Historia Agraria, 94 · Diciembre 2024 · pp. 165-201 · DOI 10.26882/histagrar.094e03b 

# Water for Whom? Unravelling the Allocation of Water Storage Capacity between Irrigation and Electricity Uses in Spain during the 20th Century

María Isabel Bartolomé-Rodríguez, Mar Rubio-Varas
and Diego Sesma-Martín

KEYWORDS: **water allocation, energy, irrigation, Spain.**

JEL CODES: **O2, Q4, Q15, Q25.**

*This work explores the intricate dynamics of water management, energy generation, and irrigation in Spain by examining the evolving regulatory framework governing water resource allocation. It introduces a novel approach to quantify water usage and unpacks the 'mixed uses' category for the first time, focusing on entities holding water allocation concessions rather than mere dam ownership. Our findings reveal the profound influence of private electricity companies on water resource management, despite the significant portion of state-owned dams. The results point to hydroelectric dominance in water allocation and underscore the complex interaction between public ownership and private management of electric companies. This research emphasises the need for nuanced policy considerations in the broader context of energy and agriculture while contributing to a richer understanding of Spain's unique water governance landscape.*

# ¿Para quién es el agua? El reparto de los usos del agua embalsable entre el regadío y la electricidad en España durante el siglo xx

PALABRAS CLAVES: **asignación de agua, energía, regadío, España.**

CÓDIGOS JEL: **O2, Q4, Q15, Q25.**

*Esta investigación examina la complejidad de la relación entre la asignación de recursos hídricos, la generación de energía y el regadío en España. Esta tarea se acomete tras el examen de la evolución del marco regulatorio de la asignación de recursos hidráulicos e introduciendo un enfoque novedoso para cuantificar los usos del agua. Por vez primera, se descompone la categoría de usos mixtos, que corresponde a la mayoría de los embalses de propiedad pública, gracias a la información disponible sobre las entidades que disponen no de la propiedad sino de las concesiones de agua. Nuestros resultados revelan el significativo peso de las compañías eléctricas privadas en la gestión de los recursos hidráulicos, pese a la prevalencia de la propiedad pública de las infraestructuras. La hegemonía hidroeléctrica en la asignación del agua contribuye a hacer patente la complejidad de la relación entre la propiedad pública y la gestión privada de las infraestructuras por parte de las compañías eléctricas. Finalmente, la contribución a una mejor comprensión de la singularidad histórica de la gobernanza del agua en España apuntala la necesidad de consideraciones más matizadas en el terreno de políticas que conciernen las relaciones entre agricultura y energía.*

Received: 2023-12-20 · Reviewed: 2024-04-03 · Accepted: 2024-06-19

**María Isabel Bartolomé-Rodríguez [orcid.org/0000-0001-9219-2916]** *is senior lecturer of Economic History and Institutions at the Universidad de Sevilla (US) and researcher at the Instituto de Economía y Negocios de la Universidad de Sevilla (IUSEN). Address: Despacho 45, Departamento de Economía e Historia Económica, Facultad de Ciencias Económicas y Empresariales, Universidad de Sevilla, Av. de Ramón y Cajal, 1, 41018, Sevilla. E-mail: mbartolome@us.es*

**Mar Rubio-Varas [orcid.org/0000-0002-8100-2651]** *is professor of Economic History and Institutions at the Universidad Pública de Navarra (UPNA) and researcher at the Institute for Advanced Research in Business and Economics (INARBE) at the same institution. Address: Despacho 2041, Departamento de Economía, Facultad de Ciencias Económicas y Empresariales, Universidad Pública de Navarra, Campus de Arrosadia s/n, 31006, Pamplona (Navarra). E-mail: mar.rubio@unavarra.es*

**Diego Sesma-Martín [orcid.org/0000-0002-6787-594X]** *is lecturer of Foundations of Economic Analysis at the Universidad de La Rioja (UR). Address: Despacho 005A, Departamento de Economía y Empresa, Facultad de Ciencias Empresariales, Universidad de La Rioja, C/ La Cigueña 60, 26006, Logroño (La Rioja). E-mail: diego.sesmam@unirioja.es*

## 1. INTRODUCTION

As the most arid country in Europe, water scarcity has been a persistent challenge for Spain. To mitigate this pressing issue, the construction of dams has been a prominent solution, providing a means to store and manage water resources. In fact, with more than 1,200 reservoirs and dams, Spain is the first European country and the fifth region in the world in terms of hydraulic infrastructures (Fernández Cebrián, 2023). These infrastructures turned out increasingly important during the 20th century. From 1905 to 2005 a high correlation is observed between the augmentation in the use of water and the reservoirs building, as well as an intensive correlation among the increase of water use and the expansion of the area of land equipped for irrigation in the world (Duarte *et al.*, 2020: fig. 8). The storage of water in reservoirs not only involves acquiring and inundating private land, which is the most obvious spillover effect, but also granting control over the flow of water in a specific channel. It affects users upstream and downstream, but more importantly, it determines who decides when and how the water is released. While multiple uses may coexist, they are hierarchically prioritised, as the quantity, quality, and timing of water releases at certain sites of the stream are the relevant factors for answering the question: for whom is the water stored in dams?

The history of water concessions provides valuable insights into who the primary beneficiaries of this storage water have been. Despite an ostensibly agrarian discourse, the arid country wholeheartedly embraced electrical infrastructure, arming itself with the necessary tools and resources[1]. As well as for agriculture, the availability of abundant and high-quality water is essential for all electricity generation processes. While hydroelectric power relies on specific hydrological conditions, all other electricity generation technologies (except solar and wind) require water to function, mainly as a cooling medium[2].

In most parts of the world inland water is a public good (Menéndez Rexach, 2012), but the Spanish administrative concession mechanism seems to have been progressively privatising the use of its flows since the de-heritage of water in the 19th century. Public regulation, through concession systems, has established, with fluctuations, a priority in the uses of the currents that assigns –to individuals/companies and a main purpose– the waters in a certain

1. For water stress, as a limiting factor in agricultural production in Spain, see Garrabou and Naredo (1996), González de Molina (2002), Santiago Caballero (2013), Serrano *et al.* (2022); for the importance of irrigation as a modernising factor, see Duarte *et al.* (2014). The political discourse in favour of increasing water-regulation infrastructures for equipping land for irrigation started out closely linked to Regenerationism (Joaquín Costa, Lucas Mallada and Macías Picavea), to the Congresos Nacionales de Riegos, the first of which was held in Zaragoza in 1913 (Díaz-Marta, 1997; Fernández Clemente, 2000; Bartolomé, 2011).

2. The hydro-dependency of the Spanish electrification, in Bartolomé (2007), Sesma-Martín and Rubio-Varas (2017), and Sesma-Martín (2019).

place and for a certain period. Despite the series of public initiatives, specifically the relevant irrigation plans of 1902 and 1933, mostly oriented to favour irrigation (Lorenzo, 1933; Gil Olcina, 2001; Mateu, 2002), the chronology of water-storage assignment in Spain was initially driven by hydroelectric development and afterwards by the rest of electric exploitation. The Ley de Aguas (Water Act) from 1876 did not hamper the early hydropower settlements whilst agrarian interests were still pushing for diverting water-facilities as irrigation channels and other means of extracting groundwater (Calatayud & Martínez Carrión, 1999). According to the law, water-power permissions were assigned on a first-come, first-served basis, with no priority given to energy uses. This was because they minimally interfered with upstream and downstream water users, including agricultural users, similar to hydromechanical sites. The enactment of the mandatory registration at district level (provincial) of the water users in 1903 provided larger guarantees: transparency and protection of property rights to water permissions recipients (Bartolomé, 2011).

This collaborative paradigm between electricity companies and irrigators came to an end coinciding with the times of the First World War. The rapid expansion of large-scale hydroelectric projects, driven by advances in long-distance electricity transmission and dam construction, led to new legislation[3]. This legislation allowed for the aggregation of water permissions to increase water storage facilities based on the principle of public interest[4]. Between 1917 and 1921 a set of legislation granted the preference of large water exploitation, dam-building included, as hydroelectricity demands were upscaling and most of the technologically available water-sites were already assigned. An early period of rapid dam-building and struggling between electricity companies and irrigators started with consecutive periods of rhetorical preference for one over the other among legislators: whilst the Primo de Rivera's dictatorship unequivocally embraced the electricity companies' goals, the Second Republic with its Plan Nacional de Obras Hidráulicas of 1933, supported agrarian and regionalist interests (López-Gunn, 2009). This approach came to an end in early Francoism, but with tiny legislation changes. In 1941, the Alarcon dam was passed by a decree which inaugurated a procedure which persisted during the rest of this regime[5]. A sizeable infrastructure was assigned to a community of users as being declared of national interest (including agrarian and electricity interests), but the priority of use was given to the electricity company Hidroeléctrica Española (Tedde & Aubanell, 2006: 224-25). The method was consecutively employed in the remainder of the important water allotments during the fifties, sixties, and early seventies. The changes that the new 2001 Water Act (Ley de Aguas) encompassed did not alter the bulk of the water-damn assignment.

3. The evolution of power transmission in Guarnieri (2013: 60). The consolidation of new building techniques, in Gómez Navarro (1932).

4. On the legislative action in the electricity sector, see Garrués (2022).

5. *Boletín Oficial del Estado (BOE)*, 5 November 1941; *BOE,* Decree 4 December, 18 December 1941.

Consequently, an intriguing paradox emerges when examining the relationship between water storage capacity and its allocation in Spain. Our hypothesis is that, despite agrarian and collectivist rhetoric, the main beneficiaries of hydraulic concessions were private utility companies, not the State or collectives like Hydrographic Confederations. Energy uses were prioritised over agricultural and other water uses. We are not the first ones to put forward this hypothesis. For example, Gaviria *et al.* (1978) and Ponce and Juárez Sánchez-Rubio (2015) pointed in a similar direction for the Francoist regime. But we want to quantify the issue, before and after the dictatorship, and put it in relation with the institutional setting. As a first approximation, Figure 1 illustrates the log transformed evolution of the three variables (water storage capacity, electricity installed capacity and the area of land equipped for irrigation)[6]. Despite the fact that irrigable land experienced its largest growth in the period from 1950s to 1980s (Cazcarro *et al.,* 2015), which fuelled the myth of the agrarian achievements of the Franco's regime[7], the correlation between installed electricity capacity and dammed water stands at a striking 0.97, surpassing the correlation of 0.92 between irrigable surface and storable water. This indicates that changes in electricity installed capacity were more strongly linked to changes in storable water levels, compared to the relationship between irrigated land and storable water.

Furthermore, comparing the irrigable surface area in relation to the evolution of the overall arable land in Spain also shows a surprising balance. The most intensive growth is not centred on the decades of the mid-century, but from 1970 onwards, when groundwater for irrigation became increasingly important (see Table 1).

