Impacto demográfico de los proyectos de regadío en España, 1900-2001. Una comparación de dos estudios de caso en la cuenca del Ebro

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The demographic impact of irrigation projects:
A comparison of two case studies of the Ebro basin, Spain, 1900-2001

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Abstract

La puesta en riego de tierras cultivables durante los siglos XIX y XX se ha considerado como una herramienta con la que evitar o reducir, e incluso atraer, población rural. Este trabajo analiza el impacto demográfico de dos de los sistemas de riegos más importantes puestos en funcionamiento en España durante el siglo XX, los Riegos del Alto Aragón y el Canal de Aragón y Cataluña. Los resultados varían en función de una serie de factores que son analizados en detalle.

Keywords: Irrigation projects; demographic impact; Spain; long-run study; comparison of two cases

Abbreviated article title: The demographic impact of irrigation projects
Introduction

Modern irrigation developed in the nineteenth and twentieth centuries, was aimed – among other things - at resettling population and reducing migration to urban centres and abroad. Population allocation projects, based on water diversion and storage, accompanied colonial expansion, contributed to the ‘interior colonization’ of large and scarcely populated countries (such as the US, Canada and Australia) and, more recently, have been part of development strategies in African, Asian and Latin American countries.

Although the economic and environmental effects of irrigation projects have received considerable attention, the literature on the demographic impact is far from abundant. The study of the effect of irrigation on population has focused on two main areas: North America and the developing countries. Studies for the US usually refer to the settlement of the irrigated West during the late nineteenth and early twentieth centuries, as well as to the impact of later irrigation projects on alleviating rural depopulation in the Midwest. A recent study analyzes irrigation projects in the Canadian Prairie West during the early twentieth century. The evaluation of irrigation projects in developing countries as a tool to reduce, or redirect, internal migration during the second half of the twentieth century, includes case studies for Bangladesh, India, Kenya, Nepal, Nigeria, Sri Lanka, Somalia and Thailand.

This literature has produced mixed results. Studies are difficult to compare, moreover, because of differences in methodology. Nevertheless, Matthew Evenden refers to three main problems that have been common to numerous irrigation projects around the world. First, irrigation programs were costly. These often involved large infrastructure works, without sufficient revenues to enable settlers, private capital or even public administrations to pay expenses. Second, environmental limitations impeded expected outcomes. Third, models from abroad, particularly from the US, produced different results in different natural and socio-political environments.

The issues of water management and population distribution have been particularly relevant in Spain, a country historically characterized by severe environmental limitations to agricultural growth and intense rural depopulation. Scarce and irregular rainfall, with seasonal drought, is a main factor in explaining
the relatively low performance of Spanish agriculture during the nineteenth and twentieth centuries, compared to other European countries.\textsuperscript{6} Rural depopulation, on the other hand, began during the late nineteenth century and intensified from the middle of the twentieth century onwards.\textsuperscript{7} Rural-urban migration first, and its subsequent effects on the demographic system, namely the depletion of women and young cohorts, have been indicated as the two main causes to an understanding of the dramatic decline in rural and agricultural populations.\textsuperscript{8} The proportion of the population living in towns of 5,000 or less has fallen from 71 per cent in 1900 to 29 percent in 2001.\textsuperscript{9} Estimates of the proportion of the population involved in agriculture, meanwhile, have fallen from around 66 per cent in 1900 to 5 percent in 2001.\textsuperscript{10} In this regard, a serious socio-economic problem in modern Spain is the existence of large and almost depopulated areas, particularly inland.\textsuperscript{11}

This paper evaluates whether irrigation projects in Spain throughout the twentieth century have achieved one of their main objectives, that is, a reduction in rural population decline. Reflections on this issue have been abundant in the political and academic arenas. The idea of introducing irrigation agriculture to reduce the loss of rural population permeated the Spanish \textit{Regenerationist} movement during the late nineteenth and early twentieth centuries. Regenerationists revolted against an inherited image of Spain as a wealthy and prosperous country, and proposed economic and political reforms. The nexus between irrigation and population retention, and even attraction, remained an important issue in rural policy during the first decades of the twentieth century, the dictatorship of Francisco Franco (1939-1975) and the years since the restoration of democracy.

Despite the existence of a rich debate, only a few studies have produced quantitative estimates and comparisons. Irrigation projects in the northeastern province of Huesca have received particular attention.\textsuperscript{12} José María de Ureña estimated population growth for 122 villages (some of them located in the adjacent province of Lérida) between 1920 and 1975.\textsuperscript{13} Angel Paniagua, similarly, has estimated population growth for selected villages between 1940 and 1991.\textsuperscript{14} Both authors coincide in showing that population in irrigated areas grew during early peaks in irrigation activity, but this growth was often minor - and always short-lived. Other studies analyzing shorter periods (less than twenty-five years) during the second half of the twentieth century show similar results.\textsuperscript{15}
The contributions of this paper are twofold. First, we compare the evolution of population in two of the earliest and most ambitious irrigation projects in Spain, the *Riegos del Alto Aragón* (Upper River Aragon Irrigation System) and the *Canal de Aragón y Cataluña* (Canal of Aragon and Catalonia), both located in the Ebro basin. The second contribution of the paper is that the time period under study covers a whole century. This long-run approach is crucial if we accept that irrigation requires time to consolidate and, therefore, its impact on population may be long delayed.

