Sustainable Water Resources Management (2023) 9:157
https://doi.org/10.1007/s40899-023-00934-y

ORIGINAL ARTICLE

Bento Almeida d'Eça: Hydraulic Agriculture under the umbrella of Engineers in Nineteenth Century Portugal

Ana Duarte Rodrigues[1] · **Pier Luigi Pireddu**[1] · **Patricia Trindade Monteiro**[1]

Received: 27 January 2023 / Accepted: 18 August 2023 / Published online: 6 September 2023

Abstract

In mid-nineteenth century Portugal, the practice of irrigation was deemed to be completely backwards in comparison with the prevailing European standards. Distant were the times of Al-Andalus, when a so-called green revolution occurred on the Iberian Peninsula. Within this context, Agricultural Hydraulics gained momentum as a scientific field. Although water governance had a long run, the 'politicisation' of water issues clearly intensified in the Regeneration political regime. From 1851 onwards, the stability required for national material progress was ensured. The country had been struggling to build roads, railways, telegraphs, ports and, therefore, the Ministry of Public Works was established in 1852 to undertake these architectural and engineering projects. This paper argues that not only due to rivers' manipulation for agriculture, but also to the rising status of engineers, Agricultural Hydraulics was under the Ministry of Public Works and, consequently, on the sphere of engineers rather than agronomists. Focusing on the making of a military engineer as an expert on Agricultural Hydraulics by sending him abroad and fostering his literary education, this paper reveals how this knowledge was appropriated and transformed into new projects for the Tagus River. Moreover, contrary to recent review that Hydraulic Services were launched in Portugal by 1884, based on the "Plan for Organization of Hydrographic Services on the mainland of Portugal", this paper highlights the crucial role played by the Portuguese engineer Bento Fortunato Almeida d'Eça through his work as Superintendent of the Tagus River and its Tributaries, twenty years earlier.

Keywords Hydraulic agriculture · Hydraulic engineer · Piemont and Lombardy · Tagus River · Ministry of Public Works · Rivers' navigation and irrigation

Abbreviations

AHM	Arquivo Histórico Militar (Army Historical Archive)
BAME	Biblioteca e Arquivo do Ministério da Economia (Library and Archive of the Ministry of Economy)
BNP	Biblioteca Nacional de Portugal (National Library of Portugal)
BISA	Biblioteca do Instituto Superior de Agronomia (Library of the Superior Institute of Agronomy)

✉ Ana Duarte Rodrigues
amnrodrigues@fc.ul.pt

Pier Luigi Pireddu
pier.pireddu@gmail.com

Patricia Trindade Monteiro
patriciatrindademonteiro@gmail.com

[1] Centro Interuniversitário de História das Ciências E Tecnologia, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisbon, Portugal

Introduction

In mid-nineteenth century Portugal, the practice of irrigation was deemed to be completely backwards in comparison with the prevailing Western European standards. Distant were the times of Al-Andalus, when a so-called "green revolution" occurred on the Iberian Peninsula (Watson 1981; Glick 2005). In 1859, a student at the Instituto Agrícola e Escola Regional de Lisboa (hereafter Agricultural Institute) affirmed that "our country is very far from being equal in this respect with the more civilized nations of Europe and from consequently being able to enjoy the advantages that this agricultural improvement could provide to it." (Veiga 1859, fl. 27). Such complaints maintained that while most provinces lacked enough precipitation and humidity, water from rivers and streams, many completely unnavigable, might serve to irrigate the fields through an appropriate purpose-built system of channels. The problems were already long-standing, and the failings of the nineteenth-century irrigation systems were widely acknowledged, and to such an extent

that "There were sites worse than the most inhospitable in Africa" (Loureiro 1907, p. 18). Traditional and successful irrigation methods had been neglected and abandoned. Within this context, Agricultural Hydraulics gained momentum as a scientific field emergent in mainland Portugal.

From the eighteenth century onwards, the era of 'modernized traditional irrigation', interlinked with the Industrial Revolution, fostered the "professionalization of irrigation and meadow cultivation evolved across Europe" in conjunction with appropriate legislation and the foundation of societies and unions (Leibundgut and Kohn 2014, p. 280). The Agricultural Revolution that preceded the Industrial Revolution in Great Britain brought about change to many of Europe's traditional systems. Moreover, during the nineteenth century, growing population and respectively, urban concentrations, drove the demand for the expansion of irrigated agriculture. This was accompanied by the development of hydraulic technology for controlling major rivers and transporting water over long distances for irrigation. Many of these developments took place in Great Britain, Italy, France and Belgium.

Furthermore, in the countries where Hydraulic Agriculture originated, a wealth of systematic studies has been produced. Not coincidentally, there is also a remarkable conjunction of discourses at that very moment in critical theory, in engineering books, in agricultural treatises and manuals, and in hydraulics, all of which sought to improve irrigation. In fact, from 1860 onwards, and quoting Hermenegildo Gorria, we may concur that hydraulics went from empiricism to a science due to "mathematical analysis, which has been and is the basis for the research of formulas and exact theoretical solutions" to the physical conditions, and that is why they hold the character of generality following their application in the varied experiments already carried out (Gorria 1908, p. 124). The empirical task of irrigation became the scientific field of Hydraulic Agriculture.

In Portugal, following a civil war declared by absolutists against liberals (1832–34), political turmoil continued and only from 1851 onwards, the Regeneration political regime ensured the stability required for national material progress. The country had been struggling to build roads, railways, telegraphs, ports and, therefore, the Ministry of Public Works, Commerce and Industry (hereafter Ministry of Public Works) was established in 1852 to undertake these architectural and engineering projects. Despite the construction of modern infrastructures, agriculture was still envisioned as the major source of the kingdom's wealth and identified as needing urgent major improvements. This revitalization of agriculture reckoned recourse to rivers for the irrigation of fields as mandatory and this required construction works on rivers. Therefore, this paper unveils what has hitherto fallen beyond the scope of historiography: how irrigation was not considered an empirical activity of agriculture but rather a specific field of engineering in Portugal. In fact, it was developed under the tutelage of engineers from the Ministry of Public Works between 1852 and 1910, to such an extent that an exclusive and purpose dedicated section – the Board of Hydraulic Agriculture – was there established.

Nineteenth century irrigation, especially the successful tradition of meadows and pastures irrigation practiced in Central Europe has been investigated, identified as *water-meadows* in English, or *Wasserwiesen* in German, or *marcites* in northern Italy (Leibundgut 1985 and 2004; Leibundgut and Kohn 2011; Cabouret 1999; Cook et al 2003; Brown 2005; Everard 2005; Cook and Williamson 2007). Moreover, the major works carried out ever since medieval times to build canal systems in Lombardy has also drawn the attention of historians (Fantoni 2008; Pugliese and Lucchini 2010). In France, these topics have been studied by geographers and historians, who identified the different techniques deployed in several regions, beyond the legal, economic and social aspects involved in the various water cultures (Carrier 1932; Bethemont 1972 and 1999; Broc 1980 and 1992; Caucanas 1993; Ruf 2001; Romagny and Riaux 2007; Girel 2012). However, the question of the politicization of water was never as vital as for the Spanish case, when, between 1890 and 1930, the political movement called *Regeneracionism* used a hydraulic utopia to mobilize the country towards the modernization of the nation, and the experts leading it were envisioned as 'hydraulic heroes' (Costa 1911; Orti 1984; Swyngedouw 1999 and 2015; Boelens and Uiterweer 2013; Duarte-Abadia and Boelens 2019).

In Portugal, the regularization of rivers for agricultural improvement remains both unexplored and remarkably poorly understood. Despite some efforts to regularize the Mondego and the Tagus rivers made by the Priest Estêvão Cabral in the late eighteenth century (Leitão 2020, and for early modern Iberian water history, Rodrigues and Toribio 2020), problems were far from being solved. Moreover, in the field of history of agriculture and rural studies, despite significant contributions on Portuguese nineteenth century agriculture (Caldas 1998; Freire and Lains 2017), there has been no study of the branch of Hydraulic Agriculture.

From the history of technology point of view, historiography has emphasized the role that engineers played as harbingers of modernity, with their knowledge deemed more scientific by the political powers on account of their education in technical universities. Consequently, they were appointed to direct the construction of railways and national infrastructures (Buchanan 1978 and 1989; Picon 1994, 2004; Diogo 1994; Matos and Diogo 2006; Pereira 2021a, b and 2022; Silva 2020). However, this article highlights how the engineer class also ruled agriculture – a subject that has hitherto received scant attention from historians.

The starting point for the 'politicization' of water by central government was considered the "Plan for the

Organization of Hydrographic Services on mainland Portugal," which was enacted into legislation on March 6, 1884. This reflected how the essential contours of a national scale water policy began to be defined after this stage. Achieving this implied a systematic and scientifically informed assessment to ascertain the national water resources, to diagnose the intervention needs to improve their conditions of use and economic exploitation, as well as establishing an administrative structure to support these interventions and their supervision (Pato 2007). However, this paper will argue that water policy actually begins in an earlier period and merges into the overlapping world and expertise from which emerged that subsequently labelled as Hydraulic Agriculture.

Under the methodological framework of micro-history, we track the making of an expert in Hydraulic Agriculture working at the Ministry of Public Works—the Portuguese engineer Bento Fortunato Moura Coutinho de Almeida d' Eça (1825–1906). Portuguese hydraulic engineers have received occasional attention in international literature and in *Water Engineering and Management through Time*, the engineer Eça is acknowledged as a "successful practising hydraulic engineer who improved the water conditions of his country" (Cabrera and Arregui 2010, p. 156). In the Portuguese literature, there are some biographic studies and articles but they only focus on Eça's work for the railway system in the later phase of his life (Quintela 2002; Costa 2005; Hager 2010; Martins 2010; Pereira 2012). This article will demonstrate how this expert on hydraulic agriculture, who was a career of civil and military engineer, had been trained through a travel abroad, to regions where hydraulic agriculture was considered more advanced, without a hydraulic engineering course in Portugal to date, as it existed in Italy already by then. Moreover, we argue that these hydraulic engineers were overshadowed by the engineers responsible for building the railways in Portugal, unlike in neighbouring Spain where they were seen as true heroes; and, finally, this case-study thereby contributes to casting light onto the circulation of knowledge between centres and peripheries, and how this was appropriated and adapted to Portugal.

To unfold our arguments, we divided this article into four sections. The first tackles the making of an expert on hydraulic agriculture at the Ministry of Public Works – Eça –, and how the government opted to prepare an engineer for hydraulic agriculture rather than an agronomist, despite their preparation for the job. The second part addresses the engineer's agronomic travel to other European countries in which advanced hydraulic agriculture was practiced. Based on this expertise acquired abroad, he was expected to be able to apply it in revitalizing irrigation along the Tagus River. Hence, the third part highlights how this knowledge served in projects designed to revitalize agriculture in the fields along the alluvial plains of the Tagus River. Finally, the fourth part discusses the projects and management plans he designed with a committee for the Tagus River. Nevertheless, economic and financial setups seem to have undermined the vision this 'hydraulic hero' had for Portugal.