This apparent contradiction forms the basis of our inquiry, as this paper seeks to delve into and shed light upon this paradox, unravelling the complex interplay between water management, energy generation, and agricultural claims in Spain. This paper provides a comprehensive analysis of the allocation of the water storage capacity in Spain throughout the 20th century by final use, advancing a methodology to unpack the so-called *mixed uses*. When referring to the institutions that determine the prioritisation, rights, and final uses of water in rivers and dams, we use the term *water allocation*. Water allocation in this paper specifically denotes the process of assigning or distributing water-storage resources among various uses and users, taking into account factors such as availability, demands, and regulations. It accurately captures the decision-making and distribution aspects of

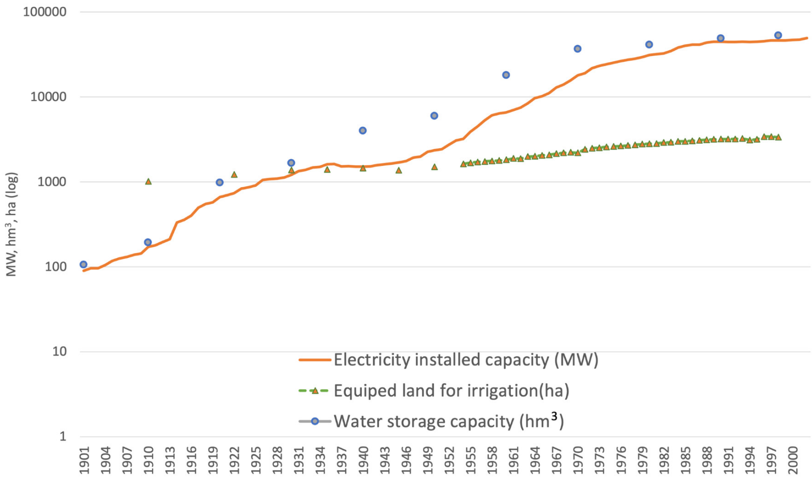
6. Logarithmic transformation is commonly used to stabilise variance and linearise relationships in variables that exhibit exponential growth, like it is the case of the three variables studied here.

7. The myth of the great agrarian achievements of Franco's regime has been very pervasive and also extended to the 1940s. According to Camprubí (2017: 119), the area of land equipped for irrigation increased twofold during the 1940s, following the Public Works Plan of 1940. Unfortunately, no evidence is shown to support this assertion and our data contradict it. The percentage of agricultural land equipped for irrigation of the total Spanish agricultural area went from 7.74% in 1940 to 7.60% in 1950. For a full overview, see Table 1.

water management, highlighting the allocation of water rights and the determination of usage priorities (Dinar *et al.*, 1997: 2-5). Therefore, the objective of this study differs from the water accounting literature and others, which quantify consumptive uses and non-consumptive uses of water, or even volumes of polluted water, by using methodologies such as that of the water footprint (Aldaya *et al.*, 2021).

**FIGURE 1**

**Water storage capacity, electricity installed capacity and area of land equipped for irrigation. Spain, 1900-2000**




Sources: water storage capacity, in Ministerio de Agricultura, Pesca y Alimentación (several years); electricity installed capacity, in Carreras and Tafunell (2005) and Red Eléctrica de España; irrigated area, own estimation by Bartolomé from data in Cuadro E1, in GEHR (1991), *Anuario de Estadística Agraria (1940, 1945, 1950, 1955)* and Cuadro 4.18, and Carreras and Tafunell (2005).

Consequently, first we will examine the evolution of the regulatory framework governing the allocation of water resources, focusing on legislative changes that have occurred over time, introducing the paradigm shift between the productivism and the environmental management of water. Secondly, we will explore the measurement of water storage capacity allocation by considering the various uses. Our approach in the allotment of water differs somewhat from previous publications, since we look at who has the concession over the water use rather than the declared property of the dam. On most occasions property and concession of water rights do not match. Yet concessions are not listed in a unified register of records, accessible as a public source and need to be reconstructed[8].

8. The 1985 regulation eliminated the Central Register by entrusting each inter-community basin organisation with setting up a Water Register of exploitation facilities with an outlet within its territorial area. All that it maintains, for precautionary reasons, is the requirement of a copy of all Water Registers in the Environment Ministry, a copy that at present does not exist (Ministerio de Medio

That is probably why, when aggregating dammed water in Spain, previous studies reflect only the property of the dam, instead of who has the right to use the water. In those studies, the accumulated dammed water appears to be mostly public[9]. We will focus on the evolution of the quantity of water theoretically storable in dams and its allocation among competing uses over the 20th century in Spain. Dammed water is the principal way by which society makes economic use of fresh water, but not the only one. Direct use of water currents for electricity generation –without the need of a permanent dam– or extracting subterranean water for irrigation remain important (Young & Haveman, 1985). Yet, dams constitute the largest water infrastructure mainly located in the middle river basins, where the dispute with irrigation is most evident[10]. Lastly, we will investigate the main repercussions of dammed water allocation, considering the diverse range of uses and users impacted by these decisions. By addressing these questions, we aim to shed light on the complex dynamics surrounding water resource management in Spain and provide valuable insights into the historical quantification of who has had the rights to use the dammed water in Spain.

**TABLE 1**
**Evolution of equipped land for irrigation, arable land, and irrigated area over total arable land in Spain, 1910-90**

| Year | Equipped land for irrigation (ha) | Total arable land (ha) | Irrigation/total arable land (%) |
|---|---|---|---|
| 1910 | 1,017,149 | 16,479,000 | 6.17 |
| 1920 | 1,220,390 | 17,228,000 | 7.08 |
| 1930 | 1,386,173 | 18,779,000 | 7.38 |
| 1940 | 1,454,376 | 18,782,000 | 7.74 |
| 1950 | 1,508,169 | 19,856,000 | 7.60 |
| 1960 | 1,828,300 | 20,522,500 | 8.91 |
| 1970 | 2,198,400 | 20,519,500 | 10.71 |
| 1980 | 2,822,300 | 20,499,200 | 13.77 |
| 1990 | 3,199,000 | 20,172,000 | 15.86 |

Sources: own elaboration from GHER (1991) and Ministerio de Agricultura, Pesca y Alimentación (varios años).

Ambiente, 2000: 346, 335-39, English version). For the evolution of Water Registers in Spain, see Bartolomé (2011).

9. See figs. 337-338 in Water in Spain (Libro Blanco del Agua) (Ministerio de Medio Ambient, 2000).

10. We are aware that the question in dispute between irrigation and electricity is more complex than what is proposed here. On the one hand, water for irrigation was extracted very early and in abundance from underground aquifers in Spain (Calatayud & Martínez Carrión, 1999; Gil Olcina, 2001). On the other hand, priority in the use of dammed water at one point in the stream could be rectified downstream. However, the relevance of the concessions analysed here is unavoidable.

## 2. THE INSTITUTIONALISATION OF WATER ALLOCATION IN THE 20TH CENTURY

Public intervention in the allocation of uses and users to water resources arises from its status as a public good, encompassing the waterbeds and watercourses, as well as the inherent characteristics of the natural monopolies formed by their storage infrastructure, such as dams, and their distribution and diversion systems, including canals (Ciriacy-Wantrup, 1967; Barca, 2007).

**TABLE 2**
**Geographical classification of water allocation regimes**

| Typology | Water allocation |
|---|---|
| Semi-arid areas | Prevailing systems of water appropriation |
| (*e.g.* Spain) | Security of tenure: |
| | Water concessions, limited in time. |
| | Variety of rights, contracts, and capacities. |
| | Flexibility among uses and users: |
| | Limited or absent. |
| | Externalities compensation: |
| | None, single purchase. |
| Humid areas | Prevailing systems of riparian rights |
| (*e.g.* France, Switzerland) | Security of tenure: |
| | Less certainty of physical possession. |
| | Flexibility among uses and users: |
| | High or very high. |
| | Externalities compensation: |
| | Collective bargaining (riparians, downstream users, etc.). |
| | Right of veto. |

Source: own elaboration, based on Hutchins (1971) and Rosenthal (1992).

Regarding the regulatory framework governing access to and ownership of water rights, it is important to note that Spain has historically followed a model of hydraulic resource allocation based on appropriation, which is common in semi-arid regions (Hutchins, 1971). In the Spanish context, this involves granting specific site concessions with limited flexibility for changes in final uses and users, and lacking compensation for externalities. Access procedure by appropriation speeded up water concessions, particularly industrial ones until First World War, while in France the Water Law of 1898 until its final revision in 1919 enshrined the right of priority and veto by riparians and offered no guarantee of continuity to concessionaires (Lévy-Leboyer, 1994; Ingold, 2011). The Italian law, a case in between, favoured access, but in return did not discriminate between applicants. Concessions were allocated based on the order in which they were applied for. Although from 1897 there was an attempt to establish some criterion of priority in concessions, it was not until 1916 that hoarding was tackled and in 1919 an exhaustive inventory of public water uses was undertaken, but the rights of riparians were not definitively restricted until the Single Text of 1933 (Ottolino, 1993). Table 2 provides the key features of the water allocation regimes by type of region.

This appropriation general regime of access to water resources was specified by the guidance of the prevailing paradigm of water management. In recent history in Spain, two paradigms have been sequentially followed. On one hand, there was a paradigm focused on river control, which was characteristic of the 19th and 20th centuries. On the other hand, there is a more recent paradigm based on sustainability, which emerged in the late 20th century and consolidated in the early 21st century.

The first paradigm, known as the Regenerationist paradigm, persevered until the 1980s, throughout our entire study period, adopted with enthusiasm by the Franco regime (Fernández Clemente, 2000: Table 2). It focused on the State's dominant role and utilised supply strategies centred around subsidising and constructing large hydraulic works. These works aimed to increase water availability for irrigating arable land and hydroelectric development through the subsequent alternating construction of canals and reservoirs over time (diverting canals, dams, transfer canals) (Garrués & Iriarte, 2022). The second paradigm, the New Water Culture, emphasised citizen participation and advocated for a water management model based on sustainability and adaptation to scarcity (Moral, 2007).

The Regenerationist paradigm aimed to assert control over rivers through extensive state intervention, allowing different degrees of participation in decision-making by potential users and those affected by spillovers (hydrographic communities from 1926 onwards). Water was viewed as a mere resource for promoting economic and social progress. Water supply strategies, driven by a productivity-centred approach on both agriculture and energy, were justified by the principle of the common good. The State assumed the responsibility of ensuring water availability, regardless of the associated economic costs and/or environmental impacts of the associated hydraulic infrastructures. Cultural, emotional, and identity values attributed to water were disregarded within this paradigm. Moreover, the notion of limited resource availability was overlooked (Casajús, 2012).

The paradigm based on the New Water Culture emerged as a response to the unsustainability crisis triggered by the previous model. This new paradigm perceives rivers, lakes, and wetlands as dynamic ecosystems that provide diverse environmental services, extending beyond their role in water supply for productive purposes. Environmental flows, in terms of both quantity and quality, are no longer viewed as mere environmental considerations but rather as essential constraints on water availability for productive use.

Theoretically, Spain underwent a transition from an economic-centric model reliant on large-scale hydraulic projects supported by substantial public subsidies to a sustainable approach focused on novel demand management strategies and the preservation of the ecological health of aquatic ecosystems (Mairal & Bergua, 2003; Estevan & Naredo, 2004; Arrojo, 2005, 2009). Yet, water extractivism has proven to be very persistent and a change of hydraulic paradigm by itself has not solved the essential issues. Table 3 depicts the principal attributes of Spanish water paradigms.