The paper is organised into six sections. First, we show that the idea of introducing irrigation to sustain rural population has persisted over time. In the second and third sections, we describe the two irrigation projects, the sources and the methodology. In the following two sections, we show that the evolution of population in each of the two projects has been substantially different. We also analyze the factors that have caused or impeded population growth. We argue that environmental and economic limitations have certainly been significant, but political and geographical factors have also played a major role. Thus, in a context of poor agriculture and inequality of access to land, irrigation projects were conceived as an easier substitute for more ambitious agrarian reforms. As has been said regarding developing countries, “the evidence suggests that land settlement programmes alone cannot be expected to solve agrarian problems”. Proximity and good access to markets, meanwhile, have become key factors in understanding the demographic success of irrigation projects. The paper ends with a review of the main conclusions.

**Irrigated agriculture as a response to population decline in rural Spain**

Irrigation techniques in Spain have been present since the time of the Roman Empire. Large irrigation projects, sometimes as part of no less ambitious fluvial transportation plans, emerged during the second half of the eighteen and the nineteenth centuries. The lack of adequate private capital, and the minor role played by the state in the largely unregulated nineteenth century Spanish economy, however, meant that the construction of large-scale irrigation projects had to wait until the twentieth century. The construction of new hydrological infrastructure would have not been possible without the financial support of a state more prone to
intervention than in earlier times. Behind this turn-of-the-century turnaround in irrigation policy were the ideas of the Regenerationist movement.\textsuperscript{21}

Regenerationists stressed the environmental limitations of Spanish agriculture.\textsuperscript{22} They referred to poor soils and inadequate climate, as well as to problems related to water supply, such as evaporation and floods and, finally, scarcity and irregularity.\textsuperscript{23} They saw hydraulic policy, particularly irrigation, as a tool to overcome environmental constraints.\textsuperscript{24} State intervention in water issues, furthermore, was also seen as a solution to the economic and social problems in rural Spain, i.e. poverty, inequality of access to land, social conflict and migration.\textsuperscript{25}

Regenerationism’s call for state intervention gained much attention during the end-of-century agricultural depression, when the integration of the world economy, and competition from the New World, put pressure on the agricultural sector in European countries.\textsuperscript{26} Both rural-to-urban migration and emigration to Latin America and the North of Africa accelerated in Spain from the end of the nineteenth century to the early 1930s.\textsuperscript{27} Lucas Mallada, one of the first and leading Regenerationists, pointed out the weakness of dry land agriculture to retain population.\textsuperscript{28} The idea of considering irrigation to prevent emigration was defended enthusiastically by Joaquín Costa, the most influential Regenerationist, particularly in his well-known \textit{Oligarquía y Caciquismo} (Oligarchy and Despotism).\textsuperscript{29} Irrigation, according to Costa, could sustain or augment employment requirements by increasing cropping areas and yields, as well as substituting cereals for labour intensive crops, such as fruits, vegetables, and forage plants (that permitted the maintenance of livestock).\textsuperscript{30}

The first national Hydraulic Plan was adopted in 1902. Lack of public (and private) funds, technical problems, and a lack of detailed planning and collaboration among administrations, however, delayed the execution of many projects.\textsuperscript{31} Hydraulic policy became more integrated with regional interests during the 1920s, when the \textit{Confederaciones Hidrográficas} (River Authorities) were created. Some of the most important projects were consolidated during those years. In 1933, a new and more comprehensive Hydraulic Plan was enacted. Manuel Lorenzo Pardo, the engineer who directed the plan, addressed the maintenance of rural population as one of the main targets.\textsuperscript{32} The hydraulic plan also conceived of irrigation as the way to facilitate rural colonization.\textsuperscript{33} Colonization programs, although debated in Spain
since the end of the eighteenth century, however, did not begin seriously until the 1950s.

In the years following the Civil War (1936-1939), water policy became a concern of the dictatorship of Franco. Between 1950 and the mid-1970s, the main elements of the national hydraulic infrastructure were built, composed of water regulation (dams) and irrigation projects. The new hydraulic plan of 1940 adopted, with minor changes, the main population objectives and tools of the two former plans. The state, in addition, tried to promote the irrigation of colonized lands with financial and technical assistance. Colonization, however, adopted the most conservative option, that is, land settlement instead of agrarian reform. Agrarian reform, as conceived before the civil war, implied some kind of land confiscation and redistribution. Land settlement, on the contrary, did not require change of land ownership, since it was based on the voluntary offer of lands on the part of the owners. This early design of colonization, however, faced serious difficulties in obtaining private lands for settlement, and, as a result, the extent of irrigation related to this scheme remained modest.

The law was reformed in 1946, permitting confiscation under certain conditions and in exchange for compensation. The subsequent expansion of irrigation and colonization during the 1950s and the 1960s, however, took place in a different economic context. Trade openness led to a change in economic policy that transformed the inward-looking development model that characterized the early years of the regime. The country undertook an intense process of economic growth, accompanied by industrialization and urbanization. The agricultural sector, now much more mechanized, became a source of food and unskilled labour directed to both the national and the international market. In comparison with previous and later periods, the 1960s in particular were the high point of unskilled migration from rural areas.