The making of a 'hydraulic agriculture' expert: Bento Fortunato Almeida d'Eca

The watering of cultivated fields has always been under the traditional wisdom of farmers. But in the nineteenth century, the empirical practices of irrigation became enshrined within the techno-scientific careers of engineers with much of its hitherto largely tacit knowledge transformed into a measurable and controlled activity. This is the case in Portugal, despite the fact that agronomists were being prepared for it. Contrary to what happened in other countries, agriculture was under the supervision of the Ministry of Public Works and it was within this framework that an engineer will be prepared for 'hydraulic agriculture'.

In other countries, such as France, agronomists took the lead in these matters. In that country, Hydraulic Agriculture was under the tutelage of the Ministry of Agriculture and the leading actor was an agronomist, the French Joseph de Mauny de Mornay (1804–1868), (Ingold 2009). The Minister of Agriculture asked Mornay to study the irrigation legislation of Piedmont (Mornay 1841 and 1844). Following his visit to the region, his report served to draft the law proposed by the government, and, in order to enforce this new legislation, he was appointed deputy head of the agricultural bureau in 1846. In 1848, the agriculture office he was running became a division of the Ministry of Agriculture. The government then acted to develop agriculture, establishing agricultural schools, regional schools and the Agronomic Institute of Versailles (Wery 1929). In France, irrigation was clearly a topic of the agriculture realm.

In Portugal, agronomists were also preparing themselves for this task. Especially as various voices claimed the country that "had always advanced itself through its agricultural products, exporting in great quantity, but which seemed to have forgotten all the traditions and retorted to primitive processes" (Loureiro 1907, p. 13). Therefore, it was considered as essential to restore the traditions of water wise management that had long been overlooked and were only still practiced in some vegetable gardens by a few farmers and gardeners.

The theses of Francisco Veiga and José Varella Sor presented at the Agricultural Institute provide such evidence (Veiga 1859; Sor 1868). Veiga's *Importância das Irrigações (The Importance of Irrigation)* starts out with a historical summary of irrigation covering the main achievements of the Egyptians, Greeks and Romans, who

had already highlighted the benefits of *solum irriguum* (irrigated land), (Veiga 1859, fl. 5–6). Later, the Moors are identified as the people with the best understanding of the utility of irrigation and introduced such practices into Europe's midi. The manuscript reveals that he was aware of the most important works made in Lombardy and Piedmont, standing out for incorporating both irrigations and navigation (Veiga 1859, fl. 7). Finally, Veiga deploys several examples from other countries to highlight what required doing in Portugal. This agronomist proposes that watering dry soils in southern Portugal was mandatory, through the storage of rainwater and by building artesian wells (Veiga 1859, fl. 36–37). And he also concludes that to take real advantage of irrigation, engineering works, social organizations (societies, companies) and financial inputs, such as those provided by bank financing, were all necessary (Veiga 1859, fl. 37–38). For an agronomist, he ends up by emphasizing the importance of engineers by stating that "the value of irrigated land is compared to that of rainfed land as is circulation on the railways to circulation on ordinary roads" (Buffon in Veiga 1859, fl. 26; Buffon 1867; on Buffon see Barraqué 2002). This puts engineers and railways as the barometer of modernity. Agronomists were not aware that by establishing these comparisons, engineers would take the lead even in their supposedly field of action.

Sor's Water and irrigated soils (1868) was another thesis presented to the Agricultural Institute on similar topics. It is divided into three parts: the first, includes general considerations about the benefices of irrigated soils; the second covers several aspects of the origin of water; and the third addresses the advantages of water supply to different cultures. It dealt with the benefits caused by water in the soil, such as the moisture it gave them, the substances it nourished the soil with, as well as due to its action as a solvent for various nutrients. Moreover, Sor called the attention to the role water supply played on the soil temperature regulation, and how it enabled current flows in the subsoil, allowing the soil's oxygenation (Sor 1868).

Despite the existence of students of agronomy dedicated to studying irrigation, the government opted to make engineers the experts in hydraulic agriculture. The Portuguese engineer Eça was the first to be prepared for the job. He played relevant roles in several branches of civil engineering, including railways, becoming the Director of Public Works and Mines of Lisbon in 1874, and general director in 1886 (Eça 1876–1877 and 1888; Eça et al 1888; Eça et al 1897). However, it was for hydraulic and agricultural matters that he became most notable (Loureiro 1907, p. 32).

Eça was of noble origins. He was the son of Dionisio de Moura Coutinho de Almeida d' Eça and his second wife, Teresa Febronia de Paiva Moura Coutinho and born in the family's villa under the coat of arms of the Almeidas, in the district of Aveiro, northern Portugal, on 17 October 1827 (Pereira and Rodrigues 1907, p. 106). During the civil war, the family lost part of their fortune. Nevertheless, Eça's father was able to maintain their lifestyle and educate his ten children (Martins 2010, p. 6).

Eça developed an academic parcourse in parallel to a military career, beginning both in 1845. This year, Eça began studying mathematics at the University of Coimbra. He graduated from here in 1850. Due to his academic preparation, he was skilled in mathematics, and his army assessments report knowledge of Latin grammar and of the French and English languages. Subsequently, he studied at the Polytechnic School of Lisbon where he concluded his final stage of education in 1853. By the same time, he received the rank of ensign, and he completed a course in military engineering at the Army School during which he was awarded two pecuniary prizes.[1] Despite pursuing his military career until appointed a general,[2] it is his professional life as an engineer of the Ministry of Public Works that is approached in this article.

In the 1860s, his army assessments stated he was robust, agile and capable of active service and that he had good military looks (Fig. 1). Regarding his behaviour, the army recorded that he lived with his family, was not a deadbeat or gambler, did not have lovers nor was drunk, did not sell or pawn his uniforms, and did not attend secret societies. As for his military conduct, the reports recognized that he got on well with his comrades, was compliant and demanded the same from his subordinates, was committed to his duties, and maintained the dignity of his post.[3]

On 26 October 1854, Eça entered the Ministry of Public Works (Quintela 2002, p. 137). Shortly thereafter, he was appointed as Director of the Public Works of Vila Real district. He sought to progress in the profession by continuing his training abroad. Thus, on 10 March 1858, he responded to a tender announced in *Diário do Governo* no. 45 of 23 February 1858, for the appointment of students who, supported by the General Council of Public Works and Mines, would be sent to foreign countries to study at schools specializing in the Art of Mines.[4] The outcome of this tender is not known but Eça was unlikely to have been selected as,

[1] AHM, Evaluation of Eça in January 1863.

[2] He began on July 19, 1845, and was promoted to ensign on September 5, 1853; to lieutenant on September 5, 1855; to captain on October 10, 1865; to Major on April 19, 1876; to lieutenant colonel on February 16, 1887; and Brigadier General on December 30, 1893, having retired on January 4, 1897 (Costa 2005, p. 333).

[3] AHM, Several evaluation documents of the Army between 1853 and 1864 on Eça's behaviour and studies.

[4] BAME, PT/AHMOP/PI/056/003, Letter from Eça to the General Council of Public Works and Mines in order to apply for a grant to study the Art of Mines abroad, 10 March 1858.

Fig. 1 Portrait of Bento Fortunato Almeida d' Eça. In Loureiro 1907, front cover versus

from 16 August onwards, he accumulated the oversight of the Public Works of the Vila Real district with Bragança district, both in northern Portugal.

In the 1860s, Eça entered a new phase in his professional life, especially when the military engineer João Crisostomo de Abreu e Sousa (1811–1895) became the Minister of Public Works on 16 January 1864.[5]

The new minister considered agriculture the "*mater* industry," and appointed someone with a similar education to his own for the study of irrigation. Not an agronomist. Minister Abreu e Sousa set Eça the challenge of studying the legislation on irrigation in southern France and northern Italy as well as its practical application to agriculture. He will make a field trip to these countries to learn from them the practices that had more success in improving the rivers for navigation and irrigation. He compiled everything in a report that was acknowledged by the public powers.[6] As a consequence, he was appointed to lead the studies of agricultural hydraulics in Portugal under the tutelage of the General Board of Agriculture of the Ministry of Public Works and to oversee the works on the Tagus River, replacing the military engineer Manuel José Júlio Guerra (1801–1869) on 2 October 1866 (Loureiro 1907, p. 15).

Guerra had engaged in a noble crusade to restore the former wealth and prosperity of the Tagus and its fields. He had surveyed the river and adjacent fields and begun their study by placing hydrometers along the extent of the river and its tributaries in order to determine its flood regime, average levels of waterflow and drought and embarking on a series of hydrometric, meteorological and statistical observations, which would form the basis for thoroughly studying how to improve the Tagus and its extensive and valuable fields (Guerra 1861). Following the lead of Guerra, when Eça took over as Superintendent of the Tagus River and Director of the 2nd Division of Hydraulics on 27 October 1866, and, later, on 25 August 1870, as Director of Works on the Tagus and its tributaries, he tried to leverage the capacities for both navigation and irrigation.

In this context, novel legislation to facilitate the regularization of the river flow was launched. However, these reforming endeavours gained little practical traction as the government needed to advance large sums for project implementation and this biased the efficiency of the legislation (Eça et al 1883, p. 119). Due to this failure, Eça asked to be exonerated from his position on July 5, 1871. This was rejected by Minister Carlos Bento da Silva, who replied that he "recognized [his] unsurpassed zeal, indisputable intelligence and commendable commitment in the use of the attributions that the law conferred on them, and the efforts that [he] had employed, and that [he was] not responsible for the non-execution of the law" (Loureiro 1907, p. 19).

Despite the several appointments Eça had, it is clear that engineers dedicated to hydraulics earned less than engineers dedicated to railways. Eça was always seeking for better financial conditions and compared his income with his colleagues working on the construction of the nation's railway system. On 26 May 1871, Eça got a 15-day allowance as he was a technical member of the Board of Health Improvements and in charge of the works on the Tagus and its affluents, for which he worked *pro bono*. This compensation was offered to several engineers employed in railway construction who received a continuous 15-day allowance per month. Therefore, Eça complained as he thought he deserved the same treatment.[7] Moreover, Eça was always

[5] Eça felt he owed him so much that he gave a special funeral eulogy at the Association of Civil Engineers (Eça 1896).

[6] Eça's report on this period of travel was acknowledged by the public powers and published firstly in 1866 and again later, divided by the journal *Archivo Rural* into diverse articles designed to foster better practices among interested farmers (Eça 1866b, pp. 85-97; 113-122; 150-160; 172-179; 209-216; 240-246;).

