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Changing rice geographies: a long-term perspective of Portuguese regional production (1860-2018)

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KEYWORDS: **rice, agricultural policy, regional inequality, historical geography.**

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From its origins in Asia, cultivation of Oryza sativa L. *in Portugal has had to adapt to local agroecological conditions. Since the late eighteenth century, there has been significant human intervention in rice production, particularly through public policies aimed at increasing production to achieve national food self-sufficiency. Using national and regional statistics on rice production, this article analyses how public policies on rice cultivation over the last 160 years have impacted and interacted with territorial agroecological conditions and the genetic characteristics of the rice varieties being cultivated. We concluded that public policies led to increased production by favouring the geographical reorganisation of rice production based on the rice varieties used and changing territorial agroecological conditions.*

As geografias do arroz: Uma análise de longa duração da produção regional de arroz em Portugal (1860-2018)

PALAVRAS-CHAVE: **arroz, política agrária, desigualdade regional, geografia histórica.**

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De origem asiática, o cultivo de Oryza sativa L. *em Portugal teve que se adaptar às condições agroecológicas locais. Assim, desde o final do século XVIII, que se assiste a uma significativa intervenção humana na produção de arroz, particularmente através de políticas públicas com o objetivo de aumentar a produção e atingir a autossuficiência alimentar. A partir de estatísticas nacionais e regionais, este artigo analisa o impacto das políticas públicas na orizicultura nos últimos 160 anos e, sobretudo, a sua interação com as condições agroecológicas locais e as características genéticas das variedades de arroz utilizadas. O resultado foi o aumento da produção, bem como a alteração da geografia orizícola portuguesa. Concluiu-se que, de forma a aumentar a produção, as políticas públicas favoreceram a reorganização geográfica da produção de arroz de acordo com as constantes mudanças das condições agroecológicas do território e as características das variedades de arroz cultivadas.*

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1. INTRODUCTION

Domesticated in the Yangtze River valley some 13,000 to 14,000 years ago (Sweeney & McCouch, 2007), Asian rice (*Oryza sativa* L.) is by far the most successful of the world's two cultivated rice species (Global Rice Science Partnership, 2013). It grows on all continents and the different varieties of *Oryza sativa* L. provide the vast majority of the world's production of this cereal. Today, rice is one of the world's most important cereals, and in 2020 more than 755 million tonnes were produced worldwide (FAO, 2022). Although this figure is not the highest of the three main cereals (maize, wheat and rice), rice is the staple food for the largest number of people on earth, feeding around half of the world's population. This is due to the higher proportion of rice used for direct human consumption compared to other cereals (78% for rice, 64% for wheat and 14% for maize) (Global Rice Science Partnership, 2013: 10). The other cultivated rice, *Oryza glaberrima* Steud., which originated in West Africa, is now largely confined to its homeland, and even there it occupies only 5% of the total rice area (Linares, 2002: 16360; Sharma, 2010: 16; Wang *et al.,* 2014). Both types of rice were domesticated under very different environmental conditions from those found in many of the regions where they are grown today (Wang *et al.,* 2014: 982). It has taken several human interventions to adapt rice in an economically and environmentally sustainable way, for example from Japan to Mediterranean Europe or the United States of America (USA). Considering that Europe's high geographical diversity strongly influences the regional impact of different crops (Hillbom & Svensson, 2013: 1-25; Lains, 2017: 279-307), this study analyses how rice has been cultivated along the Portuguese Atlantic Ocean coast since the 19th century.

From the 15th century onwards, the intercontinental circulation of various crops accelerated the transformation of the previous areas of production and consumption. This is the case of the *Oryza sativa* L. The routes that led to the productive success of this rice species from Asia, through Africa and from there to the Americas have already been studied (Pereira, 2002; Sweeney & McCouch, 2007; Sharma 2010; Bray *et al.,* 2015; Ferrão, 2016; Maat & Andel, 2018). However, its impact on different European regions is not yet fully known (Calatayud, 2002; Mendes, 2005). Moreover, as several authors have pointed out, to fully understand the successes and failures of the crops involved in this global exchange, it is necessary to assess the complexity of the biotic relationships established in each territory (Mann, 2011; Gade, 2015; Bell, 2018; Polónia *et al.*, 2018).

Therefore, the aim of this study is to understand how it was possible to successfully grow *Oryza sativa* L. in a different climate in the southern Atlantic corner of Europe. The specific objectives are a) to identify the evolution of rice production in Portugal since the late 18th century, paying particular attention to developments since the 1860s, for which

regional agricultural production statistics exist; b) to discuss its changing geography, considering three essential factors for agricultural innovation: human action, regional agroecological conditions, and biotechnological improvements; and c) to examine the role of public policies in promoting agricultural development and, in the Portuguese context, economic development.