The territorial reorganization of the state after the end of the dictatorship (1975) implied a regional decentralization of irrigation policies, which also had to adapt to the European Common Agricultural Policy and the Regional Development Programmes after Spain’s accession to the European Union in 1986. However, agriculture in the advanced European countries, including irrigated agriculture, no longer played the role of leading economic growth, as did other policies such as
transport infrastructure. The objectives of European and Spanish rural policy were reoriented from production to the maintaining of population and the improvement of the standard of living in rural areas.\textsuperscript{40} This change in orientation was included in the Spanish Water Law of 1985 and other water policy plans during the 1990s. Scholars, however, have pointed out that, in a context in which some areas have been suffering severe rural depopulation, a more exhaustive territorial analysis is necessary.\textsuperscript{41}

Irrigation has been said to play an important role in sustaining population in recent times. In the latest preliminary Hydraulic Plan of 2000 (now paralyzed), for example, experts advising on socio-economic effects have argued that the focus on transferring water from the Ebro River to the Mediterranean coast ignored the potential role of irrigation in promoting balanced territorial development in inland Spain.\textsuperscript{42} The current minister of Agriculture, Elena Espinosa, has said that “irrigation agriculture constitutes [a key factor] in fixing population to the countryside”.\textsuperscript{43} Whereas César Trillo, the president of the Riegos del Alto Aragón, one of the case studies analyzed here, has recently demanded more irrigation in order to avoid out-migration and maintain rural population in the area.\textsuperscript{44}

**Two main irrigation projects in the Ebro Basin**

The irrigation system of *Riegos del Alto Aragón* (hereafter RAA) and 60 per cent of the extension of the irrigation system of *Canal de Aragón y Cataluña* (hereafter CAC) are located in the province of Huesca (region of Aragón) [Fig. 1].\textsuperscript{45} The remaining 40 per cent of CAC is located in the neighbouring province of Lérida (region of Cataluña). Both systems are part of the Ebro Basin, which is located across the northeast of the Iberian Peninsula. Average annual precipitation in both systems is around 400 mm, and rainfall presents high inter-annual and inter-monthly irregularity.\textsuperscript{46} Frequent extremely dry years and minimum levels in the summer occur, when the requirements for some crops are higher than can be met from the available precipitation.
Each project has had its own pace of construction of infrastructure works, as shown in Table 1. Whereas works in the RAA have lasted until the beginning of the twenty-first century, the main part of the CAA was almost finished during the 1930s. The main difference between irrigated and non-irrigated lands lies in yields. Irrigation has permitted substitution of cereals for more valuable crops. Systematic data for yields are scant. In the case of the province of Huesca, available data for the late 1980s show that benefits for cultivating cereals in irrigated, instead of non-irrigated, lands were 4.4 times higher. In comparison with the irrigation of cereals, the introduction of fruit in irrigated lands during the 1960s (in either of the two provinces) increased benefits 5.7 times.\textsuperscript{47}

\textbf{Data sources and methodology}

Population data in irrigated and non-irrigated areas are provided by the Censuses of Population, which report \textit{total} population, at the level of villages, every ten years. In each irrigation system (RAA and CAC) we chose villages that fulfil the following criteria. First, in order to avoid the inclusion of urban areas, all villages considered are below 10,000 inhabitants throughout the twentieth century. Second, according to available data, a village is considered to be “irrigated” if the irrigated area represents more than 25 per cent of total cultivated land in 1981, in the case of villages that belong to the province of Huesca, or 2001, in the case of villages that belong to the province of Lerida. Among irrigated villages, we also distinguish between those in which irrigation was in the range of 25-75 per cent of total cultivated land or extended to more than 75 per cent. On the other hand, a village is considered to be “non-irrigated” if the irrigated area represents less than 10 per cent of total cultivated area during the same periods.\textsuperscript{48} Table 2 reports descriptive statistics of each group of villages.\textsuperscript{49} In the case of CAC, we distinguish between villages located in the provinces of Huesca and Lerida, whose demographic evolution, as we will see below, has been substantially different.
To compare the year-over-year growth of population in irrigated and non-irrigated villages, we will report the compound annual growth, or geometric average growth rate, between selected dates. We also include the compound annual growth for the provinces of Huesca and Lérida, which is utilized as reference. The closest (census) years to the start of infrastructure works act as baseline years: 1910 and 1900 for RAA and CAC respectively. The second benchmark is 1930, the (census) year closest to the outbreak of the Spanish civil war (1936). Our next points of reference are 1950 and 1981, the approximate (census) years of the beginning and end of the most intense period of structural change and rural-urban migration in Spain. The period under study ends in 2001, when the last available census was carried out. Aside from population data, this paper also makes use of secondary sources to supplement the information obtained from the censuses.