[7] BAME, PT/AHMOP/PI/056/003, Letter dated 26 May 1871.

seeking to obtain extra income through allowances, such as the "effective luggage" stipend which was an additional amount paid to compensate employees for their travel and accommodation.[8]

Eça also claimed for better salary. On 2 July 1874, he wrote to the Minister of Public Works to request a raise in his salary. Eça argued that he was "in charge of the Tagus Improvement Works by ordinance of 2 October 1866, and appointed a member of the Central Board of Sanitary Improvements by decree of 24 October 1867 and had sought to satisfy the service of these two commissions, with both requiring considerable endeavours, to the best of his abilities". Therefore, he claimed his salary be equal to those of the Ministry of Public Works engineers who had received raises.[9] Furthermore, while Eça received a two-fortnight subsistence allowance and, while intending to continue receiving this bonus, he asked for this to be reduced to 8$000 or 9$000 *reis* (former Portuguese currency) in order to ensure he received a salary similar to that of the aforementioned engineers.[10]

Eça was an expert in every field related with hydraulic issues. Therefore, he participated in the committee in charge of proposing the measures provisionally adopted for the capital's sewerage and cleaning systems. He subsequently became chairman of the committee responsible for setting the volume of drinking water with which each public establishment in the capital should be supplied with (1893); for studying possible infections in the Lisbon water supply (1894); and, for examining and analysing the Frazer system meter for water measurement (1895).

Eça's commitment to his work remained such that he did not want to retire. On 17 December 1896, he wrote to the king arguing he did not fall within the scope of the Age Limit Law as he was an employee of the Ministry of Public Works, and not of the Ministry of War, which had implemented this rule.[11] However, his request was turned down and retirement became a reality on 4 January 1907.

In keeping with the superior capacity of his professional performance and the great dedication and zeal for service, Eça became a member of the Portuguese Association of Civil Engineers, of the Lisbon Geography Society, and an honorary member of the Polytechnic Institute of Rio de Janeiro. He was a knight, officer, commander, grand officer and grand cross in the Military Order of Avis, decorated with the gold medal for exemplary behaviour, commander of Charles III, commander of S. Tiago and officer and commander of the Legion of Honour of France (Pereira and Rodrigues 1907, p. 106). In recognition of the valuable services rendered in important and varied positions and committees, both technical and administrative, he was awarded the title of Her Majesty's Council, as a public testimony of appreciation and consideration.

Eça received the highest honours, however none was so significant in scientific and technical terms as the one made by his biographer, when he is acknowledged as being even better than Estêvão Cabral, the first 'hydraulic expert' in eighteenth century Portugal (Leitão 2020). In view of his accomplishments, Eça's biographer emphasizes that "there was no longer a need to hand over the roads to the judges, nor the hydraulic works to the priests, even if they were as distinct as Estevão Cabral," (Loureiro 1907, p. 11).

Eça's agronomic travel: sourcing for expertise internationally

The preparation of the Portuguese engineer for hydraulic agriculture essentially consisted of sending him on a long study trip through the regions of Europe where the practice and theory of what seemed to be a new scientific area was most advanced—Piedmont, Lombardy, the Midi in France, the Netherlands and the Valencia region in Spain.

Agronomic travels, that is, study trips carried out with the aim of observing successful agricultural techniques in other regions, had already been experienced for some time. One of the figures who prised them was the British agronomist Arthur Young (1741–1820), who was also editor of the *Annals of Agriculture* and disseminated this practice. This became a trend performed by many other agronomists, some going to the same exactly regions Eça went (Châteauvieux 1843; Smith 1855; García-Pereda, Rodrigues and Parejo-Moruno 2021). The difference is that in this case an engineer was sent to observe agricultural procedures.

Tracing Eça's agronomic travel has enabled us to identify his aims and the strategies deployed to introduce the hydraulic agriculture innovations practiced in the most advanced countries. His report includes detailed information regarding the layout of the plots to be irrigated and the respective irrigation and drying channels, the levels of irrigation flows and water diversion and storage dams, as well as the means of draining swamps and recommendations for developing agricultural hydraulics in Portugal. The report received such a positive reaction that it was published by the government (Eça 1866a). Besides being informative, it explained key

[8] BAME, PT/AHMOP/PI/056/003. He first requested this on 23 August 1858. It will continue until the 1870s.

[9] BAME, PT/AHMOP/PI/056/003, Letter dated 2 July 1874.

[10] BAME, PT/AHMOP/PI/056/003, Letter dated 26 September 1874.

[11] AHM, Letter dated 17 December 1896.

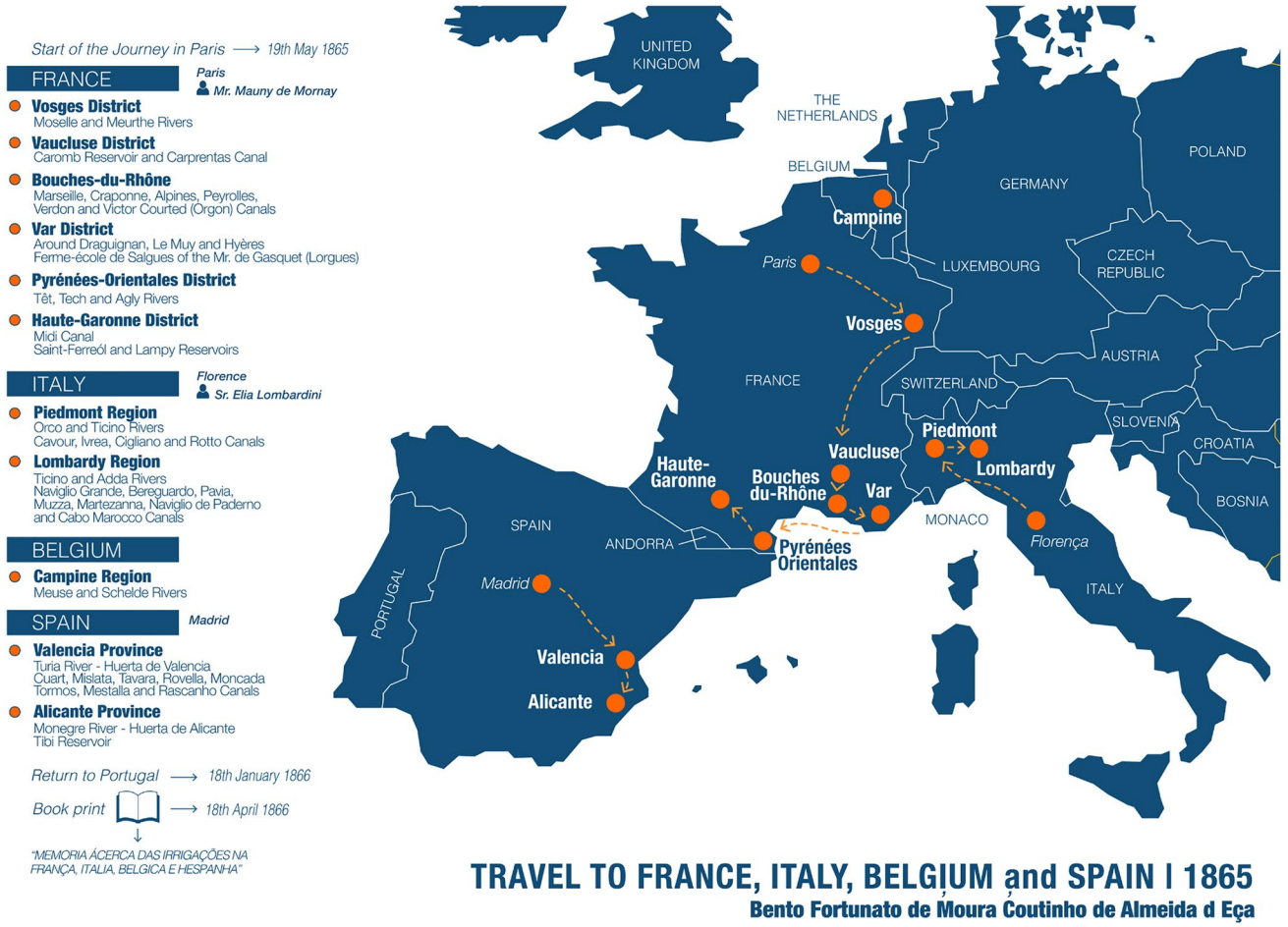

Fig. 2 Eça travel to France, Italy, Belgium and Spain, 1865. Map drawn by author

issues in language comprehensible to the non-professional lay audience, such as farmers (Loureiro 1907).

The first stop was France. arrived in Paris on 19 May 1865 and only returned on 18 January 1866 (Fig. 2).[12] He was thus abroad for months learning new technology, novel practices and legislation (Ordinance of 8 April 1865, Eça 1866a).

In France, he met the French agronomist Mornay, who was then the Director of the General Board of Agriculture of the Ministry of Agriculture, Commerce and Public Works. In that country, Hydraulic Agriculture was under the tutelage of the Ministry of Agriculture and the leading actor was an agronomist (Ingold 2009). Just as in Eça's case, Mornay had been asked to study the irrigation legislation of Piedmont, and his report served to draft the law proposed by the government (Mornay 1844). Additionally, in order to enforce this new legislation, Mornay was appointed deputy head of the agricultural bureau in 1846, and in 1848, the agriculture office he was running became a division of the Ministry of Agriculture.

Mornay guided Eça's research by indicating the books he should buy in Paris and the places he should visit. Following Mornay's advice, Eça visited the districts of Vosges, Vaucluse, Var, Pyrénées-Orientales and Haute-Garonne (Fig. 3), (Eça 1866a, p. 6).

France then reflected a long history of water development coupled with the constant search for the best agricultural usages and the fairest sharing practices for water. The riverine landowners began to transform the lands of these regions and they became the most important source of their agricultural wealth. The watered meadows were studied by many nineteenth century French agronomists as considered one of the most ingenious systems to improve production (Buffon 1853–1858; Cossigny 1874 and 1889, among many others). Their agricultural endeavours were astonishing leading Eça to write about the Midi vineyards (Eça 1888).

[12] Although his biographer states that he was sent abroad for four months, the documentation demonstrates he remained in foreign countries for eight months.