**TABLE 3**
**Fundamental characteristics of the hydraulic paradigms in Spain, *ca.* 19th and 21st centuries**

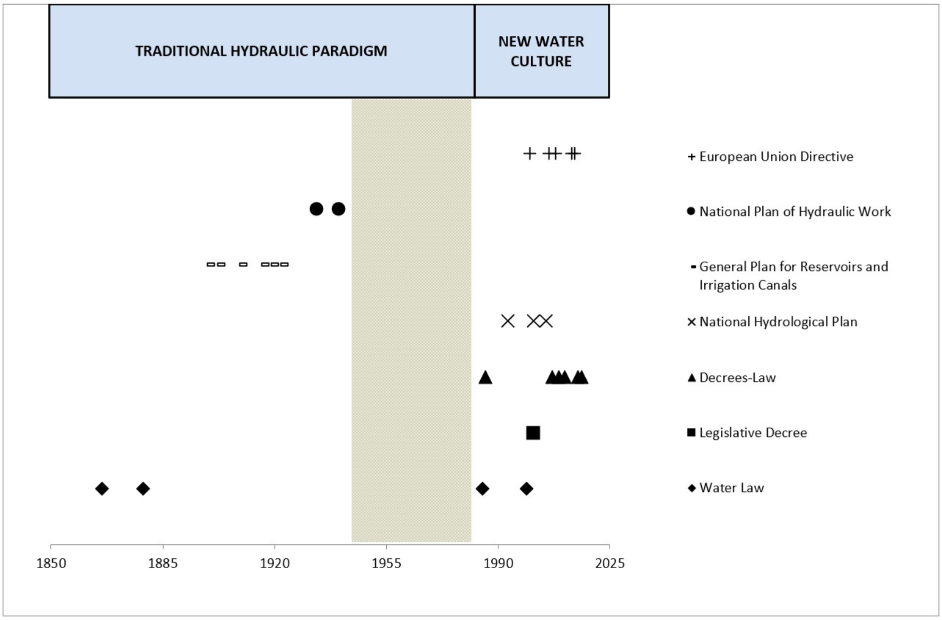
| | Traditional water paradigm | New Water Culture |
|---|---|---|
| Period | 19th and 20th centuries. | Late 20th century and consolidated in the 21st century. |
| Policy | Supply management policies through the construction of large hydraulic works (distribution, storage, and transfer, successively). | Demand management policies and institutional mechanisms. Environmental aspects of water quality and economic issues are considered equally in the management of the resource. |
| Grantees | Individuals, companies, and large corporations. | Individuals, companies, and large corporations. |
| Water uses | Water supply, irrigation, and hydroelectricity. | New uses: recreational, leisure (symbolic and cultural value of water), and ecological regulation. |
| Political-administrative scenario | State's central role. Extractivist behaviour of the State. | Public opinion, new actors, autonomy in resource management (State of Autonomies). |
| Discourse | Water for everyone. | Water forever. |

Source: own elaboration based on Gaviria (1977), Gaviria *et al.* (1978), and Baigorri (1999).

The regulatory framework adapted during our period of study to both the traditional hydraulic paradigm of water management and to the appropriation system of water allocation. By analysing this regulatory framework and the implications of the allocation system, we hope to contribute to a better understanding of water allocation practices in Spain throughout the 20th century and the complexities involved in balancing competing interests in allocating a scarce resource such as water, especially in Europe`s most arid country. Figure 2 visually summarises the broad chronology of the water regulatory framework in Spain.

As can be seen in Figure 2, the Spanish Liberal Revolution introduced changes in social relations that were also manifested in the management and uses of water. Running waters were declared public, the State retained ownership and the usage was granted under some conditions (Calatayud, 2016: 25), but the de-patrimonialisation of water also led to some forms of appropriation through the regime of concessions (Maluquer de Motes, 1983). First the water law of 1866 and, later, that of 1879 gave priority to private initiative in the exploitation of water for both uses (irrigation and energy), reserving subsidiary actions or actions of general, provincial, or local interest to the State. However, these principles of liberalism were attenuated in Spain at the beginning of the 20th century by the poor results obtained in the extension of irrigated land. At the end of the 19th century, the amount of equipped land for irrigation in Spain was approximately 900,000 hectares (Ortega, 1992), around 5% of total arable land according to Table 1.

**FIGURE 2**
**The evolution of water regulation in Spain, 1865-2025**




Source: own elaboration. See Appendix for details of the legislation involved.

The dawn of the 20th century marked a change in the direction of hydraulic works in Spain. In 1900 the Directorate General for Hydraulic Works enacted the immediate start of the technical studies necessary to establish a general plan for augmenting the water supply by promoting hydraulic works. Then, in 1901 the Regenerationism supported by Joaquín Costa inspired the drafting of the General Plan for Irrigation Canals and Reservoirs (the so-called Gasset Plan), being provisionally approved by

Royal Decree in 1902[11]. Despite its provisional nature, the 1902 Plan was the reference framework until the mid-1920s. This first plan was followed by other smaller partial plans for waterworks (1909, 1916, 1919 and 1922), all of them within the general framework of 1902 and linked to the application of extraordinary budgets, in order to improve the situation. The benefits of these works were eventually very limited until the 1920s and the inability of private initiative to take on the execution of irrigation works became evident. Since the 1911 Law on large irrigation systems[12], the construction of hydraulic infrastructures could be assumed by the State. During the Directory, its modification in 1925 opened the way to the direct execution of works by the government, but also the preference for large infrastructures and the increase of the subsidies in the case of including hydroelectric exploitation.

Hydrographic Confederations (originally Confederaciones Sindicales Hidrográficas) were designated from 1926 onwards to unify the functions of water administration in each large river basin in the Peninsula[13]. Agrarian and self-governance rhetoric encouraged these bodies with representation from all types of users involved in river basin management, but discretionary subsidies began to be fuelled to huge hydroelectric projects and irrigated land grew slightly (Bartolomé, 2011). Although this period came to an end with the Second Republic, prioritising irrigation projects through the Plan Nacional de Obras Hidráulicas by Lorenzo Pardo, it was later resumed by the facts during the Francoism and the Plan of Public Works of 1939[14]. A continuity on water policies followed by the new regimen is observed, as no new regulatory framework was decreed when dam building in Spain acquired momentum during the 1950s and 1960s, as figures 1 and 2 illustrate.

Indeed, Figure 2 clearly shows a legislative void regarding water-related matters in Spain from the mid-1940s to the mid-1980s. One might speculate that the regulations in place before the 1940s were adequate or that there was minimal change in Spanish river basins during those four decades. However, this hypothesis is contradicted by the fact that the majority of Spanish dams were constructed during this period, many of them

11. "Ministerio de Agricultura, Industria, Comercio y Obras públicas. Real orden disponiendo que por la Dirección general de Obras públicas se publique el plan de obras hidráulicas". *Gaceta de Madrid,* 29 April 1902.

12. "Ministerio de Fomento, Ley de 7 de julio de 1911 sobre construcciones hidráulicas con destino a riegos". *Gaceta de Madrid,* 8 July 1911.

13. With their own legal personality and functional autonomy, these public bodies, which play a fundamental role in the integrated and sustainable management of water resources, are responsible for the administration of inland waters flowing through a whole river basin. Among other functions, they are responsible for developing river basin hydrological plans, controlling and authorising the use of water for different purposes, and monitoring and protecting the public water domain.

14. *BOE,* 25 April 1939, p. 2236.

at sizes previously considered technically unattainable. Therefore, it is improbable that regulations dating back to the early 20th century were comprehensive enough to address this significant transformation. Instead, ad hoc decision-making took over during the period of the largest expansion of dams in Spain. The discretionary allocation system was inaugurated with a handful of simultaneous decrees, some of them of the utmost importance such as Alarcón, completion of Tranco de Beas, etc., in 1941[15]. All of them followed the same scheme: ownership was reserved by the State or granted to a semi-public entity, usually an ad-hoc created body; then, subsidies for the dam construction were defined, and the construction work and priority in final use were assigned by decree to the electricity company[16]. This mechanism avoided directly granting subsidies to electric companies (subsidies were for the dam construction), a practice used during the Primorriverist dictatorship. Following this scheme, the main hydroelectric concessions were administratively awarded to private electricity utilities and later used for thermal and nuclear purposes without changes to water legislation for over 40 years.

Throughout the closing decades of the 20th century, the increase in water uses and pollution, the incipient concern for environmental conservation, the democratisation of the country, together with other elements, led to the need for a revision of the water management model, which was reflected in the new Water Law of 1985, which replaced that of 1879 after more than one hundred years in force. Among other advances, the 1985 Law made groundwater public and incorporated the need for hydrological planning in the territorial scope of the river basin as a regulatory instrument that served to allocate resources and organise uses and actions in a coordinated manner, but in the Canary Islands. The Spanish Constitution of 1978 reaffirmed river basin management and the Hydrographic Confederations were re-founded as a result of the new law of 1985. These Confederations become more comprehensive river basin organisations. In 1986 Spain joined the European Economic Community. As a result, European water legislation became increasingly relevant, reaching its fundamental milestone with the publication of the Water Framework Directive in 2000 (Directive 2000/60/EC). This Directive aimed to address water degradation in Europe. The effect of the Water Framework Directive on Spanish legislation meant a greater focus on environmental aspects, but without forgetting that in the context of water scarcity the elements of availability and allocation of resources and management of uses continued to be important, but within a framework of sustainability. Thus, the objectives of the hydrological planning established by the Water Law (Revised Text of 2001) are twofold: to achieve good ecological status of the

15. Alarcón, Cornalbo and Tranco de Beas building works were speeded by simultaneous decrees on 4 December 1941, proceeding as explained. *BOE,* No. 352, 18 December 1941, pp. 9894-95.

16. The electricity companies had the right of first refusal to construction works and subsidies.

**TABLE 4**

**Technological development of competing uses of dammable water: electricity generation and land irrigation. Infrastructures, externalities, and relationships, *ca*. 1890-2000**

| Period | Electricity Generation | Electric sites | Electric infrastructures | Externalities: water quality | Irrigation infrastructure | Conflicts between irrigators and electricity companies | Collaboration between irrigators and electricity companies |
|---|---|---|---|---|---|---|---|
| 1890-1920 | Hydroelectric | High river courses | Runoff (diverting canals and weirs) | Non-consumptive, returns the entire flow | Distribution channels | Scarce: distribution points | |
| 1920-60 | Hydroelectric | Middle courses of the rivers | Runoff and dams, transmission lines | Non-consumptive, but stores water | Reservoirs and canals | Latent conflict: location of the reservoirs (flooding of towns and plains vegas) and seasonality of the release of water | Commonwealths and confederations |
| 1960-80 | Hydroelectric and thermal (coal, fuel oil, and nuclear) | Middle courses of the rivers | Large dams and runoff, transmission lines | Thermal generation technology returns water to a higher temperature | Canals, reservoir, and water transfers | Strong conflict: location, seasonality, water quality | Confederations, rural agricultural electrification (pumping) |
| 1980-2000 | Thermal (nuclear, coal), hydroelectric | Middle courses of the rivers | Large dams and runoff, transmission lines | Thermal and nuclear generation return water at higher temperature | Canals, reservoirs, water diversions and groundwater extraction | Lower conflict: location, seasonality, and water quality | Confederations, agricultural electrification (pumping) |
| 2000 onwards | Thermal (nuclear, natural gas, coal), hydroelectric, wind, solar PV | Middle courses of the rivers (gas-fired power plants often use seawater; neither solar nor wind power requires water) | Large dams and runoff, transmission lines | Introduction of environmental flows | Groundwater extraction canals, reservoir, and water transfers | Localised conflict (Tagus-Segura water transfer) and at specific times of drought | |

Sources: own elaboration based on Bartolomé (2007) and Sesma-Martín (2020).

public water domain and to satisfy water demands, but within a framework of regional and sectoral balance.

## 3. DECISION MAKING AND BUILDING PROCESS

The planning and management of water depend on the interests of various stakeholders and entail implications for the risks faced by different parties. These disparities can give rise to social mobilisations, tensions, and even conflicts among the involved stakeholders (Gómez Fuentes, 2012). It is evident that the codes of perception and justification of a new dam significantly differ between the proponents and the affected communities. While the project proponents seek to justify it based on legal, political, economic, and technical grounds, the affected communities tend to rely on justifications of a distinct nature, often from an environmental, cultural, or even identity perspective (Sesma-Martín, 2020).

Despite the existence of other users and uses (from drinking water to recreational purposes), the main contenders for access and ownership of the reservoir water in Spain have historically been the electric companies and the irrigation communities for agricultural purposes. The trade-off between these two types of users was partly dependent upon the evolution of their technological requirements (Table 4), but the public regulation of the assignment procedure was the key factor (Ciriacy-Wantrup, 1967).