The development of Riegos del Alto Aragón

Early irrigation projects appeared in the middle of the nineteenth century. The idea of irrigating the area arose among social reformers and local politicians at the end of nineteenth century, from the impact of the agricultural depression, which dramatically reduced exports of cereals, the main crop in the area. Working and living conditions in rural Huesca were difficult. In a context of extreme inequality of access to land, even small landowners had to supplement their income with seasonal work on larger estates. Irrigation was aimed at increasing the number of days worked per year, not only extending cultivated land and introducing new crops, but providing jobs in infrastructure works as well. Fear of change, and preservation of the status quo, however, ensured that early landowners’ support was by no means enthusiastic – nor was it unanimous.

The complete design by civil engineers was not finalised until 1911, and not approved by the state until 1915. Because of high costs, the pace of construction was slow during the following two decades, as shown in Table 1. At the outbreak of the Civil War, in 1936, only 10,000 of the planned 300,000 hectares had been
irrigated. Deficiencies in the infrastructure, moreover, meant that a significant part of irrigation was temporary.\textsuperscript{56} Even large-scale irrigation (more than 75 per cent of total cultivated land) was unable to offset the long-lasting consequences of the agricultural depression, as suggested by Table 3. The already difficult agricultural labour market, in fact, worsened during the early decades of the twentieth century, because of falling prices and limited access to credit. Many agricultural labourers and small landowners, as a result, migrated during this period.\textsuperscript{57}

[Table 3]

Aimed at increasing the extent of irrigated hectares, the project was included in the hydraulic plan of 1939. New infrastructure works, which permitted the extension of permanent irrigation, may have contributed to decelerate depopulation in largely irrigated villages [Table 3]. In the early 1950s, however, the amount of irrigated land remained modest. Half of the area under irrigation, moreover, was used in the production of cereals, a low-value crop.\textsuperscript{58}

The construction of main and subsidiary hydraulic works accelerated between 1950 and 1981.\textsuperscript{59} Deficiencies in the implementation of irrigation, as well as overall changes in the local (and national) agricultural sector, and the economy as a whole, during these decades, however, meant that significant effects of irrigation on population only applied to large-scale projects [Table 3]. First, the lack of sufficient water and other environmental constraints, such as the poor quality of soils, limited the introduction of crops other than cereals.\textsuperscript{60} The province of Huesca, in addition, became one of the main sources of basic-food supply in the Dictatorship’s agrarian policy.\textsuperscript{61} Irrigation in RAA during this period, in short, was utilized to ensure regular harvests of the same main low-value crop (i.e. cereals) as was grown on non-irrigated lands. The problem was that specialization in such a labour-extensive crop proved to be a strong incentive for mechanization when this option became available to a number of landowners, as confirmed by available information.\textsuperscript{62} In a context of growing opportunities in urban areas, the vicious circle of out-migration and mechanization developed.

Strong economic growth and structural change, achieved in Spain during the 1950s and 1960s, generated abundant, stable jobs, as well as relatively high wages,
in nearby urban areas such as Zaragoza and Barcelona. Migrations from rural Huesca, as a result, intensified [Table 3].\textsuperscript{63} Early out-migration was mainly comprised of agricultural labourers. As pointed out by scholars, this was the consequence of an irrigation policy during the Dictatorship that did not seriously consider limitations on access to land.\textsuperscript{64} The main objective of irrigation policies during the 1950s and 1960s was to increase agricultural production, whereas the greatest part of new irrigated land was reserved for existing owners.\textsuperscript{65} Early migration, moreover, meant that the price of labour increased, a fact that reinforced incentives to mechanization. This process, in the end, provoked further out-migration of small landowners, who faced difficulties both in hiring seasonal labour, and in being hired by larger estates.\textsuperscript{66} The intense out-migration from this area during this period extended to other social groups as well, such as labourers who worked in hydraulic works.\textsuperscript{67}

Out-migration decelerated from the late 1970s, but population in rural Huesca kept falling during the 1980s and the 1990s.\textsuperscript{68} This has been the case even in irrigated villages [Table 3]. Scholars agree in showing age and sex selectivity in previous migration as the main cause of the erosion of the demographic system in recent decades.\textsuperscript{69} Available data for the area of RAA at the end of the century show that both irrigated and non-irrigated areas present strong imbalances in sex and age ratios.\textsuperscript{70} The predominance of impartible inheritance, for example, became an incentive for non-inheritors to migrate, a fact that contributed to the ageing of rural society.\textsuperscript{71} The area, on the other hand, has maintained its specialization in low labour-intensive crops. The importance of cereals declined during the 1980s, when new hydraulic works permitted higher value crops such as maize, rice and forage. As in the case of cereals, however, the cultivation of these crops has permitted intensive mechanization and the requirements of labour have been relatively low.\textsuperscript{72}

The development of Canal de Aragón y Cataluña

Although private projects to irrigate the area date back to the sixteenth century, lack of capital delayed the project until 1896, when the state resumed construction.\textsuperscript{73} Again, it was the impact of the agricultural depression, as well as the abundance of droughts, that accelerated the process.\textsuperscript{74} In a context of poverty and inequality of
access to land, as in the case of RAA, politicians and social reformers regarded irrigation as a way to reduce out-migration.\textsuperscript{75} In contrast with the case of RAA, it may have been expectations created through trade with nearby urban and industrial areas that encouraged the onset, and then the expansion, of the construction of the hydraulic infrastructure.\textsuperscript{76} Demands from landowners, farmers and traders, in this regard, coincided with support for irrigation.