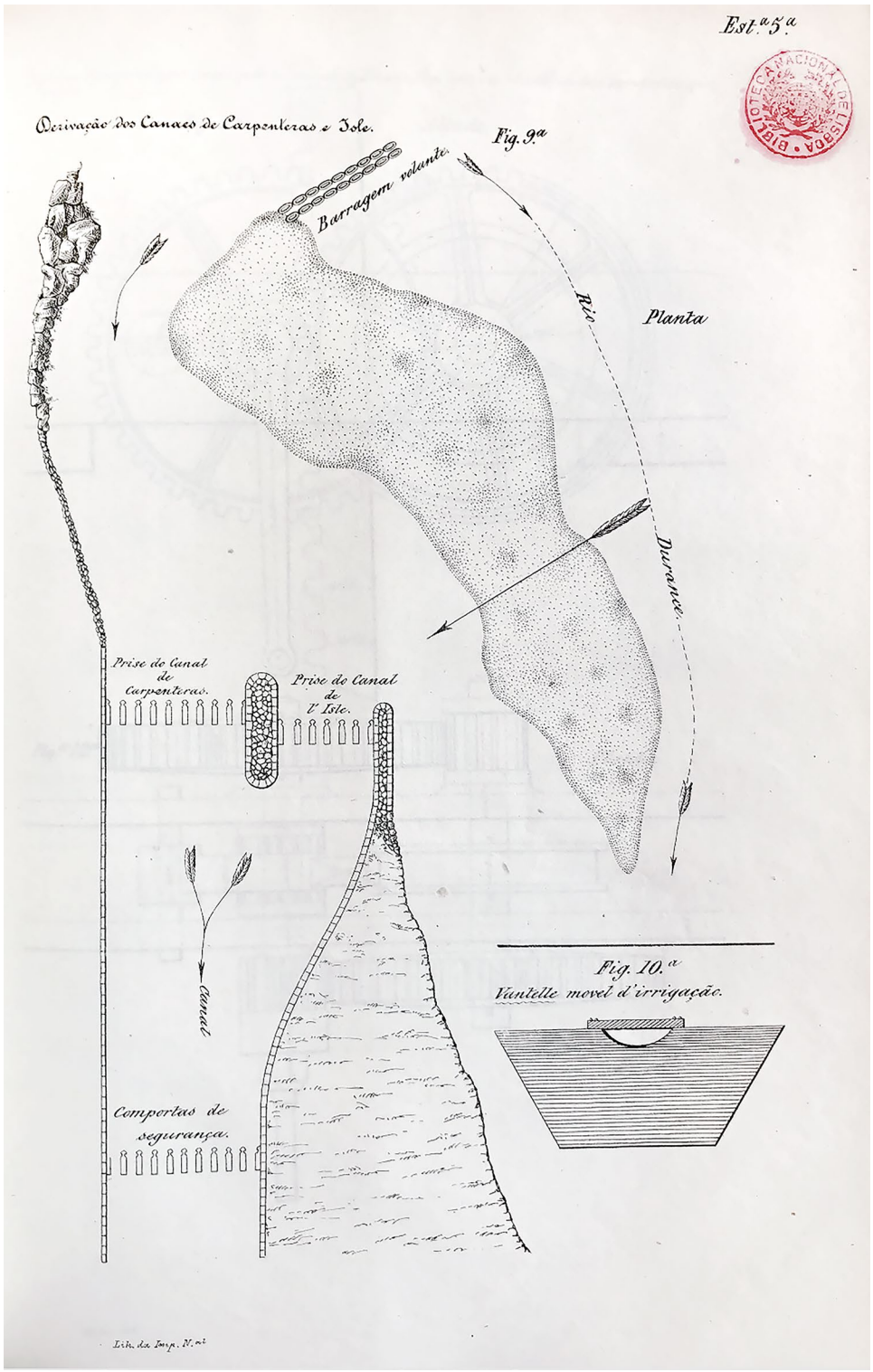

Fig. 3 Derivation and distribution of water of the Canals of Carprentas and Isle, Vaucluse, France. Drawing by Eça in Eça 1866a

Eça was able to observe first-hand the results of applied hydraulic agriculture and the regulatory laws governing them as well as analysing the preparation and layout of the lands receiving water from diversions provided by channels driving water from the reservoirs. He observed how the mountains' meadows were watered from rivers and reservoirs in order to warming the fields, a practice that is observed since the sixteenth century in the Pyrénées. The dry lands were watered by water from the *narses,* sort of stagnant ponds where the springs ended (Ardillier-Carras 2009); and reservoirs (the *gourgues*) were also built, the watertightness of which was ensured by beaten earth

(Blanchemanche 1990). Moreover, Eça saw the typical irrigation methods of the Moselle and Vaucluse meadows, such as the plank or adobe irrigation system and the canals built to increase the production of natural and artificial meadows (*alfalfa*) growing on coarse river alluvium (called *garrigues* and made up of gravel and pebbles). These meadows (nearly 10,000 hectares in 1850) were watered by submersion. They were established on land divided into watering compartments by earth mounds 20 cm high. Each compartment was fed by the irrigation water supply channel which crossed it perpendicularly (Bethemont 1972, 1999; Broc 1980, 1992; Fournier 2003; Girel 2012).

Despite meadows irrigation development in the south-east of France, French agronomists complained that it improved without, however, achieving a development comparable to that of the Italian transalpine provinces: in 1843, 96,300 hectares were irrigated in southern France, while 110,000 and 315,000 hectares were irrigated respectively in Piedmont and Lombardy (Buffon 1853–1858, in Girel 2012). Agronomists such as Nadault de Buffon, Mornay, and ending up in Ronna, largely after Eça's travel and work as Superintendent of the Tagus, would be among his main references for good (Ronna 1888–1890).

Lombardy and Piedmont were acknowledged as holding the most sophisticated system of irrigation. When Eça went to these regions, Smith's *Italian Irrigation* had already been published, following his agronomic travel to northern Italy (Smith 1852 and 1855). Eça recalled "several others have gone there to study, as in the best model, the different systems of irrigation [in Italy]; such as Mr. Nadault of Buffon, and lately the British engineer Sir Baird Smith, who spent about two years collecting the necessary data and later publishing the work entitled: Italian irrigation" (Eça 1866a, p. 38).

Eça inspected the canals running across Piedmont, a vast plain surrounded by the mountains of the Alps and Apennines which was greatly enriched by irrigation. He arrived just as the works of the Canal Cavour were ending. Ever since Roman times, the Po Valley has been subject to interventions involving regulation and drainage, deployed through numerous channel building projects for navigation, irrigation and powering the watermills. Simultaneous to the need to control excessive amounts of water, Milan lacked any river and provided for its needs through a dense network of canals, built for defence, hygiene, agriculture, transport and milling systems (Fantoni 2008; Pugliese and Lucchini 2010). The Canal Naviglio or Naviglio Grande (Great Canal), the oldest in Milan, was started in the twelfth century and played an essential role as a communications route. Other canals were built to water the fields of Lombardy. This enormously expanded the meadows under irrigation that enabled the region great development. It furthermore played a major role in rice cultivation by irrigating a large area of land (Bevilacqua 1989 and 1996).

In the nineteenth century, the most important development came with the Canal Cavour, built by Francesco Rossi to link the Po near Chivasso with its tributary, the River Ticino near Galliate, more than 80 km to the northeast. This scheme was then transformed by Carlo Noe in the 1850s and with the canal built between 1863 and 1866. Eça visited and recorded with his own drawings these works in Lombardy, such as the Canal of Martesana (Fig. 4). However, in Eça's words, the Canal Cavour was "the most remarkable canal" he visited. He spoke directly with Director Carlo Noe, the manager of the Charles Galland Construction Company, and the engineer Marchetti, who provided all the explanations he required (Eça 1866a, p. 33). The Canal Cavour became a symbol of Italy as a newly born modern nation. The huge works were the materialization of progress undertaken by the new heroes – the engineers –, whose technical expertise lay behind the construction of nations' major infrastructures. Hydraulic agriculture as it involved technical, economic and agronomic know-how became a sign of progress, side by side with railways' construction. Additionally, it served as a barometer to compare nations' modernity, to such an extent that in the conclusion to his travel memories, Eça quotes the British engineer Smith: "As regards the works themselves, whether reference is added to their designs or modes of execution, I do not think the Italians are superior to ourselves; but in the theory of distribution, on the points of the interior economy connected with water usage, and in the exactitude and details of legislation, they are far in advance of us" (Smith 1855; in Eça 1866a, p. 59). This excerpt not only highlights another foreigner noting the excellence of Italian canals, but also draws attention to the fact that the issue is not exclusively technical, but also political. The model of Piedmont, north and south of the Alps, differed from other systems by the fact that the surplus water was recovered by a drainage channel which supposed an organization between the landowners to take advantage of the irrigation. Therefore, water was at the centre of political, social and technical attention.

Moreover, due to the sheer economic importance of irrigation in the Piedmont, the education of hydraulic engineers was foreseen. The training and education of hydraulic engineers took place thoroughly and with no one allowed to assume the title, or practice the profession, without having fully graduated regularly from the University of Turin, where Prospero Richelmy (1813–1884) was Professor of Hydraulics (Smith 1855, pp. 12–13). This professional specialization, which still does not exist in contemporary Portugal, already existed in nineteenth century Turin, as the civil engineer profession in Piedmont is divided into three grades, of which the highest is the hydraulic engineer; the second, the civil architect; and the third, the surveyor or measurer.

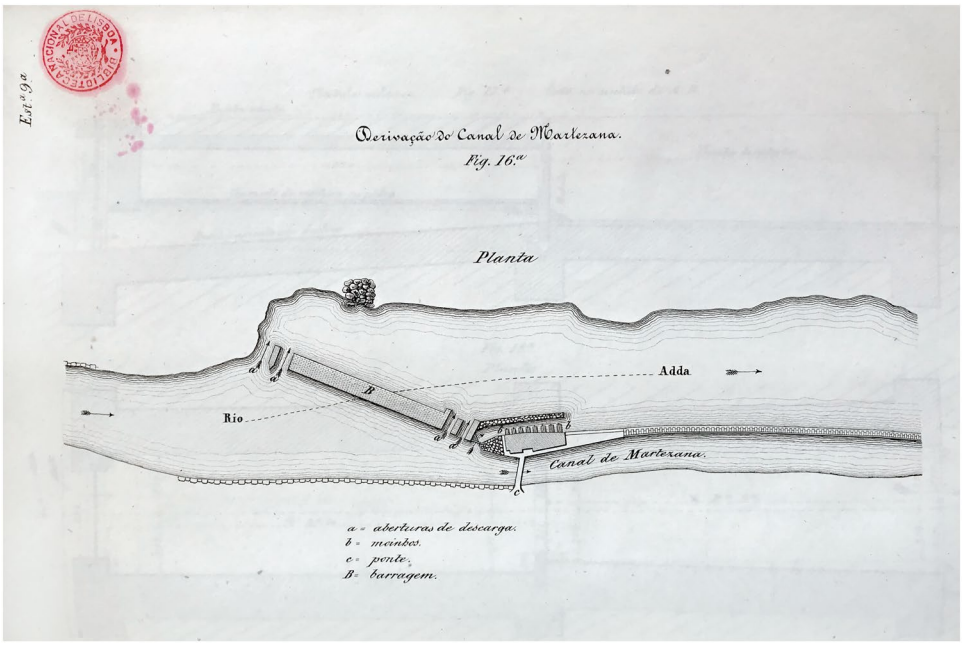

Fig. 4 Derivation of the Canal of Martesana, Lombardy. Drawing by Eça in Eça 1866a

Politicization of water will reach its apogee in Spain, where the lack of water is greater, hence, the greater the value given to it. The lack of water also exacerbated social injustice, which is why 'Hydraulic Agriculture' in Spain became the flagship of modernity (Costa 1911; Orti 1984; Swyngedouw 1999 and 2015). It would be seen as a utopia, the only chance to make the dry and sterile Spain productive, after being impoverished with the loss of its colonies. In this context, 'hydraulic' engineers like Eça will become the nation's heroes in the time of *Regeneracionism* (1890–1930), (Boelens and Uiterweer 2013). But when Eça visits Spain, this ambition of 'revolution' was still fermenting. The Regenerationist leader Joaquín Costa and Rafael Benjumea, Count of Guadalhorce, Minister of Public Works, developed and materialized the 'hydraulic utopia' based on the rebirth of the small-scale farm system typical of the Al-Andalus. Stemming from this period, the Water Court of Law of Valencia functioning from the ninth century onwards stands out as an example of water justice, securing equity among the community of farmers by their own members.