It is argued that successful agriculture involves an appropriate combination of three factors: the relationship between crops and local environmental conditions –or agroecological conditions–[1], the genetic characteristics of each plant species –or seed–[2], and human intervention that can positively enhance the effects of the previous factors. This is a new framework proposal that has been explored (Gomes & Freire, 2023) and this study on rice contributes to deepening the discussion on the interaction of this triangle of factors. Although it may be difficult to identify each one in the past, this is a dynamic set of factors that have supported agriculture since the Neolithic period. Depending on historical and environmental circumstances, agroecological conditions, seeds or human actions may have had different impacts on agricultural innovation. Given the long processes of environmental, biological and cultural adaptations that underpin agricultural production, analysing the interaction of these factors requires consideration of space and time. This article explores precisely this framework from a long-term perspective[3] in order to explain the development of rice cultivation in Portugal. In fact, rice was the only cereal in Portugal that managed to keep pace with the increase in productivity in other European countries (Faísca, Freire & Viana, 2021). Currently, it is the second most produced grain in the country and the Portuguese are the highest consumers of rice in Europe (FAO, 2018).

The characteristics of Portugal and its rice production allow a detailed analysis of the interaction between the three factors mentioned above. First and foremost, the analysis is facilitated by the agroecological and agroeconomic diversity of the country. The more northern areas where rice has been cultivated are relatively cold, wet and historically dominated by family farming. On the other hand, the more southern areas are hot, dry and have long established large farms. Faced with this diversity in a territory that has been politically unified since the Middle Ages, it is possible to identify the effects of human action, especially that of a long-lasting organisation such as the State, with the local agroecological conditions and the seed diversity of each plant species. This is true in theory, since the same State has acted over long periods of time in regions with different characteris-

1. See the OECD (2022) definition of *agroecology*.

2. The use of the term *seed* will hereafter refer to the genetic characteristics of each plant species.

3. For the possibilities of long-term analysis in virtually all the fields of science, see Guildi and Armitage (2014).

tics, making a regional analysis all the more relevant (Peña-Chocarro *et al.*, 2019). And it is correct from a practical standpoint, since the historiographical tradition and the uniform access to archives make a regional and long-term analysis of the Portuguese case a highly coherent exercise (Lains, 2017: 279-307).

Secondly, Portugal's own past provides the country with characteristics suitable for the study of agricultural innovation and its links to economic development. From the 15th century onwards, Portugal's early opening up to the world economy exposed it to the intercontinental circulation of different crops, changing the previous geographies of production and consumption within the so-called *Columbian Exchange* (Crosby, 1972; Carney, 2001; Coclanis, 2011). Although Portugal was one of the first to promote globalisation (Carney, 2001; Ferrão, 2016; Linares, 2002), it was also one of the last European countries where agriculture remained the main social and economic activity, into the 1960s (Amaral & Freire, 2017: 256). Given that the structural changes associated with modern economic growth occurred after the Second World War (Lains, 2003: 369-386), discussing the Portuguese paths to agricultural innovation contributes to a better understanding of the conditions of development on the European periphery, which is the subject of an ongoing debate (North, 1990; Lains, 2017).

In order to meet the proposed objectives, this study is structured as follows. After this introduction, the general background of the research is presented, with an explanation of the agroecological conditions required by rice and how they vary throughout the Portuguese territory, as well as a historical trajectory of rice production in Europe and in Portugal. The third section, the bulk of the research, links the three factors mentioned above: human actions (with a particular focus on public polices), agroecological conditions and cultivated seeds. The fourth section, based on the development of regional rice production, discusses how public policies have had the effect of reorganising the geography of rice cultivation in Portugal. The empirical support for the identification of regional changes is mainly provided by official Portuguese statistical data, which are only available from the 1860s onwards (Freire & Faísca, 2021), thus justifying the chronological scope of the title.

In conclusion, it is argued that several public measures from the 1910s onwards, such as the introduction of foreign, selected and hybrid seeds, technical assistance to farmers, and the increase and (from the late 1930s) the expansion of irrigation, were invaluable contributions to the success of Portuguese rice cultivation. These measures continued after 1986, when Portugal joined the European Economic Community and became subject to the Common Agricultural Policy (CAP) and rice was included as one of the crops to be supported. Favourable agroecological conditions within the European continent, as well as the contribution to convergence with the core European economies in terms of

productivity growth, justified support for Portuguese rice production. Prior to this, the Portuguese state did not have the capacity to make a decisive impact on rice production and pursued an ambivalent policy, either encouraging rice production through protectionism or restricting it due to public health problems associated with malaria. Therefore, this research shows the design of two different periods regarding the implementation of public policies, combined with the aforementioned factors (seeds and agroecological conditions), leading to very different outcomes at both national and regional levels.