Throughout the Second Republic and Franco's regime, legislators expressed a rhetorical preference for irrigation communities over electricity companies (Ortega, 1984; Gómez Mendoza, 1992; Fernández Clemente, 2000). During the Second Republic, the Plan Nacional de Obras Hidráulicas (Lorenzo, 1934) organised and embodied the demands of irrigation advocates. Franco's regime represented the climax of this discourse, concealing a preference for the electrical use of reservoirs, with Franco himself as the main proponent of the agrarian narrative. Thus, on 28 May 1952, two major reservoirs were inaugurated between Cuenca and Valencia, the Alarcón Reservoir and the reservoir known as the Generalísimo (one of Franco's heteronyms), today known as Benageber. Franco expressed himself at the inauguration of the latter:

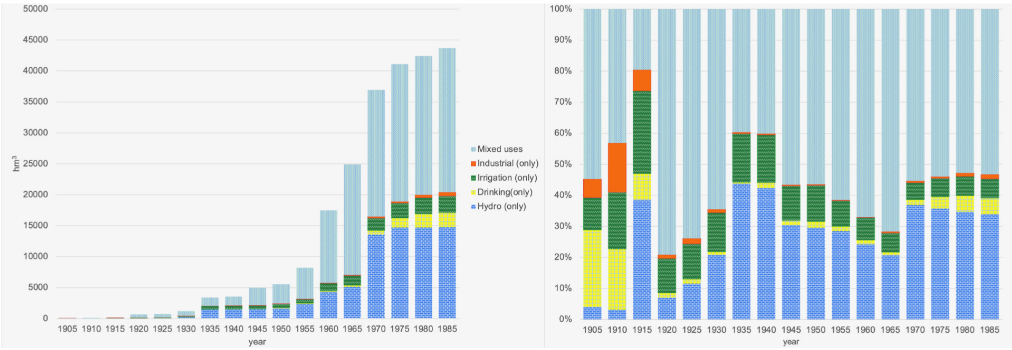
> In thirteen years, we have inaugurated 32 reservoirs and have 38 more under construction, which will soon contain billions of cubic metres of water. Today we are inaugurating two of them again: the Alarcón and the Generalísimo reservoirs. The significance of these reservoirs? The Count of Vallellano has said it very well: one year's harvests from the orchards irrigated by them are worth as much as their construction cost. This is the great task of our time in Spain. May these waters, dammed up here, blue and transparent, when they quench the thirst of your lands and make them produce and flourish, become gold for

> Spain. And gold for Spain means bread and work, peace and order, prosperity and greatness for our Spanish homeland[17].

Yet, the Benageber (aka the Generalísimo's Dam) was later assigned exclusively for hydroelectric use.

Figure 3 illustrates the dominance of the *mixed uses* category in the assigned use for water storage capacity throughout Spanish history. What the data shows is that during the central period of the Franco regime, the preference for the so-called *mixed uses* increased. While irrigation appeared to be a central concern in the rhetoric, in reality it was relegated to a residual category: the share of water storage capacity exclusively allocated for irrigation declined from 13% in 1950 to 6% in 1970. At the same time, the share of water storage capacity exclusively allocated for electricity generation increased from 29.5% to 37%. While public regulation seemed more favourable towards a paradigm of water for the future, not only was the reality that extractivism experienced the highest growth in the field of agrarian production (as shown in the Ebro's basin by Pinilla, 2008), but specifically in electricity production. Let's examine in detail how it worked by investigating what the mixed uses conceal, as historically, they represent the largest share of Spanish water storage capacity.

**FIGURE 3**
**Water storage capacity by official assigned use in Spain in absolute (left) and relative (right) values**




Note: both capacity increases and drop-outs have been corrected to the extent possible when reconstructing the annual accumulated series of water storage capacity.

Source: own elaboration adding the new dams' capacity to the pre-existing ones from MOPU (1988).

17. "28-05-1952: Inauguración del Pantano del Generalísimo en Benagéber, Valencia". Fundación Nacional Francisco Franco, https://fnff.es/actualidad/28-05-1952-inauguracion-del-pantano-del-generalisimo-en-benageber-valencia/.

## 4. QUANTIFYING THE USES OF WATER DAMMED IN SPAIN

The study draws on the inventory of dams compiled by the Spanish Ministry of Public Works (MOPU, 1988), covering 940 dams constructed prior to 1986, with a minimum height of 30 metres. Information collected includes the location, year of construction, and water storage capacity of each dam, as well as the authorised use of water (*e.g.* irrigation, energy, drinking, recreation, etc). For 689 dams, the authorised use was single-purpose, while the remaining 251 had multiple uses assigned (what was called "mixed uses" in Figure 3 above). We determined the allocation of water for these multi-purpose dams based on the qualitative description provided in the original source, assigning specific percentages as detailed in Appendix. We also performed a sensitivity analysis.

We chose 1986 as our cutoff point for several reasons. Firstly, it aligns with the limitations of our data source, as subsequent inventories lack the necessary information, particularly regarding water allocation. Secondly, it marks a significant turning point in our investigation, as the role of groundwater for irrigation began to significantly increase from the 1990s onwards. Moreover, 1986 is also strategically relevant for our study in terms of electricity generation, as nearly all electricity generated until that year relied on freshwater for either hydroelectric or thermal plant cooling. However, with the introduction of combined cycle groups, largely cooled with seawater, and the rise of renewable energy sources, the reliance on water for electricity generation has gradually diminished, making 1986 a suitable endpoint for our analysis.

It is important to highlight that in Spain there is often a discrepancy between dam ownership and water use rights. For example, the Cíjara Dam, one of the largest reservoirs in the country (see Fig. 4), is listed in the original source as owned by the Spanish State and designated for mixed uses: irrigation, electricity generation, and flood control, in that order. However, the Spanish State did not intervene in water concessions for electricity generation or irrigation rights. Electricity generation concession for the hydropower plant at the base of the Cíjara Dam was originally shared by three private electricity companies: Sevillana de Electricidad Company with a 50% stake, Hidroeléctrica Española with a 25% stake, and Unión Eléctrica Madrileña with the remaining 25% stake, grouped in what was known as Saltos del Guadiana Company (López Díaz & Riesco, 2020). The construction of the Cíjara Dam led to the creation of the Cíjara National Game Reserve in 1966 by the ICONA (National Institute for Nature Conservation), arguing the excellent hunting conditions in the forests of the Cíjara basin. In turn, the Cíjara Regional Reserve was a burden for agricultural development of the area, limiting the irrigation needs. In fact, a fourth generating group was requested by the concessionary company and approved by the government ten years after the hunting ground was created[18]. Thus,

18. *BOE,* No. 254, 22 October 1976, pp. 20730-31.

in truth, the water stored at the Cíjara Dam has historically been mostly destined to generate electricity. Thus, our quantitative approach examines the evolution of the theoretically storable water quantity in dams and its estimated allocation among competing uses throughout the 20th century by concession rather than by dam ownership.

To disambiguate the main destination of the water storable in dams is not an easy task even when it is theoretically only assigned to electricity generation. This can be illustrated with the water assignment for Cofrentes nuclear power plant. In 1977, Hidrola requested permission to extract 1,100 litres per second to cool the nuclear power plant from the Embarcaderos hydroelectric dam, which Hidrola had been operating since 1952. Yet, the assigned use of Embarcaderos Dam in our data source is merely hydroelectric, even if Cofrentes nuclear power plant was eventually connected to the national electric grid in October 1984, and no hydroelectricity was generated after that date from Embarcaderos Dam.

The licences system did specify the destination of the stored water at a specific location (a dam), but in the case of mixed uses did only loosely establish a priority but not the exact allocation of the amount of water to for the alternative allowed uses. Even in more recent times this remain unresolved, for instance, from 1999 for the entire territorial scope of the Júcar Hydrographic Confederation, the order of preference in instances where the ecological flow regulations make it necessary to reduce water use was defined as follows:

1) Drinking water supply.

2) Irrigation.

3) Hydroelectric generation.

4) Cooling of thermal and nuclear power plants.

5) Industrial, different from the previous two.

6) Aquaculture.

7) Recreational.

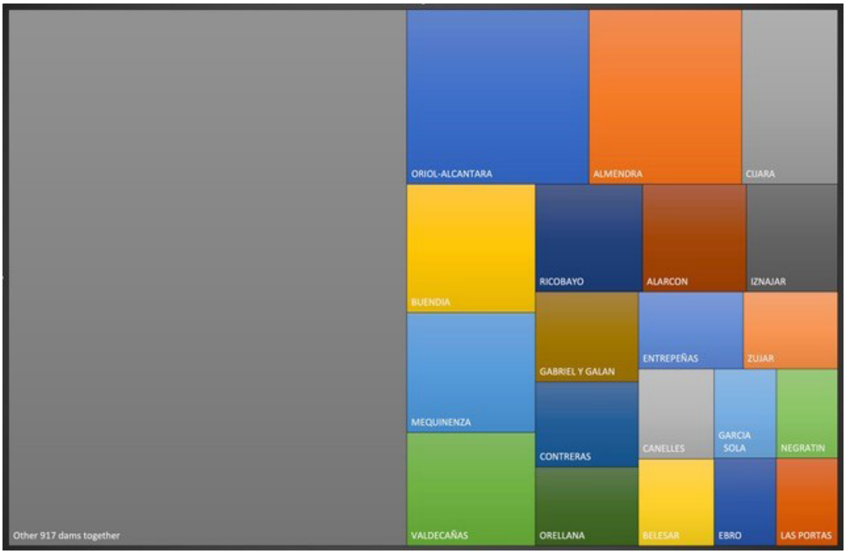
8) Other unclassified uses.

However, in the specific case of the cooling of Cofrentes nuclear power plant, the regulations include an exception specifying that nuclear cooling needs will be prioritised over irrigation needs (Sesma-Martín & Rubio-Varas, 2025). Hence, nuclear cooling jumps from fourth to second place in the order of preference, with only drinking water supply having a higher priority but no specific quantities of water allocated.

Hence, unpacking the mixed-uses dams, not only provides a snapshot of dammed water in Spain in 1986, but also allows for estimating the historical accumulated storable water capacity by final destination for each year, providing a unique long-term panoramic of the evolution of how water has been historically allocated in Spain. In the next sections, we first provide a short description of the situation in 1986, and then proceed to examine the evolution over time.

### 4.1. The situation in 1986

**FIGURE 4**
**Water storage capacity of the 20 largest dams *vs.* all the rest. Spain, 1986**




Note: proportionally drawn to reflect the water storage capacity (in hm³). Of a total of 44,000 hm³, the 20 largest dams together account for 22,900 hm³.
Source: own elaboration from MOPU (1988).

The capacity of dams in Spain in 1986 shows dependence on a few large dams, with 20 of them having the same joint water storage capacity as the remaining 917 dams (see Fig. 4). A quick review of these large dams also indicates a bias towards mixed –13 of the 20 largest dams in Spain by 1986 have assigned mixed uses. Once unpacked, the mixed uses reveal that the main destination of the stored water in the 20 largest dams in the country was hydroelectric generation: all of them had hydroelectricity as the main destination for the water stored, with 5 of them having it as its single authorised use[19].