The first part of the project was opened in 1906, and work proceeded rapidly. Three decades later, 83 per cent of the total has been irrigated, as shown in Table 1.\textsuperscript{77} Irrigation villages during the early decades of the twentieth century benefited from a process of trading integration, in which agricultural areas acted as food suppliers to growing urban and industrial areas located in the northeast, one of the most advanced areas of Spain at that time. Exports to the metropolitan area of Barcelona, as well as to medium size towns such as Zaragoza, Lérida, Monzón, Binefar and Almacellas, intensified considerably before the civil war.\textsuperscript{78} Population in irrigation villages increased during this period, as shown in Table 4. Trade was based on cereals, and, during the early 1930s, cereals still accounted for 71 per cent of the total irrigated land.\textsuperscript{79} The early hydraulic infrastructure, in fact, was designed mainly to facilitate this crop, which does not require as much water as others.

[Table 4]

A process of crop change from the late 1910s onwards may also have contributed to population growth in irrigated villages, particularly in the province of Lérida [Table 4]. Thus, whereas in the province of Huesca, cereals continued to be the main crop for decades, labour-intensive and more profitable crops, such as forage first, and later maize, fruit and vegetables, were gradually introduced in irrigated villages located in Lérida.\textsuperscript{80} New hydraulic works during the 1920s, in this regard, permitted a greater intensification in land use. Better railway and road infrastructures, in addition, facilitated exports, as in the case of forage sold to the city of Barcelona during World War I.\textsuperscript{81} An important contribution to this process was the creation of agricultural cooperatives, which spread technical information,
demanded celerity in the construction of the hydraulic infrastructure, and better communications.  

The fact that irrigation infrastructure was almost complete by the middle of the century consolidated the substitution of cereals for more valuable crops, particularly fruit and maize, in the province of Lérida from the 1950s onwards.  Population in irrigated villages in this area increased during the 1950-1981 period [Table 4]. In a period of rapid urbanization and industrialization, as well as important nutritional changes, the demand for new crops increased from nearby areas, particularly the cities of Lérida, Barcelona and Zaragoza. An interesting issue here is that, although large estates did not disappear, a great part of the agricultural production in irrigated areas has been based on small- and medium-sized family-owned farms.  

Family labour was supplemented with wage-labour on large estates or, as we will see below, agro-industries. Specialization in labour-intensive crops, furthermore, hindered the introduction of mass mechanization. This structure contributed to the increase in family income in rural areas and, in the end, reduced rural-urban migration during the 1960s and 1970s.

Differences between villages located in Lérida and Huesca accelerated from the 1980s onwards [Table 4]. The growing importance of agro-food industries in Lérida is an important factor in understanding population growth in irrigated areas in recent decades; for example, a strong development of canning and cattle industries occurred in the province of Lérida from the 1960s onwards. Farmers in irrigation villages, meanwhile, provided necessary inputs. Early specialization in forage plants, on the one hand, permitted irrigation areas to feed the local cattle industry, one of the most important production centres of pig and bovine meat in Spain. The later introduction of fruits (apples, pears and peaches) and vegetables converted irrigation villages to suppliers of a growing canning industry as well. Again, it was the existence of a well-functioning hydraulic infrastructure, experience in the cultivation of high value crops, proximity to urban markets, and relatively high population densities, that allowed irrigation villages to become the basis of the new development strategy.
Conclusions

Irrigation agriculture in Spain, since the end of the nineteenth century, has been considered a means of slowing the loss of rural population. One way or another, this idea has formed part of different economic, social and political frameworks. This study has analyzed the demographic impact of two of the early and most important irrigation projects in Spain. Differences between the two outcomes are considerable.

The rate of population growth during the twentieth century in irrigated villages located in the area of Riegos del Alto Aragón, in the best case, comes near to zero [Table 3]. Meanwhile, the rate of population growth in irrigated villages located in the area of Canal de Aragón y Cataluña, particularly its section located in the Catalan province of Lérida, has been clearly higher than in the case of the provinces (of Huesca and Lérida) as a whole, including or not urban centres [Table 4]. Different rates of population growth led to different population densities, as summarized in Table 5. Population density in irrigated areas on the Catalan side of Canal de Aragón y Cataluña is outstandingly high. Population density in irrigated areas located in Riegos del Alto Aragón, on the other hand, is lower than it was a century ago.