However, public policies were not implemented in a similar way in all rice-producing regions. In fact, human action, measured by the impact of public policies, acted consistently according to the existing agroecological conditions, supporting the regions with the best conditions for rice production. As a result, the geographical distribution of rice production in Portugal was changed somewhat, with the central and southern regions being strengthened and the remaining northern regions experiencing a substantial decline in this crop. The Portuguese public policies were crucial for the success of rice production, promoting agricultural innovation and economic development in one of Europe's least developed countries.

2. RICE CULTIVATION IN A TEMPERATE EUROPEAN COUNTRY

Although *Oryza sativa* L. is the dominant rice species in the world, it originated in a tropical climate[4] and, despite centuries of biotechnological improvements, only certain European regions meet the minimum ecological requirements for its cultivation. Rice seed germinates between 12 °C and 40 °C, with an optimal temperature range of 30 °C to 35 °C (Angladette, 1975: 36; Faria & Pinto, 1980: 3). In Europe, where these temperatures are unusual, rice is concentrated in the warmer southern countries[5]. Thus, the European production is around 4 million metric tonnes, harvested from almost 630,000 hectares, while in Asia the figures are 705 million metric tonnes, 146 million hectares, representing no less than 90% of world production (FAO, 2022).

Historically, rice cultivation in Europe was even more limited. Although known to Europeans since at least Classical Antiquity, rice was seen primarily as a medicinal or cos-

4. According to palaeobotanists, when *Oryza sativa* L. was domesticated the climate of the Yangtze basin was warmer than it is today. See SHARMA (2010: 4).

5. Rice production in Europe comes almost exclusively from countries with a Mediterranean climate such as Portugal, Spain, Italy, France, and Greece. The exceptions are Ukraine and near the Russian areas on the European/Asian border.

metic product. Only the westward expansion of Islam changed these perceptions and uses somewhat in the 8th century (Sharma, 2010: 15-8). Around this time, rice was cultivated in some regions of the Mediterranean basin, such as Sicily and Valencia. Later, in the Middle Ages, a small rice trade route developed between southern Europe and North Africa (Ferrero & Vidotto, 2010: 343). In the 15th century, an attempt was made in Italy, and in the following century in southern France, to expand the areas of rice cultivation. Both experiments faced problems that severely limited them, possibly due to the association of rice farming with malaria (Ferrero & Vidotto, 2010: 345), but also to climate adaptation. Indeed, the so-called Little Ice Age, which in Europe lasted from the early 14th century to the mid-19th century, cooled the European climate to a large extent (Oliva *et al.*, 2018; Silva, 2019: 244-57). This probably made it even more difficult to grow rice in the "Old Continent". In this context, rice production in Europe before the late 18th century was limited to a few small areas in Italy, southern France, Spain (Valencia) and, finally, a few isolated places in Portugal (Calatayud, 2002: 41; Ferrero & Vidotto, 2010: 343-45; Carmo *et al.*, 2020: 46-52).

In fact, uncertainties still persist as to when rice was first cultivated in Portugal. An ongoing debate, summarised by Faísca, Freire and Viana (2021: 245-48), concerns the chronology of the introduction of rice and whether *Oryza glaberrima* Steud. could have been cultivated in Portugal in the early 16th century (Carmo *et al.*, 2020)[6]. What is known is that rice has been used as a food in Portuguese cuisine since at least the late 15th century, as shown by several recipes in various cookery books (Manupella, 1986; Freire, 2020). Consumption was not limited to the elites. The purchase of rice by institutions such as hospitals or schools and its sale on the streets of Lisbon in the 16th century are well documented (Brandão, 1993; Oliveira, 2016; Faísca, Freire & Viana, 2021). Nevertheless, it seems that, with a few exceptions, rice was not cultivated in Portuguese territory until the 18th century (Miranda, 2017: 86).