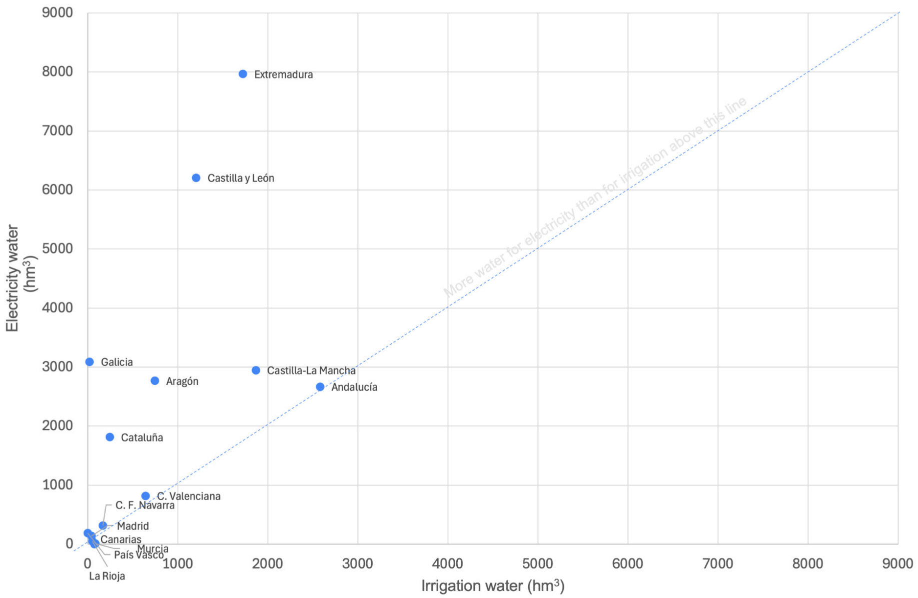
19. In the MOPU inventory the two largest dams (Oriol-Alcántara and Almendra) had hydroelectric generation as the single use assigned, as did Mequinenza, Canelles, and Belesar.

In fact, according to our base case scenario (see the Appendix), the main purposes of the overall theoretically dammed water in 1986 were electricity generation (64%), irrigation (23%), and other uses (12%).

The geographical distribution of the dams of course depends on the location of the riverbeds, but still, it is surprising the uneven distribution across the country. Even more so once we take into account the final uses of water. In all but three regions, more water was designated for electricity generation than irrigation in 1986. In the regions with the largest cumulative water capacity (Extremadura and Castilla y León), the vast majority of the water storage capacity had electricity generation as the main destination (see Fig. 5). The cases of Extremadura and Castilla y León (Amigo, 1989) should be highlighted as examples of regions sacrificed in pursuit of electrification. Almost half a century ago, Gaviria *et al.* (1978: 643) reflected: "Or any other measure aimed at reducing the monopoly currently exercised by the large electricity companies from outside Extremadura in appropriating hydraulic resources for their conversion into electricity, or at least to compensate for this appropriation to some extent".

**FIGURE 5**

**Water storage capacity by assigned use and region. Spain, 1986**

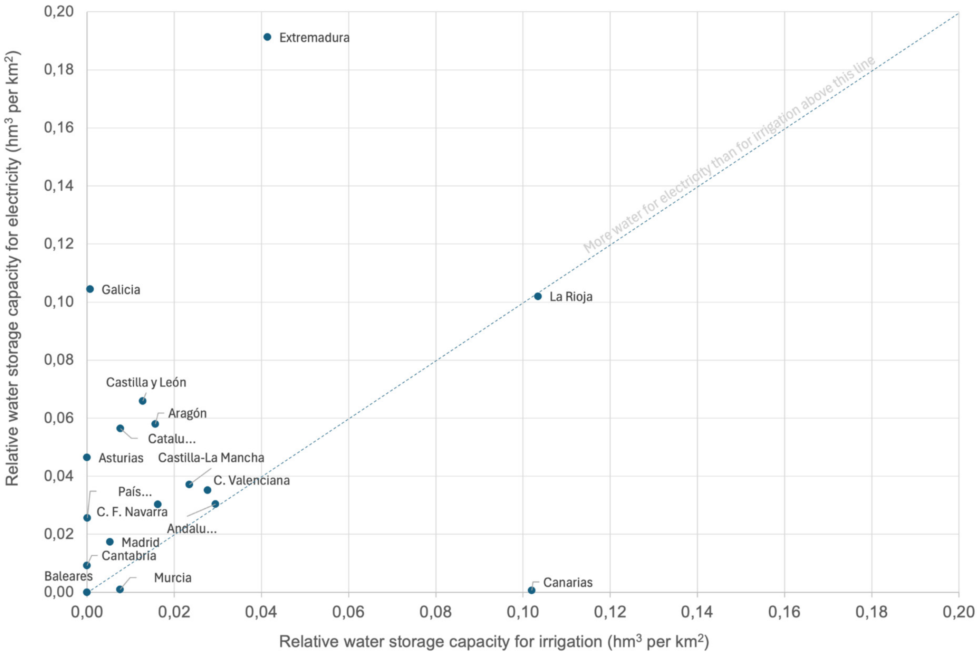



Note: the dotted line marks the frontier of equal amounts of water capacity storage for irrigation and electricity. Other uses of water excluded from the graph.

Sources: own elaboration from MOPU (1988) and the Appendix.

The findings from Figure 5 are influenced by scale, with larger regions naturally having higher cubic hectometre values. In Figure 6, we address this by presenting the results relative to regional surface area, aiming to mitigate the impact of size differences and enhance the clarity of the relationship observed. Conditions of physical geography determine where large bodies of water can be stored. But it is also important to note that, for the most part, humid Spain does not make a greater effort to store water than dry Spain. Figure 6 highlights that relative water storage capacity for electricity is dominant everywhere except in Murcia and the Canary Islands.

**FIGURE 6**
**Relative size of the water storage capacity by use and region. Spain, 1986**



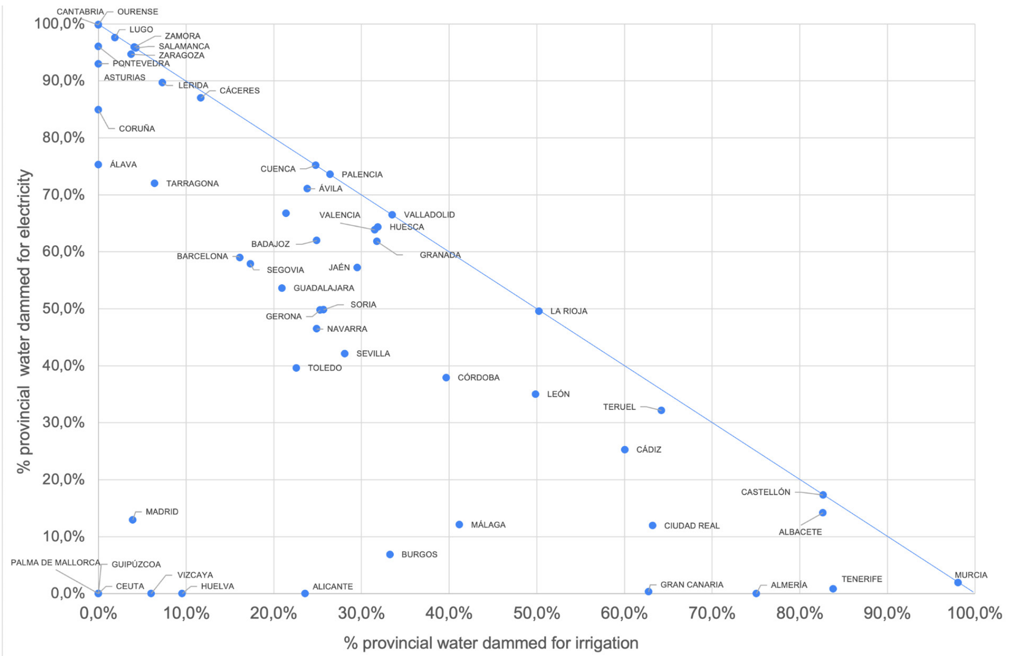

Note: the dotted line marks the frontier of equal amounts for irrigation and electricity. Other uses excluded from the graph.

Sources: own elaboration from MOPU (1988) and baseline scenario in Appendix.

In relative terms, Extremadura remains the region with the highest water storage capacity for electricity generation, even when adjusted for regional surface area, with a ratio of four to one. La Rioja stands out as the only region with almost equal water storage capacity for electricity generation and irrigation. However, this measure is highly influenced by the allocation decision for the largest dam in the region (Mansilla, used for both irrigation and electricity).

The distinct geography of the uses of water in Spain stands out more clearly when the analysis is done by province than by regions, as regions aggregate provinces with different water storage capacity and needs: in the provinces of the northwest, over 90% of the water storage capacity is destined for electricity generation, and less than 10% is used for irrigation. In contrast, in the southeast, the driest area in the country, where the water storage capacity is scarce in all cases, irrigation is the primary use (over 70%), with little or no water dedicated to electricity generation (see Fig. 7).

**FIGURE 7**
**Trade off share of water for electricity *vs.* share of water for irrigation by province, 1986**




Notes: see the text for "other uses".
Sources: own elaboration from MOPU (1988) and Appendix I.

Although there seems to exist some trade-off between water for electricity and water for irrigation in the data by provinces, there are also some interesting stories in the remaining to complete the 100% of the water capacity dammed which belongs to other uses. For instance, Burgos' largest dam (Ordunte) is a drinking water supply dam. Despite being located in Burgos, the ownership and management corresponds to the Bilbao City Council and exclusively supplies drinking water to the town, since the Basque city obtained a perpetual concession on these waters from the dictator Primo de Rivera, although it was

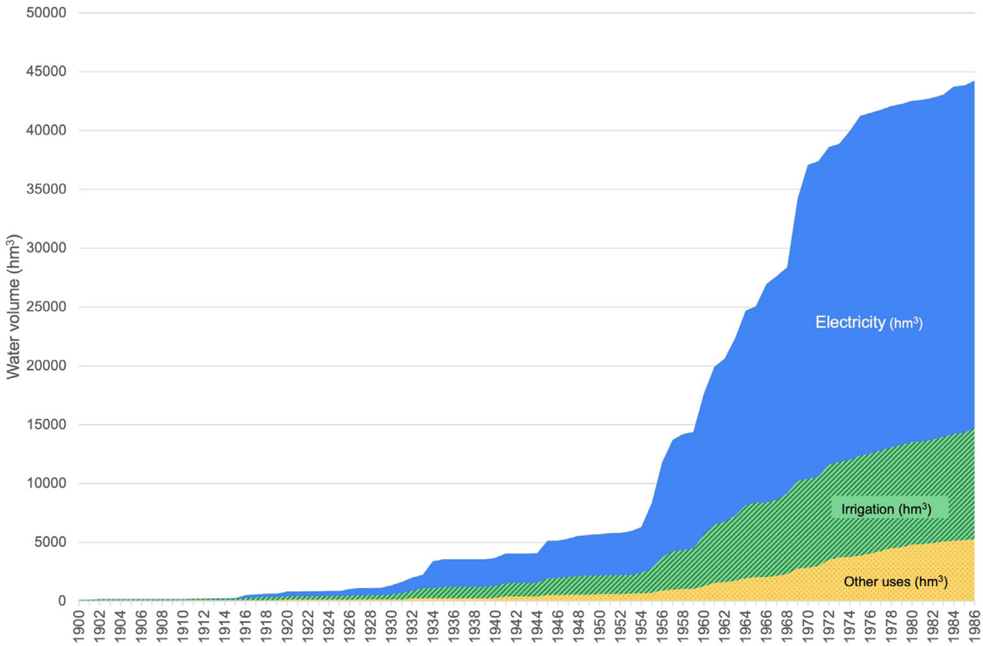

pp. 165-201 · Diciembre 2024 · Historia Agraria, 94

concluded in 1934[20]. Similarly, in Huelva, Vizcaya, Palma de Mallorca and Alicante, the largest dams in the province were built for supplying water to the population.