Eça visited the regions of Valencia and Alicante and analysed how water wise management underpinned the region's high productivity at the *huertas* of Valencia and Alicante, which were dominated by artificial prairies, orchards full of fruit trees and vineyards producing *moscatel, malvasia* and *fondillol* (Loureiro 1907, p. 14).

Eça returned from his travel with a suitcase full of technical knowledge, views, books, but also laws and policies. He understood that the modernization of the country's hydraulic systems required much more than engineering. It required governance. And this meant the establishment of government organizations, agencies, ministries and technicians that are put in place to manage waters. Correspondingly, Eça concludes his report by stating that taking advantage of Portuguese rivers for agriculture would require the founding of a special board – "Serviço de Hydraulica-Agricola" (Hydraulic Agriculture Service) – in order to decide on the various water resource planning and management related issues, such as undertaking a general survey of the fields susceptible to improvement through irrigation or protecting those exposed to recurrent floods; defining the effectiveness of reservoirs and means of storage when the water courses are not effective; and designing canals, projects to improve the means of irrigating for Portuguese agriculture (Eça 1866a, p. 64).[13] These issues are not only central to water management as the mishandling of the resource and the inadequacy of the institutions and governance structures that can ensure that every drop of water is used wisely. Moreover, as water crosses national boundaries, rivers require integrated development and management.

[13] In 1866, he suggested the government should start in the regions with greatest need such as Alentejo in southern Portugal (Eça 1866, p. 64). A suggestion that was eventual followed but only much later. A report was therefore made on the general conditions prevailing in Alentejo, both its orography and its hydrography, as well as its geology, mineral resources and hydrology, the state of crops and afforestation, climatological circumstances, economic and administrative conditions, and constitution of the property (Eça et al. 1885).

Eça's impact as superintendent of the Tagus River

Eça's biographer compared the Tagus River with the Nile in the sense that it provided the source of the greatest agricultural wealth of Portugal. He highlighted how that besides a long navigable stretch – Iberia's ancient high-route[14] –, the Tagus River runs past fertile fields on both banks and ends in the largest and most majestic estuary in the world (Loureiro 1907, p. 16).

Along 840 km, the Tagus River crosses the provinces of Castille and Extremadura in Spain and Beira Baixa, Ribatejo and Estremadura in Portugal, where it divides into *Alto Tejo*, from Spain as far as Tancos, *Médio Tejo*, from the latter to Azambuja and *Baixo Tejo* or *Tejo marítimo*, from the latter to the ocean (Fig. 5), (Eça et al 1883, p. 60).[15]

In the *Alto Tejo*, the river is squeezed between rocky and steep mountain slopes and the bed is sinuous with curves of very variable angles. Over the centuries, the waters did not form a regular bed along a uniform slope, leaving a series of rapids that make navigation very dangerous.

In the *Médio Tejo* section, the river basin widens and the waters slow down, forming magnificent fields with an average width of 5 km along 80 km of the river to Vila Franca de Xira. The riverbed here is made up of shifting sands which decrease in size towards the sea, therefore becoming more unstable in various situations, whether of drought or flood. As this the agriculturally most fertile area, it is very harmful for sand masses to be deposited on productive fields, potentially forming swamps and causing huge damage to agriculture, hygiene and public wealth.

The *Baixo Tejo* area is not that different from the *Médio Tejo* in terms of physiography, but the water from the estuary of the river until Vila Franca is brackish and, therefore, cultivation is not as productive as in *Médio Tejo*.

As from medieval times, long established regimes encompassed river navigation, agriculture and ownership. Similarly, the Tagus River always received attention from the central powers and was subject to conservation policies. Under successive regimes, provisions and laws on the Tagus marshlands were issued ever since 1568, with continuous modifications ongoing through to the early nineteenth century but with all concerning agriculture, land rents, Crown taxes or the administration of the adjacent fields. In the nineteenth century, regulating the Tagus for navigation was a

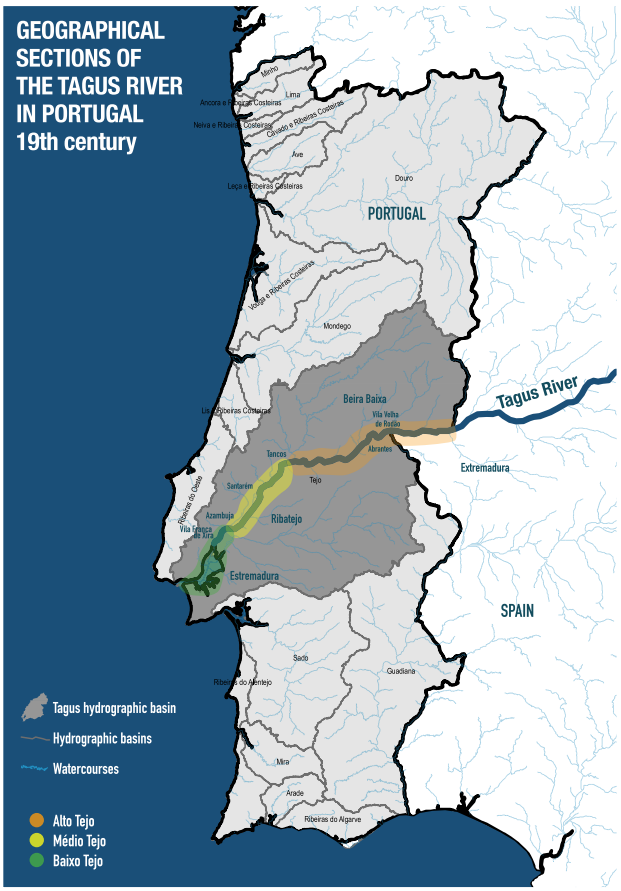

Fig. 5 Map of the Tagus river's sections, Portugal. Map drawn by Patricia Trindade Monteiro

concern on both sides of the frontier (Cabanes 1829) but not specifically in terms of its efficient hydraulic agriculture.

The Superintendence of the Tagus was founded in 1849, during the reign of Queen Maria II, in conjunction with other measures enacted to improve navigation along the river and benefit its adjacent fields. In 1866, Eça was appointed Director of the 2nd Hydraulics Directorate of the Ministry of Public Works and, later that year, Superintendent of the Tagus on 27 October 1866.

The 1 July 1867 law on the Mondego, designed by João de Andrade Corvo, aimed to bring about the disappearance of natural and artificial swamps and the rice fields that deeply affected public health while envisioning clean and dry lands, free from excess moisture (Calafate 2009). This would be reached following improvements to the rivers and navigable water streams protecting the lands against dangerous floods and facilitating irrigation while also, finally, replacing these unhealthy crops with more profitable alternatives. However, these reforming endeavours gained little practical traction as the government needed to advance large sums to implement the projects and the failure to provide

[14] An idea well explored by Gómez et al 1998.

[15] Both the identification of the sections and the length of the river indicated do not correspond to the current values and divisions. In this article, because the objective is to provide visual images of what was happening in the nineteenth century, all the data are based on Eça's texts.

such funding undermined the efficiency of the law (Corvo 1881; Eça et al 1883, p. 119).

As Superintendent of the Tagus, Eça advocated for integrated management frameworks able to generate greater utility from a given volume of water, through adjusted allocations. He also defended the reduction of groundwater mining through the interlinked management of ground and surface water, more intensive water reutilisation through the planned sequencing of uses, and the inclusion of a wider range of basin stakeholders into decision making. Despite this promise, and although highly recommendable, integrated river basin management was actually rather rare in practice as such required genuine collaboration among administrative and sectorial units. Given these potentially inhibiting factors, it is not so surprising that water management related institutions, organizations and policies became shaped primarily by the needs of locally managed irrigation.

At the time of his appointment as Superintendent of the Tagus, several works were already in progress on the Tagus River such as riverside towpaths along some river sections, repairs to dikes and with other planned works under analysis. Moreover, on taking up his position, he discovered that of the 22,000$000 allocated for the works program, 14,000$000 had been spent between the months of July and October causing him to have to lay off staff (Eça 1877, p. 5).

In Eça's opinion, hydraulic and fluvial issues were very demanding and complicated, requiring in-depth study because any inappropriate works have destructive consequences, including devastating floods with fertile land transformed into swamps (Eça 1877, p. 3). Tagus floodwaters spread across 40 000 hectares in the *Médio Tejo* basin section (Eça et al 1883).

Therefore, on becoming superintendent, he organized the work into two sections. The first to the north of the Tagus, comprised projects and the construction work between the Azambuja canal and the village of Abrantes,[16] under direction of engineer António Vasco da Gama Braga, who resided in Ribeira de Santarém. The second section between the area of Salvaterra and Ribeira de Abrantes, was entrusted to engineer Jaime Augusto da Silva, who lived in Alpiarça (Eça 1877, p. 5). In the first section, the main concerns involved maintaining the stability of the Vinte dam and carrying out repairs to the Valada dam. Eça intended to dedicate his attention to studying the direction, strength and effects of the main fluvial currents, especially during flood episodes. Despite the construction of a dike, these occurred very often in Ribeira de Santarém located on the river's bank at the bottom of the hill, while Santarém was on the top of the hill, to such an extent that villages such as Caneiras in Ribeira de Santarém were built on piles (Figs. 6, 7, 8 and 9). In the second section, the priority was work on the Alpiarça canal as this provided for the drainage of a large area of swampland, as well as designing the project for renovating the Almeirim road, which suffered damage from the seasonal floods every year. It was not then known whether the Alpiarça canal would best serve as a drainage ditch or as a channel of navigation. The decision on its intended purpose was of the utmost importance to Eça as it might serve as a means of drainage with a smaller transversal profile. However, for navigation, it would need to be larger and remove the slopes that were still then present. After having analysed studies and surveys of terrain profiles, Eça recommended that from Almeirim upstream, the watercourse was only to be considered as a drainage ditch (Eça 1877, pp. 6–7).