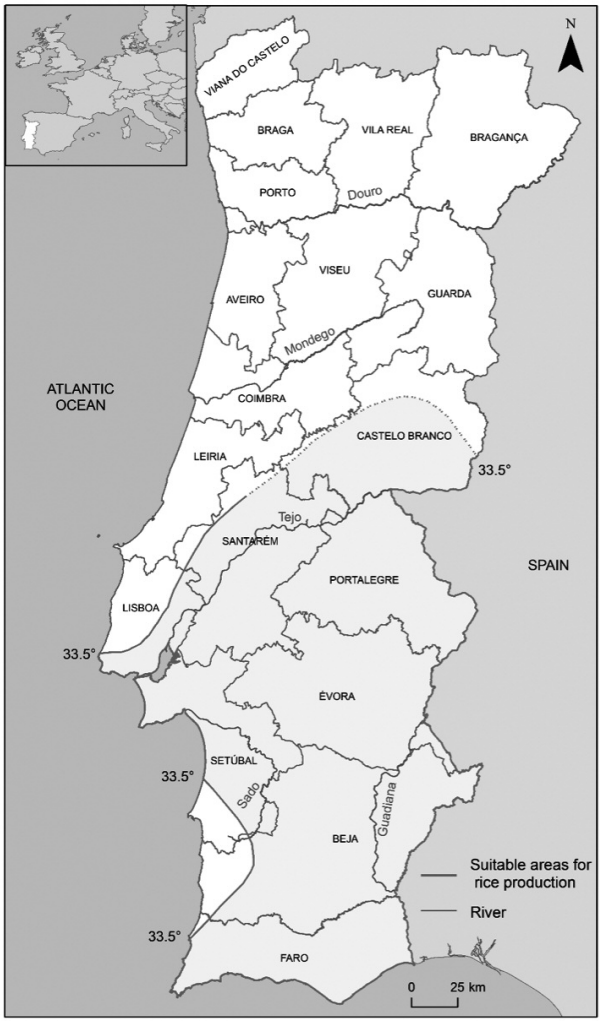
Another important condition for successful rice production is a daily temperature variation of around 4 °C (Seabra, 1938: 62). The submersion of rice fields, a characteristic of the landscape, is aimed precisely at reducing daily temperature fluctuations. In Europe, all rice is grown in artificially irrigated fields (Ferrero & Vidotto, 2010: 348). The introduction of rice cultivation on water terraces led to changes in previous local agricultural systems and land use in Europe. In saltier and/or swampy fields, rice could be the only viable crop, so these fields could be added to increase the agricultural area (Ferrero & Vi-

6. The possible introduction of "African" rice is being studied by the project *Ecologies of Freedom: Materialities of Slavery and Post-emancipation in the Atlantic World* (PTDC/HAR-ARQ/5619/2020) funded by the Portuguese Foundation for Science and Technology (FCT).

dotto, 2010: 347; Seabra, 1938: 16). However, on already cultivated land, the expansion of rice may have led to various changes: either replacing certain crops, such as maize and beans (Corvo, 1860: 47, 54, 373), or becoming part of a crop rotation with maize, fodder and, in some cases, rainfed cereals such as wheat. In fact, on land where crop rotation was possible, it was even recommended as a way of restoring soil fertility after successive years of rice production (Seabra, 1938: 18-21).

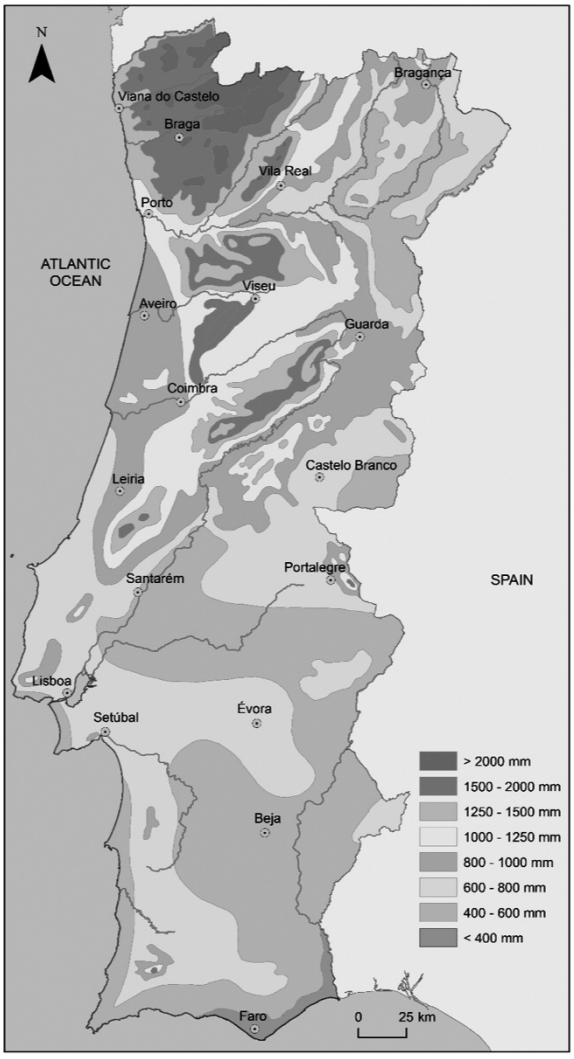
FIGURE 1

Suitable areas for rice production in Portugal in terms of temperature



Source: Faria and Pinto (1980: 16).