### 4.2. The evolution over time: public water infrastructures but private water management

Once we have identified all the dams by their year of construction and estimate the share of water for each use, we were to build an estimation of the historical accumulated water storage capacity by final destination for each year from 1900 to 1986 (Fig. 8). Both capacity increases and drop-outs have been corrected to the extent possible when reconstructing the annual accumulated series of water storage capacity.

**FIGURE 8**
**Water storage capacity in Spain by use after unpacking mixed uses, 1900-86**




Note: other uses include drinking water supply, recreation, flood control, navigation, canalization/derivation, industrial uses and fishing.

Sources: original data by MOPU (1988), our baseline estimates for unpacking mixed uses (see the Appendix).

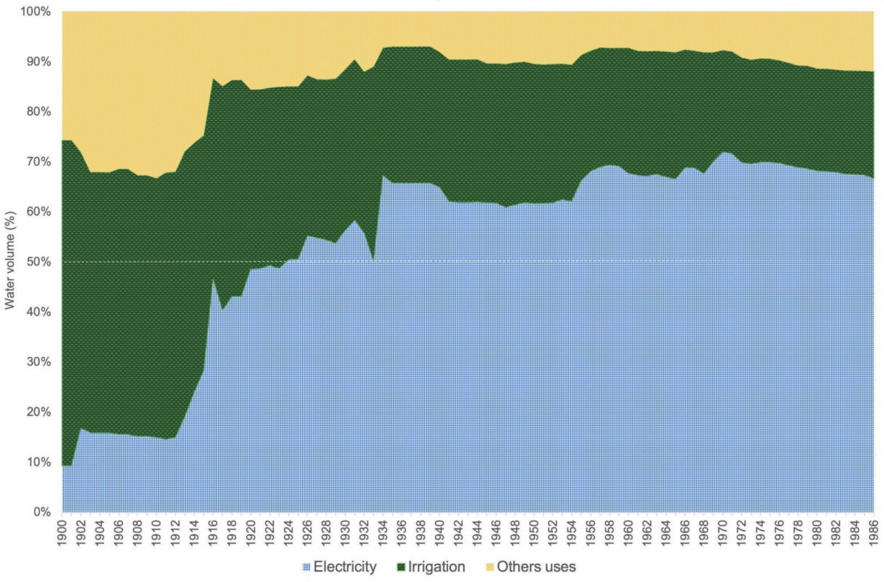
20. The concession was reviewed in its day (1985 Law) and currently has an expiration date (2061). Sociedad Española de Presas y Embalses, http://www.seprem.es/ficha.php?idpresa=766&p=30.

Unpacking the "mixed uses" category reveals that most of the water in Spanish dams was indeed destined for electricity generation from the 1930s and has remained so ever since. The evolution reflects the chronology of the electricity generation development in Spain described above (see also Table 3). In the first decades of the 20th century, with the diffusion of long-term transmission in electricity, the rush for building hydropower dams led to the sudden increase of storable water for electricity generation, eased by the reform of traditional allocation systems shifted in favour of sizeable infrastructures (1917 and 1927, Cambó and Guadalhorce decrees, respectively), driven by the lobbying of hydroelectric companies (Bartolomé, 2007). During the Primo de Rivera's dictatorship, the agrarian and collective approaches to water assignments seemed to prevail (*confederaciones hidráulicas*), but a major subsidy program was left in the government hands, which substantially favoured electricity interests (Bartolomé, 2011). In January 1931, the subsidies program was halted, but by the mid-1930s over 60% of the storable water in Spain was committed to generate electricity. On 8 September 1932, the State authorised the construction of the Alarcón Reservoir, considered the axis of the entire hydraulic redistribution of the Castilian Plateau. The State would go ahead directly with the construction of the reservoir, since it considered that this would prevent other concessionaires from harming the interests of irrigators. Lorenzo Pardo's Plan appeared in 1933 and the priorities actually reoriented in favour of irrigation (Ministerio de Obras Públicas, 1934).

This period came to an end with Francoism. The agrarian rhetoric remained, but the very Alarcón Dam was mainly reoriented to electricity power production (Tedde & Aubanell, 2006), as the whole country was suffering a deep shortage of power (Gómez Mendoza *et al.*, 2007). The pattern was replicated several times, the State retained either partial or total ownership of the dam and assumed part of the expenses, but electricity companies were designated as the major concessionaires. Under the umbrella of a collectivist and agrarian rhetoric, decisions were centralised and substantially favoured the interests of the electricity companies over the following decades fifties and sixties when the installed hydropower followed a similar pattern as the water storage capacity of the country. Garrués and Iriarte (2022: 9) have suggested that Spanish electricity companies were favoured in the electricity billing reform in 1954 and 1972 and with the control of dammed water in exchange for the expansion of the electricity network and the subsequent expansion of rural electrification. However rural electrification proceeded unhurriedly.

Indeed, the accumulation of water in dams experienced remarkable growth in subsequent decades, as evidenced by the data presented in Figure 8. However, what's particularly striking is the enduring dominance of hydroelectric purposes in water usage, which has remained a consistent feature up to the present day, as illustrated in Figure 9.

**FIGURE 9**
**Water storage capacity (%) by use in Spain after unpacking mixed uses, 1900-86**




Note: other uses include drinking water supply, industrial uses, recreation, flood control, navigation, canalization/derivation, and fishing.

Sources: original data by MOPU (1988), our baseline estimates for unpacking mixed uses (see the Appendix).

It is important to note that, according to sources such as the *Libro Blanco del Agua* (Ministerio de Medio Ambiente, 2000: figs. 337-338), approximately 55-67% of Spain's total water storage capacity has been under state ownership throughout the examined period. However, what truly underscores the complexity of the situation is that, despite this state ownership, our new estimates reveal that the management and control of the majority of Spain's water storage capacity have historically been firmly in the hands of private electricity companies. Since the 1930s, these companies have consistently managed 50-70% of the water storage capacity. This interplay between public ownership and private management has been absent from the legislative rhetoric, and to our knowledge, from most of the literature about water resource governance in Spain[21].

## 5. CONCLUDING REMARKS

This study delves into the intricate dynamics of water resource management in Spain, unveiling the often-overlooked interplay between public ownership and private control,

21. Some qualitative references on the hydroelectric character of the hydraulic policy during Francoism, in Ponce and Sánchez-Rubio (2015).

which has been a defining characteristic of the country's dammed water resources throughout its history. While a substantial portion of the Spanish dams are indeed under state ownership, our research underscores that the true complexity lies in the fact that private electricity companies have historically, and continue to, wield significant influence over their management and utilisation. This is consistent with the hydraulic resource allocation based on appropriation followed in Spain. Remarkably, this nuanced relationship, in particular the pre-eminence of the electric uses, has been notably absent from the legislative discourse and remains relatively underrepresented in existing literature on water resource governance in Spain. Focusing on the water concessions rather than on the property of the dams and unpacking the mixed uses category, we shed light on this critical aspect, offering fresh insights that contribute to a more comprehensive understanding of the Spanish water landscape.

Finally, we must acknowledge some limitations of our research. The implications of the mixed uses in the Spanish water concession system, which we prove was the most widely used from very early on, are constrained by an allocation system that loosely prioritises but does not specify the exact amount of water for each permitted use. We use the water storage capacity, representing potential water available in each dam. While this capacity is rarely fully achieved in some cases, it may be reached multiple times a year in others, as we aggregate reservoirs of various sizes and purposes: seasonal, annual, and pluriannual. One further limitation of our study is that we primarily focus on the exclusive allocation of dammed water to specific locations and time periods. While this approach provides valuable insights into the historical trends and dynamics, it does not capture the potential for broader, downstream uses that may occur at later stages. Future research could explore the downstream effects and secondary uses of dammed water. Yet, the monopolisation of large portions of river basins by electricity companies may just add to our conclusion rather than hampering it: downstream the water use remained electrical on many occasions. But this needs to be further explored. Another limitation is the exclusion of groundwater from our analysis. Groundwater resources are vital, particularly for agrarian purposes (Martínez Carrión & Calatayud, 2005; Garrués & Iriarte, 2022), and their interaction with dammed water systems could significantly impact water resource management strategies. To gain a more comprehensive understanding of water governance in Spain, future studies should consider the interconnectedness of surface water from dams and groundwater resources.

## ACKNOWLEDGEMENTS

This work belongs for the most part to the research project HAR2017-860086-R, although the final stages also benefited from the research project reference PID2023-146159OB-I00, both funded by MCIN/AEI/ 10.13039/501100011033 and by

"ERDF A way of making Europe". A preliminary version of this paper was presented at the I Colóquio Internacional Usos e Patrimónios da Água em Perspectiva Histórica (Évora, Portugal, 2024), the XXIV Reunión de Economía Mundial (Sevilla, Spain, 2024), and the XIII Congreso Internacional AEHE (Bilbao, Spain, 2022). We acknowledge the helpful comments and suggestions received. We express our gratitude for the observations of the anonymous reviewers of the journal *Historia Agraria*. Their comments led to significant improvements to this paper. The remaining errors are solely ours.

## REFERENCES

Aldaya, Maite, Sesma-Martín, Diego & Rubio-Varas, Mar (2021). Tracking Water for Human Activities: From the Ivory Tower to the Ground. *Water Resources and Economics*, (36), 100190. https://doi.org/10.1016/j.wre.2021.100190

Amigo, Pedro (1989). Orígenes y evolución de la especialización castellanoleonesa en la producción nacional de energía eléctrica. *Anales de estudios económicos y empresariales*, (4), 103-22.

Arrojo, Pedro (2005). Hacia una nueva cultura del agua. *Cuadernos del CENDES*, *22*(59), 139-43.

Arrojo, Pedro (2009). El reto ético del agua. *Relaciones Internacionales,* (12), 33-53. https://doi.org/10.15366/relacionesinternacionales2009.12.002

Baigorri, Artemio (1999). Del Estado depredador a la región sostenible. In Mini-Conference on The Environmental State Under Pressure, RC24 (ISA).

Barca, Stefania (2007). Enclosing the River: Industrialisation and the 'Property Rights'. Discourse in the Liri Valley (South of Italy), 1806-1916. *Environment and History*, (13), 3-23.

Bartolomé, Isabel (2007). La industria eléctrica en España (1890-1936). *Estudios de Historia Económica,* (50).

Bartolomé, Isabel (2011). ¿Fue el sector eléctrico un gran beneficiario de la política hidráulica anterior a la guerra civil (1911-1936)? *Hispania. Revista española de historia,* (71), 789-818. https://doi.org/10.3989/hispania.2011.v71.i239.360

Calatayud, Salvador (2016). Antes de la política hidráulica: La gestión del agua bajo el Estado liberal en España (1833-1866). *Historia Agraria,* (68), 13-40.

Calatayud, Salvador & Martínez Carrión, José Miguel (1999). El cambio tecnológico en los sistemas de captación e impulsión de aguas subterráneas para el riego en la España mediterránea. In Ramon Garrabou & José Manuel Naredo (Eds.), *El agua en los sistemas agrarios: Una perspectiva histórica* (pp. 15-39). Visor.

Carreras, Albert & Tafunell, Xabier (Eds.) (2005). *Estadísticas históricas de España, siglos xix-xx.* Fundación BBVA.

Cazcarro, I., Duarte, R., Martín-Retortillo, M., Pinilla, V., & Serrano, A. (2015). Water scarcity and agricultural growth in Spain: from curse to blessing?. In Natural Resources and Economic Growth (pp. 339-361). Routledge.

Camprubí, Lino (2017). *Los ingenieros de Franco: Ciencia, catolicismo y guerra fría en el Estado franquista.* Crítica.

Casajús, Lourdes (2012). *Nuevos paradigmas en la gestión del agua en España: Crisis de gobernabilidad del agua en Aragón: Los conflictos de Yesa y Matarraña*. PhD thesis. Barcelona: Universitat Autònoma de Barcelona.