The Almeirim road, running perpendicular to the Tagus River and crossing the fields, was continually subject to flood damage, dragging the sand, the paving and then the foundations into the fertile fields and thus also adding more sand to the riverbed. Eça, therefore, proposed the English profile and a road surface with greater resistance (Eça 1877, p. 7). Besides these two sections, Eça proposed organizing a third to span the works between Abrantes and the mouth of the Sever River and correspondingly destroying dams built by private individuals for fishing and which had hindered navigation; destroying fisheries; cutting back some rock ends; designing and building walkways on riverside path walls; and concluding and maintaining riverside path walls.

The system then in effect for the conservation of canals and dikes did not seem the most appropriate. Eça, just like Estevão Cabral almost a century earlier, judged transversal dikes, such as the Vinte's, and also "unsubmersible" longitudinal dikes, to be substandard solutions. Notwithstanding, these construction projects were already underway and he was unable to stop them.

Eça began to issue written instructions so that they would be followed as precisely as possible. He also leased some lands at public auction, sold wood and other products to contribute to governmental coffers, as well as commissioning a general inventory of the state- owned terrains along the banks of the Tagus (Eça 1877, p. 10). Furthermore, he organized this service in keeping with that prevailing for most roads in the country, dividing the Alpiarça canal into six cantons, with men on horseback guarding each of section to prevent wild cattle causing damage to the hedges and foliage covering dams (Eça 1877, p. 9).

Substantiating his vision on what should be done to the Tagus River, Eça applied both the specialist bibliography and what he had seen during his travel through Italy, France, Belgium and Spain in 1865. The general idea was that the hydraulic works undertaken in the valleys of great rivers

[16] For an overview of the issues of irrigation and drainage of the neighbouring lands of the Azambuja Ditch see Brandão and Malaspina 2022.

Fig. 6 Plan of the Ribeira de Santarém with a dike built to avoid floods from the Tagus River, in Eça 1877. **7** View from the other bank of the Tagus River towards Ribeira de Santarém at a low level and Santarém on the hill, 1846. BNP, E. 4667 P. **8** Photograph of a house at Caneiras on piles, in Ribeira de Santarém. Anonymous authorship. Ca 1900. **9** Photograph of floods at Ribeira de Santarém by Joshua Benoliel (1912), in Vieira 2010

strive to improve navigation, benefit marginal lands and make improvements to public health and industry.

However, opinions on what should be done to deal with river waters differed from region to region. In some areas, the understanding was that the best system was securing the waterways with overflow dikes and thus protect the land from flooding. In other regions, the practice was to leave fields to nature; while elsewhere, an intermediate system was selected to take advantage of the currents and, while not applying total resistance to the floods, instead attempting to control them. Eça was certain that the third system represented the best approach also basing his opinion on the disastrous effects of the massive construction of dikes had on the 1855 floods in the Netherlands. According to him, the Italian system that he had been able to see in person was similar to the Dutch one (Eça 1877, p. 13). The works of the dikes in the Po valley were the subject of important, but sometimes mutually contradictory, studies in the nineteenth century. On the one hand, some alarmist voices stated that the dikes had caused the floodwaters to exceed the roofs of houses in Ferrara, but the Italian engineer and general director of the Lombardy Works Elia Lombardini's study (1844) argued that the canal system in Lombardy dated back to the Etruscans and achieved a general connection in around 1300, functioning since then.

Eça reasoned that in the case of the Tagus, with its floodwaters loaded with fertilizing sediments, blocking them completely would be a mistake while leaving them free also causes enormous destruction annually. Hence, the most logical option was to act to control the floods (Eça 1877, p. 15). This purpose required the digging of diversion channels, absorbing wells, submersible or unsinkable dikes, clogging decks, discharge channels, ordinary or waterfall bridges, locks and plantations. Eça stated that the success of the Nile arose from natural plugging and artificially expanding the reach of floodwaters by opening canals and constructing dams (Eça 1877, pp. 16–17). Moreover, he recalled the plugging system in effect in France and concluded that the plugging system as used for the Nile and in France along the Girard reflected in much better outcomes than the dike systems deployed in the Netherlands and Italy (Eça 1877, pp. 14–17). He quoted the letter from Dutch engineer William Albert Scholten to the French Raymond Thomassy in which the former acknowledges the superiority of the plugging system with the dike system considered a terrible mistake running against the law of nature (Eça 1877, p. 17). Regardless of these works, important studies were also carried out in the Tagus drainage basin, including a survey of the general layout of the river and its banks from Vila Velha to Carregado, various longitudinal and transversal levelling measurements,

observations on the speed of currents, volume and height of the floods, as well as navigation movements and evaluation of adjoining plantations (Eça 1877, p. 18). As most of these works were of particular usage to agriculture, Eça maintained that the respective landowners should organize themselves into associations or companies and thereby raise funding for improvement works even though their technical supervision should belong to government engineers (Eça 1877, p. 21). Eça also concluded that the true engineer must resemble the true doctor; thus, to strive to make it as unlikely as possible that, having once operated, there would be any need to resort to any further treatment. In diseases of the body as well as in those of the land, nature had to wield the main influence and the work of the physician, like that of the engineer, was to guide its forces (Eça 1877, p. 27).

During his superintendency of the Tagus, there were several works undertaken in the *Alto Tejo*: annual clearing of gravel from the riverbed, rectifications or increases to the angles of the tightest curves, opening navigation channels with a minimum width of 10 m, the construction of large walls along the riverbanks with the gravel removed from the riverbed, thus covering the margins to facilitate navigation. Between Abrantes and Vila Velha de Rodão, the towpaths constructed spanned over 28 km, leaving only 18 km to complete the 46 km that were estimated necessary. The committee recommended that the remaining works be discussed with the Spanish government as regularizing this section of the river would be of relevance to the exploitation of mines. Moreover, as there were no forests or tree plantings along this path, this helped prevent the accumulation of rocks on the river bed.

In the *Médio Tejo*, the most urgent needs involved ensuring the scope for navigation, the protection of adjacent fields and agricultural improvements. The river carries in its waters the sediments that, when meeting the tidal water mass, are deposited, raising the amount of alluvium on the riverbed that might then lead to further water flowing back into the fields, transforming them into swamps, with ponds deprived of drainage. Therefore, a committee proposed studying the Tagus and its tributaries with hydrometric scales along the entire length to ascertain the different slopes that the current takes, longitudinally and transversally during the dry season, average navigation waters and the ordinary and extraordinary levels of flooding. Júlio Guerra, as well as the engineers working on the Azambuja canal, also carried out these hydrometric studies and measurements. All of these hydrometric scales were to be interlinked with very rigorous topographic levelling analysis.

Having determined as accurately as possible the Tagus hydrographic basin and the extent of its drainage area, Eça ordered the multiplication of the meteorological stations to record the barometric and thermometric variations and register rainfall observations. These data, in conjunction with direct measurements of the river flow in different locations, would enable the calculation of the absorption coefficient of the Tagus basin as well as determining its modulus and maximum and minimum product in accordance with the volume of appreciation due to surface currents or groundwater. They also considered it advisable to ascertain the temperature of the surface waters at different depths in the river along with its chemical and mineralogical composition and nature as these are subsequently incorporated into the agricultural makeup of the land (Eça et al 1883, pp. 81–82).

Thus, they were seeking a solution to force the waters to regularly deposit their sediments throughout the valley, both longitudinally and transversally, to ensure the drainage of the lands. Therefore, there is no doubt that Eça's agronomic and hydraulic travel had huge impact on his performance as Superintendent of the Tagus River.

Eça's vision for the Tagus River

Despite all of Eça's work as superintendent of the Tagus, there was still a lot to do. In 1880, he was part of a committee of five members, in which Adolfo Loureiro (1836–1911), his future biographer, also participated, to draw up the *General plan of works to be done to improve the Tagus river and benefit the adjacent fields*.[17]

The main problems that remained were the uncontrollable floods; the weak fixation and permanence of the riverbanks, which would require mass tree plantations on these banks; the inequality with which the transported sediments are distributed, creating sandbanks in some areas, which makes the river unnavigable; the furrows that the currents open in different directions during floods; the entry of floods into the fields when they are sown.

The planting of trees on the banks of the rivers, or on longitudinal and transversal facades in the marginal fields, functioning as filtering dikes, which moderate the speed of the currents, without impeding the passage of the waters rich in sediments, would be one of the most beneficial measures. However, as a work like this is dependent on a huge number of owners, which are not just the state, it is doomed to failure.

Therefore, the report also drew attention to the need for forestry legislation ensuring landowners take responsibility and contribute to the afforestation of the riverbanks (Eça et al 1883, p. 104).

That is why the committee stated that unions and associations had an important role to play here, in the sense of aggregating wills for the realization of a collective benefit,

[17] This plan was later published in the *Revista de Obras Públicas e Minas* (Eça et al 1883).

which, under the direction of an expert, would design a complete plan to be presented to the Ministry of Public Works (Eça et al 1883, p. 69). Therefore, the report recommended the formation of small unions, committees representing a certain number of landowners, elected by this group, to facilitate the exploitation of common land, including sharing the machinery and equipment used in modern agricultural holdings, as well as developing irrigation works (Eça et al 1883, p. 105). In order to guarantee the implementation of uniformity in designing and planning the works, and the legislative measures necessary to govern of the Tagus and its waters, these committees be under the same tutelage with its authority naturally deriving from the engineer directing the Tagus public works. The latter was correspondingly to promote, administer and direct the works of collective utility (Eça et al 1883, p. 102).

The formation of sandbanks and swampy areas along the tributaries of the Tagus in properties that belong to the Companhia das Lezirias (Company of Lezirias) stands as another problem difficult to solve. The Company is responsible for opening and repairing ditches and for securing protective plantations. In view of this, it receives a tax from the tenants and landowners. However, the Company complains that the tax is not enough to pay for the costs. Eça and the committee propose that the Company no longer receive the tax, but also that it is no longer obliged to carry out such works, which should be the responsibility of the government and the expense distributed among the various owners, including the Company (Eça et al 1883, p. 77).

The report stated that these legal and administrative inputs were as important as any technical improvements: "It is not enough to technically resolve the issue of improving the Tagus and its adjacent fields; it is also necessary to find the means of (without prejudice to the legitimate property rights) not hindering but rather helping all the works of interest to the indicated improvements" (Eça et al 1883, p. 98). This meant novel legislation. Based on the report's contents, on 11 March 1882, the politician Hintze Ribeiro (1849–1907) proposed legislation to parliament for improving navigation and irrigation along the Tagus. However, the multiple ownership of riverbanks constituted a problem to apply the law. Moreover, financial problems explain most of the delay in implementing the necessary works. The eventual decisions were always constrained by budget issues and the need to reduce expenses, concluding that "hydraulic works were always those that gained the most disaffection from the public authorities" (Gorria 1908, p. 123). Hydraulic engineers report that the argumentation "Because it was cheaper, it was almost a refrain". As soon as a budget was presented, the directors immediately thought about where to cut, which resulted in a "smaller budget, but the works were always limited, and it seemed they were planned out of fear" (Gorria 1908, p. 123). Water was clearly 'politicised' in a negative sense as political and economic calculations influenced and distorted policies and decisions.