FIGURE 2
Average annual rainfall in Portugal in the 1930s

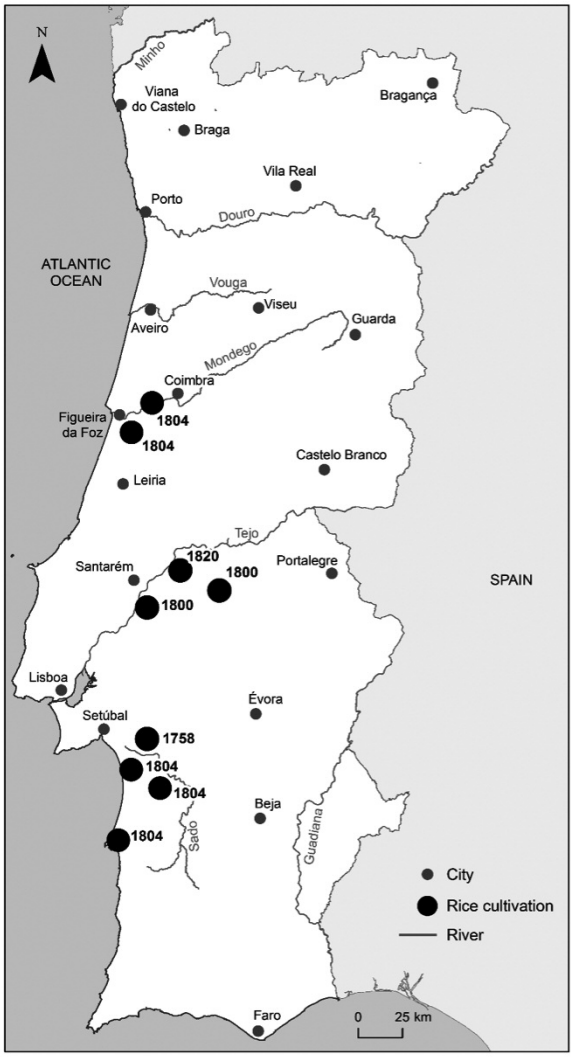


Source: Girão (1941: 188).

While water and temperature are vital, soils, although important, tend to play a rather secondary role in rice production. In the past, agronomists claimed that rice could be grown on almost any type of soil, from sandy to clayey soils, although clay-silico-calcareous soils are the most suitable (Seabra, 1938: 18-21; Silva, 1969: 131). Due to its relative resistance to salinity, rice can be grown in marshlands with the use of fresh water, as is the case in Valencia in Spain (Ferrero & Vidotto, 2010: 347) or in West Africa (Carmo *et al.*,

2020: 57). In these cases, rainfed rice cultivation promotes desalinisation, allowing for future crops other than rice (Silva, 1969: 132). Thus, the main variations in rice agroecology –the relationship between agricultural crops and the environment– are temperature and water. Therefore, our analysis focuses on these two agroecological elements.

FIGURE 3
Places where rice cultivation is mentioned between the mid-18th century and the early 19th century



Sources: Telles (1800, 10), Brotero (1804, 596), Corvo (1860, 136), Cornide (1894, 227), Cornide (1897, 106) and Fonseca (2000, 89).

Rice production in Portugal has never been possible without a stable water supply, nor has it been possible to have the right temperature throughout the territory. With regard to the Portuguese climate, the water and temperature conditions for rice production are paradoxical, since the growing season runs from April to September (Faria & Pinto, 1980: 6), which is precisely the time when rain is scarce in the southern regions, while in the northern regions low temperatures are frequent. In a study on the relationship between rice cultivation and temperature in Portugal, Faria and Pinto (1980) concluded that only the central and southern areas of the country were fairly suitable for rice production (Fig. 1).

Nevertheless, rice has historically been produced in several regions north of the line shown in the previous figure (Fig. 1), but never north of the Douro River, where temperatures are too low. For this reason, the regional division of rice production in Portugal, which has been established by many authors over time, differs from others usually used for agronomic, administrative or political purposes (Seabra, 1938; Baptista, 1993). It is therefore necessary to redefine certain regional boundaries for rice production: the northern region covers the districts of Aveiro, Coimbra and Leiria; the central region extends to the districts of Santarém and Lisbon; and the southern region includes the districts of Setúbal, Portalegre, Évora, Beja and Faro (Fig. 1). On the one hand, while low temperatures threatened the expansion of rice in the northern areas, the lack of rain and, therefore, of water during the hot season was a threat to the central and southern areas. On the other hand, rain and water are more abundant in the north (Fig. 2). In order to consolidate rice production, it was therefore essential to ensure a regular water supply in the warmer regions of the central and southern parts of the country.