Ciriacy-Wantrup, Siegfried (1967). Water Policy and Economic Optimizing: Some Conceptual Problems in Water Research. *American Economic Review, 57*(2), 179-89.

Díaz-Marta, Manuel (1997). *Las obras hidráulicas en España.* Doce Calles.

Dinar, Ariel, Rosegrant, Mark & Meinzen-Dick, Ruth Suseela (1997). Water Allocation Mechanisms: Principles and Examples (No. 1779). *World Bank Publications*.

Duarte, Rosa, Pinilla, Vicente & Serrano, Ana (2014). The Water Footprint of the Spanish Agricultural Sector: 1860-2010. *Ecological Economics,* (108), 200-07. https://doi.org/10.1016/j.ecolecon.2014.10.020

Duarte, Rosa, Pinilla, Vicente & Serrano, Ana (2020). Revisiting Water and Economic Growth from a Long-Term Perspective. In *Water Resources and Economic Processes* (pp. 9-33). Routledge.

Estevan, Antonio & Naredo, José Manuel (2004). *Ideas y propuestas para una nueva política del agua en España.* Nueva cultura del agua, 12. Bakeaz.

Fernández Cebrián, Ana (2023). Roots under the Water: Dams, Displacement, and Memory in Franco's Spain (1950-1967). In Luis Prádanos-Garcia (Ed.), *A Companion to Spanish Environmental Cultural Studies* (vol. 3, pp. 55-60). Boydell & Brewer.

Fernández Clemente, Eloy (2000). *Un siglo de obras hidráulicas en España: De la utopía de J. Costa a la intervención del Estado.* Prensas Universitarias de Zaragoza.

Garrabou, Ramon & Naredo, José Manuel (Eds.) (1996). *La fertilización en los sistemas agrarios: Una perspectiva histórica.* Visor.

Garrués-Irurzun, Josean (2022). The Regulation of the Spanish Electricity Sector: A Long Way to Convergence. *Energies, 15*(19), 6931. https://doi.org/10.3390/en15196931

Garrués-Irurzun, Josean & Iriarte-Goñi, Iñaki (2022). Rural Electrification in Spain: Territorial Expansion and Effects on the Agricultural Sector (c. 1900-c. 2000). *Rural History, 32*(2), 201-219. https://doi.org/10.1017/S0956793322000218

Gaviria, Mario (1977). *El Bajo Aragón expoliado: Recursos naturales y autonomía regional.* DEIBA.

GAVIRIA, Mario, NAREDO, José Manuel & SERNA, Juan (1978). *Extremadura saqueada: Recursos naturales y autonomía regional.* Ruedo ibérico. http://www.elrincondenaredo.org/Biblio-1978-Extremadura_saqueada.pdf

GIL OLCINA, Antonio (2001). Del Plan General de 1902 a la planificación hidrológica. *Investigaciones geográficas,* (25), 5-31. http://dx.doi.org/10.14198/INGEO2001.25.0

GÓMEZ FUENTES, Anahí Copitzy (2012). Movimiento social por una nueva cultura del agua en España. *Espacios públicos, 15*(35), 96-113.

GÓMEZ MENDOZA, Josefina (1992). Regeneracionismo y regadíos. In Antonio GIL OLCINA & Alfredo MORALES, *Hitos históricos de los regadíos españoles* (pp. 309-34). Ministerio de Agricultura, Pesca y Alimentación.

GÓMEZ MENDOZA, Antonio, SUDRIÀ, Carles & PUEYO, Javier (2007). *Electra y el Estado.* 2 vols. Thomson Civitas.

GÓMEZ NAVARRO, José Luis (1932). *Saltos de agua y presas de embalse.* 2 vols. Revista de Obras Públicas.

GONZÁLEZ DE MOLINA, Manuel (2002). Environmental Constraints on Agricultural Growth in 19th Century Granada (Southern Spain). *Ecological Economics, 41*(2), 257-70. https://doi.org/10.1016/S0921-8009(02)00030-7

GRUPO DE ESTUDIOS DE HISTORIA RURAL (GHER) (1991). ESTADÍSTICAS HISTÓRICAS DE LA PRODUCCIÓN AGRARIA ESPAÑOLA, *1859-1935.* Ministerio de Agricultura, Pesca y Alimentación.

GUARNIERI, Massimo (2013). The Alternating Evolution of DC Power Transmission [Historical]. *IEEE Industrial Electronics Magazine, 7*(3), 60-3. https://doi.org/10.1109/MIE.2013.2272238

HUTCHINS, Wells Aleck (1971). *Water Rights Laws in the Nineteen Western States.* Vol. 1. Natural Resource Economics Division, Economic Research Service, US Department of Agriculture.

INGOLD, Alice (2011). Gouverner les eaux courantes en France au xixe siècle: Administration, droits et savoirs. *Annales. Histoire, Sciences Sociales,* (1), 69-104. https://doi.org/10.1017/S0395264900005473

LÉVY-LEBOYER, Maurice (1994). Panorama de l'électrification: De la grande guerre à la nationalisation. In Maurice LÉVY-LEBOYER & Henri MORSEL, *Histoire générale de l'électricité en France 2: L'interconnexion et le marché, 1919-1946.* Fayard.

LÓPEZ DÍAZ, Juan Carlos & RIESCO, Sergio (2020). Extremadura y el cierre del oligopolio eléctrico en el oeste de España durante el régimen de Franco. *História e Economia,* 24 (1), 38-66.

LÓPEZ-GUNN, Elena (2009). *Agua para todos:* The New Regionalist Hydraulic Paradigm in Spain. *Water Alternatives, 2*(3), 370-94.

LORENZO, Manuel (1933). *Plan Nacional de Obras Hidráulicas.* Sucesores de Rivadeneyra, S.A.

Mairal, Gaspar & Bergua, José Ángel (2003). From Economism to Culturalism: The Social and Cultural Construction of Risk in the River Ésera (Spain). In *Anthropological Perspectives on Local Development* (pp. 85-105). Routledge.

Maluquer de Motes, Jordi (1983). La despatrimonialización del agua: Movilización de un recurso natural fundamental. *Revista de Historia Económica,* (2), 79-96. https://doi.org/10.1017/S0212610900012684

Mateu, Josep Joan (2002). Política hidráulica e intervención estatal en España (1880-1936): Una visión interdisciplinar. *Revista española de estudios agrosociales y pesqueros,* (197), 35-61. https://doi.org/10.22004/ag.econ.184336

Martínez Carrión, José Miguel & Calatayud, Salvador (2005). El cambio tecnológico en el uso de las aguas subterráneas en la España del siglo xx: Un enfoque regional. *Revista de Historia Industrial,* (28), 81-116. https://doi.org/10.1344/rhi.v1i28.19572

Menéndez Rexach, Ángel (2012). El agua como bien jurídico global: El derecho humano al agua. *Anuario de la Facultad de Derecho de la Universidad Autónoma de Madrid,* 187-202.

Ministerio de Agricultura, Pesca y Alimentación (varios años). *Anuario de Estadística Agraria.*

Ministerio de Medio Ambiente (2000). *Libro Blanco del Agua.* http://hispagua.cedex.es/node/66958 [English version available in https://www.miteco.gob.es/content/dam/miteco/es/agua/temas/planificacion-hidrologica/water-in-spain_tcm30-527170.pdf].

Ministerio de Obras Públicas (1934). *Plan Nacional de obras hidráulicas.* Suc. de Rivadeneyra.

Ministerio de Obras Públicas y Urbanismo (MOPU). Secretaría General Técnica. (1988). *Inventario de presas españolas, 1986.* Ministerio de Obras Públicas y Urbanismo.

Moral, Leandro del (2007). Desde la política hidráulica tradicional a la nueva cultura del agua. *Revista de Andorra,* (7), 45-60.

Ortega, Nicolás (1984). Las propuestas hidráulicas del reformismo republicano: Del fomento del regadío a la articulación del plan nacional de obras hidráulicas. *Agricultura y sociedad,* (32), 109-52.

Ortega, Nicolás (1992). El plan nacional de obras hidráulicas. In *Hitos históricos de los regadíos españoles* (pp. 335-64). Ministerio de Agricultura, Pesca y Alimentación.

Ottolino, Marco (1993). L'evoluzione legislativa. In Luigi De Rosa (Ed.), *Storia dell'industria elettrica in Italia 2: Il potenziamento tecnico e finanziario, 1914-1925* (pp. 465-509). Laterza.

Pinilla, Vicente (Ed.) (2008). *Gestión y usos del agua en la cuenca del Ebro en el siglo xx.* Prensas Universitarias de Zaragoza.

Ponce, Gabino & Juárez Sánchez-Rubio, Cipriano (2015). Del "Franquismo" al "Electro-franquismo": Las grandes infraestructuras hidráulicas al servicio de los modelos socioeconómicos de la España de la Dictadura (1939-1975). In Simposium Internacional de historia de la electrificación.

Rosenthal, Jean-Laurent (1992). *The Fruits of Revolution: Property Rights, Litigation and French Agriculture, 1700-1860.* Cambridge University Press.

Santiago-Caballero, Carlos (2013). Trapped by Nature: Provincial Grain Yields in Spain in the Mid-18th Century. *Revista de Historia Económica/Journal of Iberian and Latin American Economic History,* (31), 359-86. https://doi.org/10.1017/S0212610913000165

Serrano, Ana, Pinilla, Vicente & Duarte, Rosa (2022). A grandes transformaciones agrarias, grandes impactos hídricos: Un análisis histórico del consumo agrario de agua en España. *Sociedad de Estudios de Historia Agraria-Documentos de Trabajo. DT-SEHA,* (2202).

Sesma-Martín, Diego (2019). The River's Light: Water Needs for Thermoelectric Power Generation in the Ebro River Basin, 1969-2015. *Water, 11*(3), 441. https://doi.org/10.3390/w11030441

Sesma-Martín, Diego (2020). Cooling Water: A Source of Conflict in Spain, 1970-1980. *Sustainability, 12*(11), 4650. https://doi.org/10.3390/su12114650

Sesma-Martín, Diego & Rubio-Varas, Mar (2017). Freshwater for Cooling Needs: A Long-Run Approach to the Nuclear Water Footprint in Spain. *Ecological Economics,* (140), 146-56. https://doi.org/10.1016/j.ecolecon.2017.04.032

Sesma-Martín, Diego & Rubio-Varas, Mar (2025). Water: The Limiting Factor for Nuclear Power Generation in Spain? In Per Högselius & Siegfried Evens (Eds.), *The Nuclear-Water Nexus.* MIT Press.

Tedde, Pedro & Aubanell, Anna (2006). Hidroeléctrica Española (1907-1944). In Gonzalo Anes (Dir.), *Un siglo de luz: Historia empresarial de Iberdrola* (pp. 193-278). Iberdrola.

Young, Robert & Haveman, Robert (1985). Economics of Water Resources: A Survey. In Allen Kneese & James Sweeney (Eds.), *Handbook of Natural Resource and Energy Economics* (vol. 2, pp. 465-529). Elsevier.

## APPENDIX

The essential element in legislation regarding the use and exploitation of water in Spain is the concept of *administrative concession*. By means of concession, the Administration grants an individual a real entitlement to use the waters, under certain conditions, for a certain term. The granting of concessions is discretionary, and its priority is as laid down in the basin plans, that the resource must be dedicated to the granted use and may not be applied to other, different ones, nor different land in the case of irrigation (Ministerio de Medio Ambiente, 2000, English version). At least in theory. However, this allocation system only loosely establishes a priority but not the exact amount of water when alternative uses are allowed. Since no one knows the precise allocation of water on a yearly basis, we opted for the theoretical allocation of the water storage capacity. This is a maximum of the potential water available in each dam, that hardly, if ever, is obtained in some cases, but it may be achievable several times a year in other instances. Yet, the water storage capacity is a consistent measure across time and space.