[Table 5]

Initial costs and lack of unanimity contributed to the delay in the construction of hydraulic works in the case of the Riegos del Alto Aragón. A further problem was that even the already-finished hydraulic network had only limited impact on agricultural performance, since irrigation was often impermanent and environmental constraints limited the introduction of crops other than cereals. Construction of more and better infrastructure accelerated during the second half of the twentieth century, precisely when the agricultural sector lost its major role in economic growth, and rural out-migration increased dramatically. In this context, the area of the Riegos del Alto Aragón became particularly exposed, because of its specialization in a low-value crop (cereals) susceptible to intense mechanization, and the unresolved problem of access to land.
The chain of interactions has had more positive effects in the case of the Canal de Aragón y Cataluña, particularly in its Catalan section. The basic infrastructure was almost finished during the 1930s. This meant that some areas were well irrigated when agriculture was still the most important economic sector in Spain. Commercial expectations played an important role here. Since the beginning of the twentieth century, different social groups coincided in the demand for better irrigation and transport infrastructures, in order to become main suppliers to the expanding urban and industrial centres. Irrigated villages in this area, in addition, responded quickly to changes in demand. Exports of cereals gave way to exports of more valuable crops such as forage and fruit. Specialization in labour-intensive crops, moreover, contributed to reduce rural out-migration during its apogee between approximately 1950 and 1980.

These results seem to confirm that, as pointed out by leading scholars, reasons to hope that irrigation projects can solve demographic problems have to be considered cautiously and individually. Irrigation projects may have contributed to population growth in certain historical contexts, especially when the agricultural sector played a major role in the economy. Even in the successful case of Canal de Aragón y Cataluña studied here, the capacity to retain rural population may have lost part of its strength during the second half of the century [Table 4]. An important issue here, in any case, is what is produced on irrigated lands, and where this production is going to be sold. Further options in rural policy, such as tourism and the conservation of nature, may also be considered in particular situations - even more so if we consider that water scarcity appears to be a possible feature of future scenarios.
Figure 1. Location of Riegos del Alto Aragón and Canal de Aragón y Cataluña
Tables

Table 1.
Irrigated areas, selected dates

<table>
<thead>
<tr>
<th>Year</th>
<th>Riegos del Alto Aragón</th>
<th>Percentage of final size</th>
<th>Canal de Aragón y Cataluña</th>
<th>Year</th>
<th>Hectares</th>
<th>Percentage of final size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1936</td>
<td>10,000</td>
<td>8.5</td>
<td>1937</td>
<td>81,807</td>
<td>83.1</td>
<td></td>
</tr>
<tr>
<td>1952</td>
<td>30,167</td>
<td>25.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1980</td>
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<td>59.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2001</td>
<td>118,000</td>
<td>100</td>
<td>2002</td>
<td>98,400</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Irrigated and non-irrigated villages

<table>
<thead>
<tr>
<th>Project and percentage of irrigated land</th>
<th>Number of villages</th>
<th>Average population, baseline year</th>
<th>Average population, 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riegos del Alto Aragón</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>9</td>
<td>579</td>
<td>575</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>15</td>
<td>1249</td>
<td>880</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>12</td>
<td>839</td>
<td>310</td>
</tr>
<tr>
<td>Canal de Aragón y Cataluña</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huesca (Aragón)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>10</td>
<td>1347</td>
<td>2245</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>9</td>
<td>1312</td>
<td>804</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>13</td>
<td>1134</td>
<td>367</td>
</tr>
<tr>
<td>Lérida (Cataluña)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>7</td>
<td>1274</td>
<td>2837</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>6</td>
<td>1696</td>
<td>2352</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>9</td>
<td>973</td>
<td>484</td>
</tr>
</tbody>
</table>

Note: Baseline years are 1910 and 1900 for Riegos del Alto Aragón and Canal de Aragón y Cataluña respectively.

Sources: For population data, Censuses of Population, various years, Madrid; For percentage of irrigated land, A. Ibarz, *El canal d’Aragó y Catalunya: Cent anys d’esperança i de progrés*, Huesca, 2005, and unpublished data provided by the Regional Government of Aragón (*Gobierno de Aragón*), Department of Agriculture.
Table 3.
Riegos del Alto Aragón: Percent change in population compound annual growth rate, 1910-2001

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area as percentage of total cultivated land (average of villages)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>-0.3</td>
<td>0.1</td>
<td>0.9</td>
<td>-0.7</td>
<td>0.02</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>-0.2</td>
<td>-0.2</td>
<td>-0.1</td>
<td>-0.5</td>
<td>-0.3</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>-0.1</td>
<td>-1.1</td>
<td>-1.8</td>
<td>-0.9</td>
<td>-1.1</td>
</tr>
<tr>
<td>Provinces</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huesca</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.2</td>
</tr>
<tr>
<td>Huesca, rural</td>
<td>-0.2</td>
<td>-0.5</td>
<td>-1.2</td>
<td>-0.6</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Note: The compound annual growth rate or the geometric average growth rate represents the year-over-year growth rate. It can be explained using the following calculation: \((\text{Ending date}/\text{Starting date})^{1/n} - 1\); where \(n\) refers to the number of years from start to end. Rural Huesca and Lérida refer to the average of villages below 10,000 inhabitants.