3. PUBLIC POLICIES, AGROECOLOGICAL CONDITIONS AND SEEDS

Public policy regarding rice cultivation began around 1781, when the Portuguese crown encouraged through the establishment of a favourable import tariff policy (Martins, 2005: 230-31). In this early period, rice fields spread along Portugal's main central and southern rivers: Sado (Lisbon/Setúbal), Tejo (Santarém), Mondego (Coimbra) and Vouga (Aveiro) (Fig. 3) (Daveau, Ribeiro & Latensach, 1988, 1021). The rivers located more to the north, such as the Douro, were excluded because rice did not thrive in these regions due to the low minimum temperatures, even during the summer months (Daveau, Ribeiro & Lautensach, 1988: 1021). This form of public support remained in place, albeit with some fluctuations. It continued throughout the 19th century, as the protection of the national production was maintained in the tariff revisions of 1837, 1841, 1861 and 1892 (Silva, 1956: 11-31). After a period of reduced trade protectionism between the late

1910s and the 1920s, the dictatorship regime (1926-74) not only reinstated it, but even reinforced it by fixing the retail price of rice (Pires, 2020: 107-24). More recently, since Portugal joined the European Economic Community (EEC)/European Union (EU) in 1986, and due to the EU's deficit in rice production, public support for its cultivation has almost always been maintained. This is done in two main ways: by price intervention, which at the beginning of the 21st century amounted to 298.5 €/tonne, and production subsidies, which in the same period amounted to 318.53 €/hectare (Costa, 2017: 36).

As rice cultivation expanded in the second half of the 19th century, popular protests arose and even the scientific community criticised the public policies that promoted this crop. The reason was the link between rice and malaria, a deadly disease even today. At the time, this link was based on the *miasma theory*, which claimed that intermittent fevers were caused by emanations (miasmas) from decaying organic matter, especially in swampy areas such as rice fields (Vaquinhas, 1991: 689-703). This led to an ambiguous position of the State towards rice cultivation. While supporting the crop through a clear set of protectionist political policies, the State also published public health laws restricting cultivation (Baptista, 1993: 127).

However, the first decades of the 20th century marked a new phase in public rice policies. In addition to protectionism, the Portuguese state tackled the problem of malaria, invested in the development of biotechnology, and solved the problem of water scarcity in the southern regions through irrigation. In terms of public health, the scenario became increasingly favourable for rice production when, at the beginning of the 20th century, science began to fully understand the causes of malaria and found that the disease was not a direct consequence of rice cultivation. In fact, malaria is caused by a parasite transmitted by the Anopheles mosquito, which thrives in stagnant water (Gomes *et al.,* 2016). In 1916, as a result of these discoveries, Decree-Law No 2223 of 17 February 1916 greatly reduced the restrictions that made it difficult to expand rice fields with the help of flowing water. This law also introduced a tax incentive for new rice fields if pre-existing wetlands were drained. By the end of the 1950s, the disease had been eradicated, thanks to the combined efforts of two Portuguese public institutions (Instituto de Malariologia and Direcção-Geral dos Serviços Anti-Sezonáticos) with the support of the Rockefeller Foundation, a private organisation from the United States of America (Saavedra, 2017: 51-9). Without malaria, one of the main obstacles to rice production in Portugal disappeared.

Public policy also intervened in the agroecological conditions required by the crop. The scarcity of water, particularly in the south of Portugal, meant that, from the 17th century, building irrigation systems was discussed as a way of encouraging agricultural improvement (Faria, 1655). Although, the idea survived various historical periods and political

decisions with very little success, there were some concrete plans to implement it starting in the late 19th century (Ministério das Obras Públicas, Comércio e Indústria de Portugal, 1884). In 1916, the construction of public irrigation systems as a strategy to promote rice cultivation was also included in the aforementioned law. However, mainly due to financial problems, the state did not start building these until the late 1930s, which had a real impact on agriculture, especially rice production, in the following decades.

Thus, by 1974, the year in which the Estado Novo dictatorship ended, more than 80,000 hectares of new public irrigation areas were available for agriculture (Baptista, 1993). Since then, another 170,000 hectares have been irrigated, bringing the current total to almost 250,000 hectares (Direção Geral de Agricultura e Desenvolvimento Rural, 2022). Much of this water was unevenly available for rice cultivation across the country. Most public irrigation systems were built in the central and southern regions, where land concentration and/or agribusiness predominate. Although State-sponsored irrigation was originally intended to promote family farming and land reform, this did not happen. In practice, agribusiness and large landowners were the real beneficiaries (Silva, 2020). In this way, more than 80% of the 80,000 hectares of irrigation built under the dictatorship regime benefited large estates (Baptista, 1993: 80), as farmers used the increased water supply mainly for rice production (Daveau, Ribeiro & Lautensach, 1988: 1018).