The basic source of our database is an inventory of the Spanish dams which provides the designated use of the dammed water for 940 dams built before 1986 (MOPU, 1988: 29-68). The information collected includes the location, riverbed, year of construction, and water storage capacity of each dam, as well as the authorised use for the water. The list of designated uses includes the following:

Irrigation (I)

Energy (H)

Potable water supply (S)

Recreation (R)

Flood control (C)

Navigation (N)

Industrial uses (UI)

Canalization/derivation (D)

Fishing (P)

The Table A1 specifies how many dams are per label (or mixed labels which is what indeed defined the mixed uses) and how much water is accumulated under each category in 1986.

**TABLE A.1**
**Water allocation assigned for specific uses by 1986 of the Spanish water storage capacity (sorted by total cumulative water)**

| Water destination as described in the original source | Number of dams | Water storage capacity accumulated (hm$^3$) | Total number of dams (%) | Total hm$^3$ (%) |
|---|---|---|---|---|
| H | 243 | 14,778.4 | 25.9 | 33.4 |
| I/H | 57 | 12,253.6 | 6.1 | 27.7 |
| I/H/S | 19 | 4,695.3 | 2.0 | 10.6 |
| S | 173 | 2,319.2 | 18.4 | 5.2 |
| I | 273 | 2,248.2 | 29.0 | 5.1 |
| I/H/C | 1 | 1,670.0 | 0.1 | 3.8 |
| I/S | 35 | 1,569.0 | 3.7 | 3.5 |
| H/I/S | 8 | 976.7 | 0.9 | 2.2 |
| I/H/C/S | 2 | 725.0 | 0.2 | 1.6 |
| H/I | 14 | 722.9 | 1.5 | 1.6 |
| I/C | 5 | 540.6 | 0.5 | 1.2 |
| S/H | 6 | 360.0 | 0.6 | 0.8 |
| I/H/S/UI | 5 | 347.0 | 0.5 | 0.8 |
| UI | 41 | 252.1 | 4.4 | 0.6 |
| H/S | 3 | 214.0 | 0.3 | 0.5 |
| N | 1 | 133.0 | 0.1 | 0.3 |
| S/UI | 9 | 79.7 | 1.0 | 0.2 |
| D | 6 | 70.5 | 0.6 | 0.2 |
| S/I | 2 | 61.2 | 0.2 | 0.1 |
| S/UI/P | 1 | 60.0 | 0.1 | 0.1 |
| N/I/S | 2 | 34.0 | 0.2 | 0.1 |
| H/R | 1 | 34.0 | 0.1 | 0.1 |
| H/I/UI | 1 | 19.0 | 0.1 | 0.04 |
| D/I | 2 | 11.9 | 0.2 | 0.03 |
| R | 9 | 7.4 | 1.0 | 0.02 |
| I/UI/H | 1 | 7.0 | 0.1 | 0.02 |
| C | 2 | 5.0 | 0.2 | 0.01 |
| I/D | 1 | 5.0 | 0.1 | 0.01 |
| I/R/S | 1 | 4.0 | 0.1 | 0.01 |
| I/P | 5 | 3.8 | 0.5 | 0.01 |
| I/S/H | 1 | 3.0 | 0.1 | 0.01 |
| P | 6 | 2.1 | 0.6 | 0.005 |
| S/UI/D | 1 | 2.0 | 0.1 | 0.005 |
| P/S | 1 | 0.3 | 0.1 | 0.001 |
| S/I/H | 2 | 0.0 | 0.2 | 0.000 |
| **Total** | **940** | **44,313** | | |

Source: own elaboration from MOPU (1988: 29-68).

For 689 of the 940 dams in the inventory the designation was a unique use from that list, but the remaining 251 dams had mixed uses for which we had to decide the allocation of water. Those mixed-uses dams represent the majority of the water storage capacity for the most part of Spanish history (see Fig. 3 above). The single major use, however, is electricity production (H) with a 33.4% of water storage capacity in dams whose unique administrative concession was the production of electricity by 1986.

For the mixed-uses dams, our aim was to disambiguate who had the right to decide when to open the floodgates, for how long, and at which speed to empty the reservoirs. In our understanding, that is the most important decision, even if the water is later used downstream for another use (which may again be electric, or irrigation or else).

The key issue for us was to define whether I/H had the same implications of H/I. Since the first seems to indicate a priority for irrigation over electricity generation and the latter the contrary and the volumes involved are rather different (I/H accounts for 27% of the water storage capacity while H/I for just 1.6%), we needed to be reasonably sure about the allocation. We had no other option but to research individually the dams involved.

We researched the 57 dams in the second largest category (I/H). All reservoirs with the seven largest capacities in the I/H group have concessions to electricity companies, including some of the largest and most famous hydroelectric dams (Buendía, Valdecañas, Alarcón, Gabriel y Galán, Contreras, Entrepeñas, García de Sola). All together, these seven accumulate over 7,000 $hm^3$ of the 12,253 $hm^3$ of the I/H category. So, in our baseline scenario we allocated 75% of their water storage to electricity generation.

In the third largest category (I/H/S), the three largest dams accumulate over half of the water of the group and happen to be property of electricity companies once more: Endesa (Iznájar and Orellana) and Iberduero (Ebro). Given their ownership, it is challenging to allocate the majority of their water to uses other than electricity generation. In our baseline scenario for I/H/S dams, we allocated 50% for electricity, 25% for irrigation, and 25% for potable water supply.

Furthermore, there is only one reservoir labelled I/H/C (irrigation, energy and flood control) with a storage capacity that is, on its own, the seventh largest on our list. It happens to be the Cíjara Dam, which story we developed above: the water stored at the Cíjara Dam has historically been mostly destined to generate electricity. Thus, even if the irrigation label comes first, our preference was to allocate most of its water to electricity generation, as with I/H with 75% for electricity and 25% for irrigation.

We also investigated where the water for cooling thermal power plants (those generating electricity with coal, oil, or nuclear) appeared in the inventory. The answer is not straightforward: some thermal electric reservoirs are listed under industrial uses (*e.g.*, the reservoirs of Almaraz and Trillo for nuclear power plants, or Aboño which is a large coal-fired power plant). However, some thermal power plants have cooling water classified under mixed-use dams, such as the Compostilla thermal power plant (Bárcena Dam). To complicate things further, in some cases of large coal-fired power plants such as Velilla, the reservoir is sometimes listed solely for hydroelectricity. Therefore, water for cooling thermoelectric generation plants is not specifically identified but is embedded in various categories. This indicates that electric companies had even more control over water resources than our approach suggests.

As the precise percentages of water allocation for mixed-use dams are unknown, we conducted a sensitivity analysis to ensure our assignment decisions did not unduly influence our results. In this analysis, we explored various scenarios. These ranged from assigning up to 85% of the water to electricity generation in mixed-use dams and also adding the water from industrial-use dams used for thermal cooling, to progressively reducing the water allocated to electricity in mixed-use dams and excluding water for industrial use. We even considered scenarios with minimal water allocated to electricity generation in mixed-use dams (down to 25%), which, while inconsistent with the actual power generated, were useful for understanding the impact on our water allocation assessment. Table A.2 details the different scenarios, using a simplified categorization of Table A.1, based on our research.

**TABLE A.2**
**Sensitivity analysis of water attribution scenarios**

| Category | Super electric scenario (%) | | | Baseline scenario (%) | | | Equal shares scenario (%) | | | Marginal hydro scenario (%) | | | hm³ per category in 1986 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electr | Irrig | Other | Electr | Irrig | Other | Electr | Irrig | Other | Electr | Irrig | Other | |
| 1 | 100 | | | 100 | | | 100 | | | 100 | | | 14,778 |
| 2 | 85 | 15 | | 75 | 25 | | 50 | 50 | | 25 | 75 | | 14,646 |
| 3 | 80 | 15 | 5 | 50 | 25 | 25 | 33 | 33 | 33 | 25 | 50 | 25 | 6,416 |
| 4 | | | 100 | | | 100 | | | 100 | | | 100 | 2,511 |
| 5 | | 100 | | | 100 | | | 100 | | | 100 | | 2,799 |
| 6 | | 75 | 25 | | 75 | 25 | | 75 | 25 | | 75 | 25 | 1,623 |
| 7 | | 75 | 25 | | 25 | 75 | | 25 | 75 | | 25 | 75 | 73 |
| 8 | 85 | | 15 | 50 | | 50 | 50 | | 50 | 25 | | 75 | 493 |
| 9 | | | 100 | | | 100 | | | 100 | | | 100 | 364 |
| 10 | 100 | | | | | 100 | | | 100 | | | 100 | 252 |
| 11 | 85 | 10 | 5 | 25 | 50 | 25 | 33 | 33 | 33 | 25 | 60 | 15 | 357 |
| hm³ assigned | 33,335 | 7,266 | 3,712 | 29,307 | 9,478 | 5,528 | 24,604 | 13,613 | 6,090 | 20,256 | 18,441 | 5,615 | 44,313 |

Notes to simplified classification: 1 = H; 2 = I/H, H/I, I/H/C; 3 = H/I/S, I/S/H, H/I/UI, I/H/C/S, S/I/H; 4 = S; 5 = I, I/C; 6 = I/S, I/R/S; 7 = S/I, D/I; 8 = S/H, H/S; 9 = C, N, P, R, S/UI; 10 = UI; 11 = I/H/S/UI.

Source: Own elaboration from data described in Table 1 and in the text.

The sensitivity analysis shows that electricity generation remains the primary use of water across all scenarios, with significant allocation variations mainly in electricity and irrigation. Hydropower consistently emerged as the dominant use of water, among other things, because besides being the largest single category, the mixed uses majoritarily include a hydroelectric use in most occasions. Even in the most extreme case where minimal water was allocated to electricity in mixed-use dams (25%) the water for electricity still holds the upper hand. This is relevant because this last scenario is simply inconsistent with the historical hydroelectric generation. Despite the variation, the main point about most of the water remaining under the control of electricity companies holds true in the most extreme scenario, demonstrating the robustness of the findings. We believe that our base case scenario is fair to the historical use of water.

Table A.3 summarises the water legislation in Spain, collecting the information shown in Figure 2.

**TABLE A.3**
**Summary of water legislation**

| | 19th Century | 20th Century | 21st Century |
|---|---|---|---|
| Water Law | 1866<br>1879 | 1985<br>1999 (amendment of the previous law) | |
| Legislative Decree | | | Royal Legislative Decree 1/2001, of 20 July |
| Decree-Law | | Royal Decree 849/1986, of April 11 | Royal Decree 907/2007 approving the Hydrological Planning Regulation<br>Royal Decree 1341/2007, of 11 October<br>Royal Decree 1514/2009, of 2 October 2009, which regulates the protection of groundwater<br>Royal Decree 60/2011, of 21 January<br>Royal Decree 817/2015, of 11 September<br>Royal Decree 1075/2015, of 27 November<br>Royal Decree 638/2016, of 9 December |
| National Hydrological Plan | | 1993 (preliminary draft of the National Hydrological Plan) | 2001<br>2005 |
| General Plan for Reservoirs and Irrigation Canals | 1899 (advance of the General Plan) | 1902<br>1909<br>1916<br>1919<br>1922 | |
| National Plan of Hydraulic Work | | 1933<br>1940 | |
| European Union Directive | | | Directive 2000/60/EC (Water Framework Directive)<br>Directive 2006/7/EC<br>Directive 2006/44/EC<br>Directive 2006/118/EC<br>Directive 2008/105/EC<br>Directive 2013/39/EC<br>Directive 2014/80/EU |

Source: Own elaboration.