growth in output resulting from a simultaneous increase in area and in production per hectare.

The results presented in Table 6 clearly show that both the increase in the area irrigated and the change in output per hectare (in euros) were very significant in the Ebro Basin as a whole, but that the latter effect was in fact considerably more important. There are significant

TABLE 6. Reasons for growth in total irrigated farm output in the Ebro basin, 1950–90 (per cent)

	<i>Alava</i>	<i>Navarre</i>	<i>Rioja</i>	<i>Huesca</i>	<i>Teruel</i>	<i>Zaragoza</i>	<i>Lerida</i>	<i>Tarragon</i>	<i>EBRO B.</i>
$P_1 (S_n - S_1)$	39.7	12.9	19.0	32.4	5.7	24.8	9.1	34.2	24.3
$S_1 (P_n - P_1)$	8.7	68.7	52.5	25.1	88.6	43.9	72.9	52.0	47.2
$(S_n - S_1) \times (P_n - P_1)$	51.6	18.4	28.4	42.5	5.7	31.3	18.0	13.8	28.4
$Y_n - Y_1$	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: calculated from Table 5 as explained in text.

differences at the level of individual provinces. In those provinces where growth in the area irrigated has been significant, such as Alava, Huesca and Zaragoza, the contribution of this factor to growth in output was also substantial, while in the remaining provinces it tended to be slight, with the exception of Tarragona – possibly as a result of the already high starting level of output per hectare. Technical and crop changes have played a key role in the Ebro Basin as a whole, and the contribution of these factors was in fact higher than that of the expansion of irrigation in almost all cases. Finally, we should remind ourselves that the increases in output explained were far from negligible, with output increasing 3.5 times, measured at constant prices, over the period analyzed in the Ebro Basin as a whole (Table 5).

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Irrigated agriculture currently accounts for over half of Spanish farm output, although it occupies a proportionally much smaller share of cultivated land. Furthermore, the crops grown are generally less dependent on subsidies under the Common Agricultural Policy (CAP) and have a greater presence in international markets. This aspect takes on particular importance at a time a substantial reduction in these subsidies is foreseen. Unquestionably, this is the most dynamic sector of Spanish agriculture, and its future prospects are excellent.

This record of growth in agricultural productivity has not been without its costs. It is necessary to acknowledge to the impact that the increase in irrigated agriculture has had on the natural environment. This has been particularly marked in the last 25 years.³⁶

One problem that has emerged is the salinity of the agricultural land. Whilst this is a common phenomenon in large areas lying in the central section of the Ebro Basin, it has nevertheless been significantly increased by irrigation. This has had a negative effect on crop productivity, on the range of crops that can be grown and on the ecological system itself. Indeed, in extreme cases, it has led to the abandonment of land. The surface area affected by problems of salinity within the Ebro Basin is now more than 300,000 hectares which, when consideration is given to the large-scale irrigation systems, represents more than 50 per cent of the cultivated land.³⁷ A second problem is that the intensive use of chemical fertilizers

³⁶ For a synthetic vision of these ecological impacts, see P. Ibarra, J. de la Riva, I. Iriarte, V. Rodrigo and I. Rabanaque, 'Gestión del agua y medio natural', in Pinilla (ed.), *Gestión*.

³⁷ F. Alberto, 'La desertización por salinización en el Valle del Ebro', *Azara*, 1, (1989), L. Pinilla, *Informe técnico sobre los problemas de salinidad en los grandes polígonos de riego de la Cuenca del Ebro* (1990).

and phytosanitary products in the irrigated areas since the end of the 1960s has made an important contribution to the widespread pollution of water by nitrates and phosphates.³⁸

In addition, there is the threat posed to the preservation of the Ebro Delta as a result of the decline in the volume of water flowing down the River Ebro. This has been particularly noticeable since the 1960s and is at least partially the consequence of the increase in water consumption for which irrigated agriculture has been responsible in no small part.³⁹ The high level of water regulation has also had a negative influence on the Delta by reducing the volume of sediments being laid down. It has been estimated that there has been a fall in the volume of solid sediments from more than 22 million tonnes/year in the 1940s to a current level of just 0.10 tonnes/year. As a result, the encroachment of sea water into the Delta, coupled with the increase in the salinity of the River Ebro in its final stretch as a result of the decline in the volumes of fresh water, represents a serious threat to the sustainability of the Delta.

From a social point of view, it is also important to acknowledge the popular opposition which has emerged since the beginning of the 1990s to the building of further dams in the Pyrenees. This has taken the form of a new unwillingness amongst the inhabitants of the affected areas to having their land or houses expropriated. As a result, there has been a clash between their interests and those of farmers lower down the river who have anticipated that additional regulatory works would result in a further expansion of the irrigated areas or an improvement in the supply to those already in existence. It is the view of those who oppose these large-scale projects that the mountain areas paid a very high price throughout the twentieth century in terms of the flooding of population centers and cultivated lands, and the enforced movement of whole populations as a consequence of reservoir construction.⁴⁰ It is in Aragon where this movement has become most important and where the arguments raised by the proponents of the new water culture, who reject the continuance of policies that increase the supply of water and, instead, place emphasis on the management of demand and on efficiency, have enjoyed the greatest acceptance.⁴¹

³⁸ J. Sánchez-Chóliz and R. Duarte, 'Analysing pollution by way of vertically integrated coefficients, with an application to the water sector in Aragon', *Cambridge J. Economics*, 27 (2003), pp. 433–48.

³⁹ Irrigated agriculture is responsible for 95% of water consumption on the Ebro Basin. However, a substantial part of this water corresponds to inputs supplied to other sectors (livestock rearing, the food industry, etc.). When the water included in these activities is discounted, direct consumption falls to 20%. See J. Bielsa, *Gestión integrada del agua en el territorio desde una perspectiva económica* (1998); R. Duarte, J. Sánchez-Chóliz and J. Bielsa, 'Water use in the Spanish economy: an

input-output approach', *Ecological Economics* 43 (2002), pp. 71–85.

⁴⁰ For an estimate of the population expelled from their villages as a result of the construction of dams and reservoirs in the Aragonese Pyrenees, see A. Herranz, 'La construcción de pantanos y su impacto sobre la economía y población del Pirineo aragonés', in J. L. Acín and V. Pinilla (eds.), *Pueblos abandonados. Un mundo perdido?* (1995), pp. 79–102.

⁴¹ For an anthropological perspective, see G. Mairal, J. A. Bergua and E. Puyal, *Agua, tierra, riesgo y supervivencia* (1997); G. Mairal and J. A. Bergua, *De Joaquín Costa al Pacto del Agua. Los aragoneses y el agua* (2000).