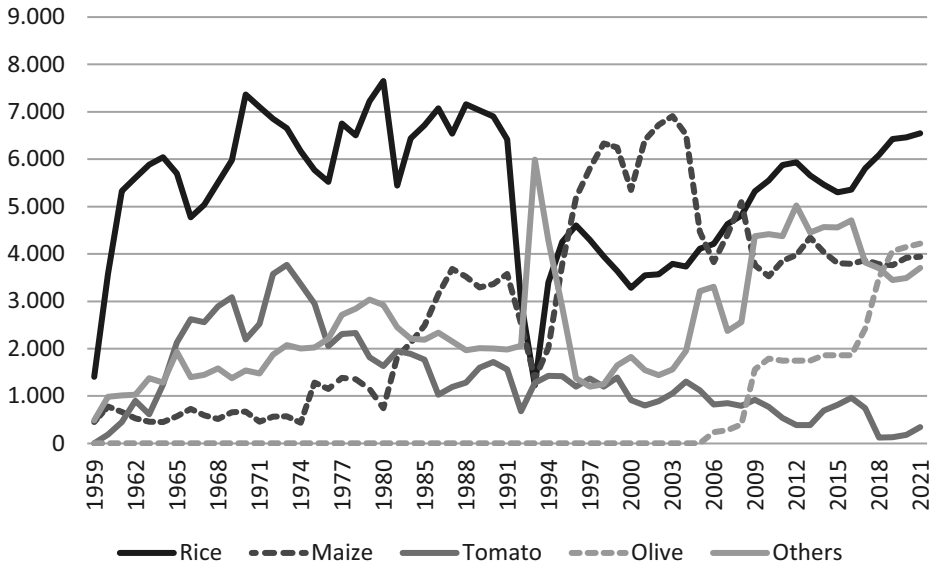
One example is the irrigation system of the Sorraia River Valley, which benefits rice fields in the district of Santarém (central region). With more than 16,000 hectares under irrigation, most of this land has been used to grow rice since 1959 (Graph 1). There have been similar experiences in other public irrigation systems in the south, even those that were not originally designed for rice cultivation. This was the case with the irrigation systems around the Sado River, which had a direct impact on agriculture in the Setúbal District (southern region). Originally designed to improve fodder and vegetable production, rice and later tomato became the dominant crops due to their profitability (Baptista, 1993: 85).

These watersheds were built where rice was already grown, and where the crop expanded both in area and in productivity, thanks to a permanent, fairly adequate and stable supply of water. However, there were other southern regions that had no previous experience of rice cultivation, particularly in the hinterland districts of Portalegre and Évora, where rice became part of local agriculture. In Elvas, for example (district of Portalegre), rice occupied a modest area in 1952 (Russo & Santos, 1952). Following the inauguration of the Caia irrigation system, a tributary of the Guadiana River, the rice area expanded around the 1970s, to more than 1,700 hectares (Baptista, 1993: 118). The expansion of the rice area has mainly been carried out using freshwater irrigation systems. This has led

to an increase in the proportion of freshwater rice cultivation and a decrease in the proportion of estuarine polders, where rainfall allows for soil desalinisation for and by rice cultivation.

GRAPH 1

Irrigated area in hectares by crop of the Sorraia irrigation system, 1959-2019



Source: Associação de Regantes e Beneficiários do Vale do Sorraia (2021).

Conversely, still in the south, in the districts of Beja and Faro, the increase in irrigated areas did not lead to an increase in rice production. In these regions, according to Baptista, given its great scarcity, the water consumption required for rice cultivation was difficult to achieve, dictating its gradual disappearance (Baptista, 1993: 85). In fact, rice was a marginal crop in the early 1990s and is now almost nonexistent in the region (Table 1).

The northern districts had two different public irrigation situations. In Leiria and Aveiro, the public irrigation systems were less ambitious. In Leiria, this type of irrigation covers about 2,145 hectares, of which only 190 hectares were originally planned for rice growing, because it was considered that the region did not have all the agroecological conditions required by the crop (Pacheco, 1959: 105). In Aveiro, there is only one irrigation system, built in 1940, that covers an almost insignificant area of 169 hectares. Thus, the irrigation of the fields of the Vouga River in the district of Aveiro was excluded from the final public plan approved in 1938, although it had been included in the 1935 version (Baptista, 1993: 72-3).