Source: Censuses of Population, various years, Madrid.
Table 4
Canal de Aragón y Cataluña: Percent change in population compound annual growth rate, 1900-2001

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated area as percentage of total cultivated land (average of villages)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Huesca (Aragón)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>0.8</td>
<td>0.8</td>
<td>0.3</td>
<td>-0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>0.5</td>
<td>0.5</td>
<td>-0.1</td>
<td>-0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>-0.5</td>
<td>-1.1</td>
<td>-1.8</td>
<td>-0.9</td>
<td>-1.1</td>
</tr>
<tr>
<td><strong>Lérida (Cataluña)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 75 per cent</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Between 25 and 75 per cent</td>
<td>0.8</td>
<td>0.4</td>
<td>0.6</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>-0.1</td>
<td>-0.6</td>
<td>-1.3</td>
<td>-0.8</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

Provinces

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Huesca</td>
<td>-0.03</td>
<td>-0.1</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.2</td>
</tr>
<tr>
<td>Huesca, rural</td>
<td>-0.1</td>
<td>-0.5</td>
<td>-1.2</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
<tr>
<td>Lérida</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Lérida, rural</td>
<td>0.2</td>
<td>-0.2</td>
<td>-0.6</td>
<td>-0.01</td>
<td>-0.2</td>
</tr>
</tbody>
</table>

Note: For the compound annual growth rate, see Table 3. Rural Huesca and Lérida refer to the average of villages below 10,000 inhabitants.
Source: Censuses of Population, various years, Madrid.
Table 5.
Population density: inhabitants per km$^2$

<table>
<thead>
<tr>
<th></th>
<th>Baseline year</th>
<th>2001</th>
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<tbody>
<tr>
<td><strong>Riegos del Alto Aragón (Huesca)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 25 per cent</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td><strong>Canal de Aragón y Cataluña, Huesca</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 25 per cent</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td><strong>Canal de Aragón y Cataluña, Lérida</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 25 per cent</td>
<td>40</td>
<td>94</td>
</tr>
<tr>
<td>Less than 10 per cent</td>
<td>34</td>
<td>19</td>
</tr>
<tr>
<td><strong>Provinces</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huesca</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Lérida</td>
<td>21</td>
<td>30</td>
</tr>
</tbody>
</table>

Notes: Baseline years are 1910 for Riegos del Alto Aragón and 1900 for Canal de Aragón y Cataluña and the provinces of Huesca and Lérida.

Source: Censuses of Population, various years, Madrid.
Notes


5 M. Evenden, Precarious foundations, 90.


8 L. A. Camarero, Pautas demográficas; C. Faus and A. Higuera, Does a demographic deficit exist?,  

9 X. Tafunell, Urbanización y vivienda, in A. Carreras and X. Tafunell (Eds), *Estadísticas Históricas  

10 R. Nicolau, Población, salud y actividad, in A. Carreras and X. Tafunell (Eds), *Estadísticas  
Históricas*, 77-154.

11 See, for example, C. Faus and A. Higuera, Does a demographic deficit exist?; and O. de Cos and  
P. Reques, Modernización económica.

12 See the importance of irrigation in Huesca in relation to the national total in V. Pinilla, The  
development of irrigated agriculture in twentieth-century Spain: a case study of the Ebro basin,  

13 J. M. de Ureña, *La gestión de la planificación territorial. Análisis del caso de los regadíos del Alto  

14 A. Paniagua, Consecuencias sociodemográficas de la creación de nuevos regadíos en la provincia  

15 S. Parra, Secanos y emigración, in J. Domínguez-Lasierra (Ed.), *Historias de los regadíos*,  
Zaragoza, 1974, 220-222; M. Sanagustín, El Plan Nacional de Regadíos: impacto en Aragón,  
*Revista de Estudios Agrosociales* 175 (1996), 249-264; C. Faus and A. Higuera, Two examples of  
environmental transformation.

16 In their valuable book on Riegos del Alto Aragón. J. M. García-Ruiz, T. Lasanta and F. Biarge,  
*Agua, tierra y paisaje. Complejidad y diversidad en el territorio de Riegos del Alto Aragón*, Zaragoza,  
2003, 93, include a graph showing the evolution of population for irrigated and non-irrigated areas in  
the long run (index numbers). The baseline year, however, refer to a date, 1900, much before the  
beginning of hydraulic works (1915). The authors, in addition, neither report figures nor explain  
criteria defining irrigated and non-irrigated areas (number of inhabitants and extent of irrigation in  
each village, changes across time, establishment of new colonization villages, etc.).

17 A. S. Oberay, Migration, Urbanisation and Development, 79.

18 A. Gil-Olcina and A. Morales-Gil (Eds), *Hitos históricos de los regadíos españoles*, 1992, Madrid;  

19 A. Gil-Olcina, Las políticas hidráulicas del reformismo ilustrado, in A. Gil-Olcina and A. Morales-Gil  
(Eds), *Hitos históricos*, 143-181.

20 E. Pérez-Pérez, Disposiciones decimonónicas sobre aguas. Ley de 1879, in A. Gil-Olcina and A.  

21 N. Ortega, El Plan Nacional de Obras Hidráulicas, in A. Gil-Olcina and A. Morales-Gil (Eds), *Hitos  
históricos*, 335-364; J. Romero, El Plan Nacional de Obras Hidráulicas. Precedentes y  
condicionantes, in A. Gil-Olcina and A. Morales-Gil (Eds), *Planificación Hidráulica en España*, 1995,  
Murcia, 257-282.