As problems of an economic-financial, political-legislative and social nature made it difficult to implement Eça's vision for the Tagus, his ambition, along with new opportunities, led him to work on the railways, joining to colleagues with whom he had long fought for equality from 1880s onwards.

Final remarks

Irrigation ceased to be approached as an empirical practice in the nineteenth century. Portugal, which had already experienced successful practices, clearly lagged behind other regions that either directly underwent Agricultural Revolutions in the eighteenth century or experienced their influences. Despite some attempts to modernize agriculture and efforts to regularize rivers' flow, there were no significant shifts in the Portuguese panorama. However, after the founding of the Regeneration political regime, and with the much-desired material progress then becoming a reality, a new perspective emerged for agriculture.

The Regeneration in Portugal began in 1851 and attained its zenith in the 1880s, and it is in this context that this story takes place. It does not coincide at all with the Spanish *Regeneracionism*, developed between 1890 and 1930. In this period, Portugal faced several challenges: bankruptcy in 1890, regicide in 1908, implementation of the First Republic in 1910, participation in World War I in 1917–18, another bankruptcy in 1926 and military dictatorship established from 1928 onwards. Hydraulic endeavours were left behind. The great public works will only be resumed in the 1940s under the dictatorship of Estado Novo, and only in this period, hydraulic works on both countries of the peninsula will be developed.

The main reference for Eça was Mornay and the works he observed in France. Curiously, all developed under the tutelage of a different ministry and of different experts. Even in Portugal, the perception of the absolute need to take advantage of rivers for agriculture seems to arise from agronomists, who by that time held higher education qualifications from the Institute of Agriculture. However, engineers quickly took matters into their own hands as agriculture came under the tutelage of the Ministry of Public Works, established in 1852. In fact, it was Bento Fortunato Almeida d'Eça, a military engineer from the Army School, who held a bachelor's degree in mathematics from the University of Coimbra, and worked at the Ministry, that was dispatched on a study trip abroad, with the objectives to observe the great works of canals, dikes and reservoirs constructed in France, Italy, Belgium and Spain, to collect bibliography, as well as impressions with the best experts on these subjects.

As soon as this engineer arrived back, he produced a report that clearly stated an agricultural hydraulic service with specialized management as absolutely necessary. He referred to specific training for civil engineers, which already existed in Italy, specifically at the University of Turin, but not in Portugal. However, at that time, the Association of Civil Engineers was already under foundation with its library incorporating this specialist field with hydraulics dedicated sections.

The Portuguese engineer trained by the Ministry of Public Works in hydraulic agriculture would then be placed in charge of the Tagus works where he defended that the works carried out must align with nature and not run counter. Therefore, he correspondingly considered the system of dikes built in the Netherlands and Italy, in the Po region that he visited, was not appropriate for the Tagus.

He advocated for the clogging system, channelling the waters in order to control them but without completely blocking their strength, especially because the fertility of the fields along the banks of the Tagus depended on the floods, just as was the case with the Nile system and the one he observed in France. This case furthermore clearly illustrates how the appropriation of knowledge from the centre to the periphery was processed; there was clearly an extensive study of various situations in countries considered to be at the forefront before then opting for original solutions perceived as best tailored to the Portuguese reality and that correspondingly distanced themselves from the role models.

Eça did not apply straightforward what he learned, but critically used that knowledge to what he thought better for the Tagus River. Surplus yields depended upon delivery of adequate supplies of water at the right time to the right places as well as protection against catastrophic flooding. This required much more than technical expertise. Eça was completely aware that many setbacks were not under his control. They depended on political power, different legislation and social organization and will. It is not surprising that major public works and requiring labour-intensive water management challenges were delivered under dictatorships in both Iberian countries. On the other side, power and social organization also depended upon regimented, and concentrated control of water supply, especially evident in the Spanish case.

Although the hydraulic model deployed under Eça's supervision would be superseded by new technical, political and social formations, it fostered a state-controlled irrigation source. The Tagus' bounty, however, depended upon flooding. However, this required a balance impossible to control as excessive flooding inundated entire villages and wiped away cropland. The evidence of this incapacity are the houses built on high stakes on the riverbank, which protected inhabitants from dramatic flooding until two decades ago.

Acknowledgements This research took place under the auspices of the AQUA-PTDC/HAR-HIS/28627/2017 Project, coordinated by Ana Duarte Rodrigues and funded by the Portuguese Foundation for Science and Technology (2018-2022). Its website is available at https://aqua.ciuhct.org. We thank the editor and referees of *Sustainable Water Resources Management* journal for all their revisions, comments and suggestions. We, finally, thank the financial support of the Portuguese Foundation for Science and Technology under the research projects AQUA-PTDC/HAR HIS/28627/2017 and UIDB/HIS/UI0286/2020.

Funding Open access funding provided by FCT|FCCN (b-on).

Data availability Our manuscript has no associated data availability.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

Ardillier-Carras F (2009) La maîtrise de l'eau pour l'agriculture en Limousin. Un exemple de gestion de la ressource en moyenne montagne océanique. Norois 210(1):27–42

Barraqué B (2002) Génie rural et droit des cours d'eau: Benjamin Nadault de Buffon (1804–1880). La Houille Blanche 88:136–145. https://doi.org/10.1051/lhb/2002073

Bethemont J (1972) Le thème de l'eau dans la vallée du Rhône. Essai sur la genèse d'un espace hydraulique. Publications de l'Université de Saint Etienne (Saint Etienne)

Bevilacqua P (1996) Tra natura e storia, Ambiente, economie, risorse in Italia. Donzelli Editore, Rome

Bethemont J (1999) Sur la dynamique du changement technique dans les régions de tradition hydraulique: la référence comtadine». In: Marié Larcena DM, Dérioz P (eds) Cultures, usages et stratégies de l'eau en Méditerranée occidentale, tensions, conflits et régulations, Séminaire d'Avignon. L'Harmattan, Paris, pp 353–370

Bevilacqua P (1989) Le rivoluzioni dell'acqua. Irrigazione e trasformazioni dell'agricoltura tra Sette e Novecento. *Storia dell'agricoltura italiana in età contemporanea*, 255–318. Marsilio, Venezia

Blanchemanche P (1990) Bâtisseurs de paysages. Terrassement, épierrement et petite hydraulique agricoles en Europe, XVIIe-XIXe siècles. Editions de la Maison des Sciences de l' Homme, Paris

Boelens R, Uiterweer P (2013) Hydraulic heroes: the ironies of utopian hydraulism and its politics of autonomy in the Guadalhorce Valley, Spain. J Hist Geogr 41:44–58

Brandão JM, Malaspina EF (2022) Uma obra (in)consequente: a Vala da Azambuja em meados do século XIX. Revista de História da Sociedade e da Cultura 22: 165–188 https://doi.org/10.14195/1645-2259_22-1_6
Broc N (1980) L'hydraulique agricole en Roussillon: aspects historiques. Bulletin De La Société Languedocienne De Géographie 14(2/3):299–323
Broc N (1992) Dictionnaire illustré des explorateurs français du XIX siècle, Tome 2. CTHS, Paris
Brown G (2005) Irrigation of water meadows in England. Ruralia, Conference Ruralia, Water Management in Medieval Rural Economy, 27 September–2 October 2003, Turnhout. Brepols Publishers, Lyon/ Villard-Sallet, pp 84–92
Buchanan RA (1978) Science and engineering: a case study in British experience in the mid-nineteenth century. Notes Rec R Soc Lond 32:215–223. https://doi.org/10.1098/rsnr.1978.0018
Buchanan RA (1989) The Engineers: A History of the Engineering Profession in Britain, 1750–1914. Kingsley, London
Buffon NH (1867) Hydraulique Agricole. Dunod Éditeur, Paris
Buffon NH (1853–58) Cours d'agriculture et d'hydraulique. Carilian Goeury et V. Dalmont Éditeurs, Paris
Cabanes FX (1829) Memoria que tiene por objeto manifestar la possibilidad y facilidad de hacer navegable el Rio Tajo desde Aranjuez hasta el Atlantico. Imprensa de Don Miguel de Burgos, Madrid
Cabouret M (1999) L'irrigation des prés de fauche en Europe occidentale, centrale et septentrionale. Essai de géographie historique. Editions Karthala, Paris
Cabrera E, Arregui F (2010) Water Engineering and Management through Time – Learning from History. CRC Press, London and New York
Calafate P (2009) O Pensamento Político e Geoestratégico de João de Andrade Corvo. Revista Estudos Filosóficos 3:67–75
Caldas EC (1998) A agricultura na história de Portugal. Empresa de Publicações Nacionais, Lisbon
Carrier EH (1932) Water and Grass. A Study in the Pastoral Economy of Southern Europe. Reprint edn of 1980. Christophers, London
Caucanas S (1993) Aménagements hydrauliques en Roussillon du IXè au XVè s. Revue Géographique Des Pyrénées Et Du Sud-Ouest 63:65–72
Châteauvieux LF (1843) Voyages agronomiques en France. Maison Rustique, Paris
Cook H, Williamson T (2007) The later history of water meadows. Water Meadows: History, Ecology and Conservation, Cook H, Williams T (eds). Windgather Press, Macclesfield
Cook H, Stearne K, Williamson T (2003) The origins of watermeadows in England. Agricultural History Review 51: 155–162. http://www.bahs.org.uk/AGHR/ARTICLES/51n2a2.pdf
Corvo JA (1881) Da água para as regas. Empreza Commercial e Industrial Agrícola, Lisbon
Cossigny JC (1874) Notions élémentaires théoriques et pratiques sur les irrigations appliquées aux terres en culture, aux jardins et aux prairies. Société des agriculteurs de France, Paris
Cossigny JC (1889) Hydraulique Agricole: Amenagement des Eaux, Irrigation des terres. Librairie Polytechnique, Paris
Costa JM (1911) Política hidráulica: Misión social de los riegos en España. Biblioteca J. Costa, Madrid
Costa AJP (2005) Bento Fortunato de Moura Coutinho de Almeida d'Eça General de Divisão (1827–1906). Os Generais do Exército Português, ed. António José Pereira da Costa 2:333. Biblioteca do Exército, Lisbon
Diogo MP (1994) A construção de uma identidade profissional, a Associação dos Engenheiros Civis Portuguezes (1869–1937). PhD dissertation, Universidade de Lisboa
Duarte-Abadia B, Boelens R (2019) Colonizing rural waters: the politics of hydro-territorial transformation in the Guadalhorce Valley, Málaga, Spain. Water Int 44(2):148–168
Eça BFMC (1866a) Memoria acerca das irrigações na França, Italia, Belgica e Hespanha. Imprensa Nacional, Lisbon
Eça BFMC (1866b) Memoria ácerca das irrigações na França, Italia, Belgica e Hespanha. O Archivo rural, Jornal de Agricultura 9:85–97; 113–122; 150–160; 172–179; 209–216; 240–246
Eça BFMC (1877) Memorias acerca do regimen do Tejo e outros rios apresentadas ao Ministerio das Obras Publicas nos annos de 1867 e 1872. Imprensa Nacional, Lisbon
Eça BFMC (1888) As vinhas no meio-dia da França e o seu tratamento. Imprensa Nacional, Lisbon
Eça BFMC (1896) Elogio historico do Conselheiro João Chrysostomo d'Abreu e Sousa. Imprensa Nacional, Lisbon
Eça BFMC, Almeida A, Gomes JS, Loureiro FA, Braga AV (1883) Plano geral das obras que convem fazer para melhorar o regimen do Tejo e beneficiar os seus campos adjacentes. Revista de Obras Publicas e Minas, Anno XIV – Tomo XIV, 159:58–121
Eça BFMC, Cabral NAC, Cunha HL, Guerreiro JVM, Gomes JPS (1885) Memoria acerca do aproveitamento das aguas no Alentejo. Imprensa Nacional, Lisbon
Eça BFMC, Lecoq LV, Trigueiros JPT, Veiga JH, Teixeira ACJ, Carvalho ALS, Magalhães FP (1888) Regulamento para a fiscalisação da construcção de caminhos de ferro. Relatorio da commissão. Revista De Obras Públicas e Minas 219–220:76–80
Eça BFMC, Lopes PI, Cordeiro CX, Navarro AJA, Vilhaça AE (1897) Regulamento para projectos, provas e vigilancia das pontes metallicas. Imprensa Nacional, Lisbon
Eça BFMC (1876–1877) Caminho de ferro da Beira Alta. Memoria Justificativa. Revista de Obras Públicas e Minas 82–86: 381–399, 409–437, 447–460, 44–57, 61–75
Everard M (2005) Water Meadows, Living Treasures in the English Landscape. Forrest Text, Ceredigion
Fantoni G (2008) Water management in Milan and Lombardy in medieval times: an outline. J Water Land Develop 12:15–25. https://doi.org/10.2478/v10025-009-0002-0
Fournier P (2003) Aménagements hydrauliques et structuration de l'espace: les métamorphoses de l'eau en Provence et Comtat-XVIIème siécle, 221:585–601
Freire D, Lains P (2017) An agrarian history of Portugal, 1000–2000: Economic Development on the European Frontier. Brill, Leiden, Boston
Garcia-Pereda I, Rodrigues AD, Parejo-Moruno FM (2021) "The Boutelou Brothers: From gardening to agronomic practices, education and travels in Spain at the turn of the nineteenth century", Notes & Records of the Royal Society of London, 1–19. https://doi.org/10.1098/rsnr.2020.0053
Girel J (2012) La prairie arrosée: un système ingénieux du patrimoine agricole européen Rôle sur la biodiversité des communautés et des paysages et perspectives de restauration et conservation. LECA, UMR 5553 CNRS, Joseph Fourier Grenoble-Univ. de Savoie
Glick T (2005) Islamic and Christian Spain in the early middle ages. Brill, Leiden Boston
Gómez AL, Llera FA, Bullón CC (1998) Filipe II y el Tajo. In Millán J M (ed) Europa y la monarquía católica. Departamento de Geografía, Universidad Autónoma de Madrid, Madrid. https://www.researchgate.net/publication/29727313_Felipe_II_y_el_Tajo
Gorria H (1908) Importancia da hydraulica aplicada. A Construcção Moderna, Casa da Ex.ma Sr.a D. Guilhermina de Andrade Bastos Anno VIII – No. 17 – 1 de Janeiro – No. 245
Guerra MJJ (1861) Estudos chorographicos, phisicos e hidrographicos da bacia do Tejo comprehendida no Reino de Portugal, acompanhados de projectos e descrição das obras tendentes ao