22 Two recent studies on Regenerationism’s ideology written in English are S. L. Driever, “And since  
heaven has filled Spain with goods and gifts”: Lucas Mallada, the Regenerationist movement, and

23 J. Gómez-Mendoza, Regeneracionismo y regadíos, in A. Gil-Olcina and A. Morales-Gil (Eds), *Hitos históricos*, 231-262.


26 N. Ortega, La política hidráulica, 160.


28 S. L. Driever, Lucas Mallada, 41.


39 Colonization of new settlements slowed down since the early 1970s. In this regard, see A. Paniagua and V. Rodríguez, *Agrarian Reform*, 102-103.


43 *El Mundo*, 22 March 2007, p. 46.

44 *Heraldo de Aragón*, 14 December 2006, p. 5 , “[L]a agricultura ... es inviable sin regadío y mantener el territorio y evitar que todos acabamos en Zaragoza es importante”.


47 The Regional Government of Aragón (*Gobierno de Aragón*), Department of Agriculture, has provided unpublished data, based on surveys carried out in 1988, for the case of Huesca. For Lérida, see F. García-Pascual, *La ganadería en Cataluña*, Lérida, 1998, 202.

48 In the case of RAA, we did not consider the sixteen new colonization villages established from the 1950s onwards. We deal with this issue below.

49 The complete list of villages is available from the authors upon request.


52 C. Frias, Los regadíos en el siglo XIX. La reivindicación del agua, in C. Laliena (Ed.), *Agua y progreso social. Siete estudios sobre el regadío en Huesca, siglos XIX y XX*, Huesca, 1994, 163-194; A. Sabio, La incidencia del regadío, 150.

53 A. Sabio, La incidencia del regadío, 144-192.


57 L. Germán and C. Forcadell, La crisis finisecular, 81-87; V. Pinilla, Evolución de la producción agraria, 115-116; A. Sabio, La incidencia del regadío, 158.

58 V. Pinilla, Evolución de la producción agraria, 118-119.


65 A. Paniagua and V. Rodríguez, Agrarian Reform, 99-100; N. Ortega, Algunas orientaciones de la política agraria española posterior a la guerra civil: de la colonización a la ordenación rural, in A. Gil-Olcina and A. Morales, Medio siglo de cambios agrarios, 15-29; C. Barciela and M. I. López-Ortiz, La política de colonización, 351-353.

66 J. M. Naredo, La evolución de la agricultura, 203-206; A. Sabio, La incidencia del regadío, 185-186.

67 A. Sabio, La incidencia del regadío, 171. The demographic evolution of the sixteen colonization villages established between 1946 and 1968 was very negative indeed. In this regard, see A. M. Martínez-Cordón, Los poblados de colonización en el sistema de Riegos Bardenas-Alto Aragón, Geographicalia 25 (1988), 145-155; J. M. García-Ruiz, T. Lasanta and F. Biarge, Agua, tierra y paisaje, 84-90.


71 A. Sabio, La incidencia del regadío, 176.


A. Ibarz, *El canal d’Aragó y Catalunya*, 100 and 109; V. Bretón, Regadío y colonización agraria en el occidente catalán: las tierras de Lleida y la zona regable del Canal de Aragón y Cataluña bajo el franquismo, in V. Pinilla (Ed.), *Gestión y usos del agua*.

J. J. Mateu, Entre la especulación y la modernización, 6 and 15. See also J. Simpson, *La agricultura española*, 184-185.

Some problems in relation with poor water control, such as salinization and paludism, appeared in the early years. See L. Germán, *Obras Públicas e ingenieros en Aragón durante el primer tercio del siglo XX*, Zaragoza, 1999, 37; and J. J. Mateu and F. García-Pascual, *Conmemoración*, 28-29.


J. Mateu, Entre la especulación y la modernización, 21; J. J. Mateu and F. García-Pascual, *Conmemoración*, 29; J. M. Ramón, Los usos del agua en la cuenca del Ebro: la agricultura de regadío en Lleida y Tarragona durante el siglo XX, in V. Pinilla (Ed.), *Gestión y usos del agua*.

J. J. Mateu, Entre la especulación y la modernización, 21.


Colonization projects in this area, for a number of reasons, were marginal. See V. Bretón, *Tierra, estado y capitalismo*, 166, 208 and 354.


V. Bretón, *Tierra, estado y capitalismo*, Lérida, 2000, 231 and 354; J. J. Mateu and F. García-Pascual, *Conmemoración*, 50; V. Bretón, Regadío y colonización agraria en el occidente catalán: las tierras de Lérida y la zona regable del Canal de Aragón y Cataluña bajo el franquismo, in V. Pinilla (Ed.), *Gestión y usos del agua*; V. Pinilla, La agricultura de regadío en Aragón en el siglo XX, in V. Pinilla (Ed.), *Gestión y usos del agua*; J. M. Ramón, Los usos del agua en la cuenca del Ebro: la agricultura de regadío en Lleida y Tarragona durante el siglo XX, in V. Pinilla (Ed.), *Gestión y usos del agua*.


J. J. Mateu and F. García-Pascual, Conmemoración; V. Pinilla, The development of irrigated agriculture, 137; J. L. Pérez-González, Criterios de gestión, 198.

In this regard, see L. M. Frutos, Los cambios en la agricultura, 788.