melhoramento da navegação d'este rio e protecção dos campos adjacentes. Imprensa Nacional, Lisbon
Hager WH (2010) Hydraulic advances in the 19th and 20th centuries: From Navier over Prandtl into the figure. In: Cabrera E, Arregui F (Eds) Water Engineering and Management through Time: Learning from History. CRC Press, Taylor & Francis Group, New York
Ingold A (2009) To historicize or naturalize nature: hydraulic communities and administrative States in nineteenth-century Europe. Fr Hist Stud 32:385–417. https://doi.org/10.1215/00161071-2009-003
Leibundgut C (1985) Meadow irrigation in Central Europe. DVWK Bulletin 9:95–107. Parey, Hamburg/Berlin
Leibundgut C (2004) Historical meadow irrigation in Europe, a basis for agricultural development. IAHS Publ 286:77–87
Leibundgut C, Kohn I (2011) L'irrigation traditionelle dans le contexte européen. Evolution – diffusion – fonctions – avenir. Annales Valaisannes 2010–2011:155–195
Leibundgut C, Kohn I (2014) European traditional irrigation in transition part I: Irrigation in times past, a historic land use practice across Europe. Irrig Drain 63:273–293. https://doi.org/10.1002/ird.1826
Leitão H (2020) The Making of a Hydraulics Expert: Estevão Dias Cabral (1734–1811). In: Rodrigues AD, Marín CT (Eds) The History of Water Management in the Iberian Peninsula. Springer Birkhäuser, Cham, pp. 369–384 https://doi.org/10.1007/978-3-030-34061-2_17
Lombardini E (1844) Cenni idrografici sulla Lombardia, Sono compresi nelle Notizie naturali e civili sulla Lombardia. Tipografia G. Bernardoni, Milan
Loureiro A (1907) Elogio Historico de Bento Fortunato de Moura Coutinho d'Almeida d'Eça. Imprensa Nacional, Lisbon
Martins RMM (2010) João de Moura Coutinho de Almeida d'Eça (1872–1954), Arquitectura e urbanismo. PhD dissertation, University of Porto
Matos AC, Diogo MP (2006) Bringing it all back home: Portuguese engineers and their travels of learning (1850–1900). J History Sci Technol 1:155–182. http://hdl.handle.net/10174/2400
Mornay MJM (1841) Traité de l'irrigation en Lombardie. Imprimerie royale, Paris
Mornay MJM (1844) Rapport pratique et legislation des irrigations dans l'Italie supérieure et dans quelques états d'Allemagne. Imprimerie Royale, Paris
Ortì A (1984) Política hidráulica y cuestión social: orígenes, etapas y significados del regeneracionismo hidráulico de Joaquín Costa. Agric Soc 32:11–107
Pato JH (2007) O valor da água como bem público. PhD dissertation, University of Lisbon
Pereira HS (2012) A política ferroviária nacional (1845–1899). PhD dissertation, University of Porto
Pereira HS (2021a) Harbinger of progress: Portuguese illustrated journal 'O Occidente' in the late nineteenth century (1878–1899). Historia y Comunicación Social 26:165–180
Pereira HS (2021b) Appropriation, integration, and nation building: Portuguese railways in the second half of the nineteenth and early years of the Twentieth Century. Soc Sci Hist 45:391–416
Pereira HS (2022) Herald of progress: Karl Emil Biel's photographs of the technical modernisation of Portugal. Photographies 15:101–123
Pereira E, Rodrigues G (1907) Portugal. Dicionário Histórico, Corográfico, Heráldico, Biográfico, Bibliográfico, Numismático e Artístico, Vol. III-DK, João Romano Torres Editor, Lisbon
Picon A (1994) L'invention de l'ingénieur modern: l'École des ponts et chaussées, 1747–1851. Presses de l'École nationale des Ponts et chaussées, Paris
Picon A (2004) Engineers and engineering history: problems and perspectives. Hist Technol 20:421–436. https://doi.org/10.1080/0734151042000304367
Pugliese R, Lucchini M (2010) Milano città d'acqua. Nuovi paesaggi urbani per la tutela dei navigli. Alinea Editrice, Firenze
Quintela AC (2002) Vultos portugueses em hidráulica e recursos hídricos, Bento Fortunato de Moura Coutinho de Almeida d'Eça 1825–1906. Revista Recursos Hídricos 23:141–146
Rodrigues AD, Toribio Marín C (2020) The History of Water Management in the Iberian Peninsula, Between the Sixteenth and the Nineteenth Centuries, Trends in the History of Science book series. Springer/Birkhauser, Cham. https://doi.org/10.1007/978-3-030-34061-2
Romagny B, Riaux J (2007) La gestion communautaire de l'eau agricole à l'épreuve des politiques participatives: regards croisés Tunisie/Maroc. Hydrol Sci J 52(6):1179–1196
Ronna A (1888–90) Les Irrigations, 3 vols: I. Les eaux d'irrigation et les machines, II. Les canaux et les systèmes d'irrigation, III. Les cultures arrosées. L'économie des irrigations. Histoire, législation et administration. Firmin - Didot et cie, Paris
Ruf T (2001) Droits d'eau et institutions communautaires dans les Pyrénées-Orientales. Histoire & Sociétés Rurales 16:11–44
Silva AF (2020) Thirsting for efficiency: Technological and transaction-cost explanations for the municipalisation of water supplies. In Rodrigues AD, Marìn CT (Eds) The history of water management in the Iberian Peninsula. Springer Birkhäuser, Cham, pp. 89–111
Smith BR (1852) Italian Irrigation being a report on the Agricultural canals of Piedmont and Lombardy. W. H. Allen and Co., London
Smith BR (1855) Italian Irrigation being a report on the Agricultural canals of Piedmont and Lombardy, addressed to the Honourable the Court of Directors of the East India Company. William Blackwood and Sons, Edinburgh
Sor JV (1868) A Ágoa e os Solos Irrigaveis, Thesis presented at the Agricultural Institute, BISA, RB-21, manuscript
Swyngedouw E (1999) Modernity and hybridity: nature, regeneracionismo, and the production of the spanish waterscape, 1890–1930. Ann Assoc Am Geogr 89(3):443–465
Swyngedouw E (2015) 'Regeneracionismo and the Emergence of Hydraulic Modernization, 1898–1930', Liquid Power: Contested Hydro-Modernities in Twentieth-Century Spain. MIT Press, Cambridge
Veiga FM da (1859) Importância das Irrigações, Thesis presented at the Agricultural Institute, BISA, RB-7, manuscript
Vieira J (2010) Fotobiografia Século XX – Joshua Benoliel. Editor Temas & Debates, Lisbon
Watson AM (1981) A medieval green revolution. In: Udovitch A (ed) The Islamic Middle East, 700–1900. The Darwin Press, Princeton, pp 29–58
Wery G (1929) Nos grandes écoles: XIX: l'institut national agronomique. Revue Des Deux Mondes 1829–1971(51):418–435