TABLE 1
Share of irrigated rice area in the total irrigated area of the Mira Hydro-Agricultural Development, 1991-2018

Year	Rice crop area (ha)	Total irrigated area (Ha)	Share of rice crop
1991	325.4	5,708.2	5.7%
1995	230.8	5,416.0	4.3%
2000	145.3	8,946.4	1.6%
2005	49.0	7,856.4	0.6%
2010	15.9	6,894.6	0.2%
2015	0.00	6,987.2	0.0%
2018	11.1	7,253.7	0.2%

Source: Associação de Beneficiários do Mira (2021).

The main exception is the district of Coimbra, which has more than 5,500 hectares of irrigated land. The irrigation system for the Baixo Mondego River was completed in 1981, but it follows others that have existed in the past (Vaquinhas, 1991: 691). In 1995, Silva claimed that the continuation of rice cultivation in the district of Coimbra depended essentially on the availability of water, and referred to several forecasts that pointed to the disappearance of the crop in the short term (Silva, 1995: 35). However, this has not been the case and currently a significant amount of water from the Baixo Mondego irrigation system is still used for rice production. Rice currently accounts for around a third of irrigated land, equivalent to an average of 1,850 hectares per year between 2015 and 2019, and is only surpassed by maize[7].

During the 20th century, rice was the only Portuguese crop to match the productivity growth of other European countries. In addition to the factors mentioned above, a certain modernisation of rice production took place in the context of the *Green Revolution*, which became the dominant trend in world agriculture from the mid-20th century (Freire & Lanero, 2013: 183-203)[8]. Among other things, there was a renewal of cultivation techniques, seed hybridisation, greater use of fertilisers, and the integration of agricultural machinery (Soares, 2005: 157-85). While private farmers played a key role in this process, especially those with the capacity to invest, public policies led to the creation of infrastructures capable of disseminating the latest knowledge related to rice cultivation. Thus, between 1937 and 1942, three experimental stations were created within the Direcção–

7. Data obtained directly from the Associação de Beneficiários da Obra de Fomento Hidroagrícola do Baixo Mondego.

8. The specific pathways of *Green Revolution* implementation in the Iberian Peninsula are analyzed in Freire and Lanero (2013).

Geral dos Serviços Agrícolas. Although their real impact has been questioned (Amaral & Freire, 2017: 256), their location indicates the places that public policy considered most important for the future of rice cultivation. In 1937, the Mondego station, in the district of Coimbra (northern region), and the Sado station, in the district of Setúbal (southern region), were opened; the Tejo station, in the district of Santarém (central regional), was inaugurated in 1942 (Silva, 1956: 57). In any case, and although the public services themselves recognise that the objectives of these infrastructures were often not achieved, it is known that these stations provided some effective technical support and distributed foreign, selected and hybrid seeds to local farmers (Borges, Silva & Sá, 1986: VII, 1-3).

In fact, public policy also focused on seeds. For example, in 1910, the state, aware that a private farmer in the district of Coimbra was growing foreign seeds of Asian origin imported from Italy, sent a special mission to that European country. Several seeds were brought back and soon after distributed to farmers. The distribution of seeds became a regular task of the public agricultural services (Seabra, 1938: 41). These seeds had undergone biotechnological intervention at the Vercelli Rice Station in Italy to adapt them to the Mediterranean climate (Seabra, 1938: 42). This kind of initiative, followed by the Portuguese public services, was in line with what other states were doing at the same time. For example, in the early 20th century, the USA began to distribute foreign and selected seeds to American farmers through experimental stations and land-grant universities (Kloppenburg, 2004: 12). In Portugal, a little later, from 1936 onwards, a permanent Rice Improvement Section was set up within the Department of Genetics and Improvement of the National Agricultural Station. This state-run organisation continued to distribute foreign, selected and hybrid seeds to farmers through a network of regional stations until the late 1980s (Borges, Silva & Sá, 1986: VII, 1-3). After an interregnum, the improvement of hybrid seeds in Portugal was resumed in 2003 through the Centro Tecnológico do Arroz, a scientific research organisation owned by public and private entities (COTArroz, 2022).

The introduction of foreign rice varieties was also unequal. Until then, regardless of the regions, only *Praganudo* rice, known as "common" rice, or *Vand* rice, known as *Carolino,* had been grown (Corvo, 1860: 355). As mentioned above, the State wanted to increase rice production and, from 1910 onwards, the distribution of foreign seeds with genetically improved characteristics directly to farmers became a regular task of the agricultural services (Seabra, 1938: 41; Silva, 1956: 34). However, not all the varieties were suitable for sowing in the Portuguese regions. For example, the *Chinês Originário* variety had the highest productivity, but also a long growing cycle, between 165 and 174 days. This meant that its growing cycle could last until mid-September, a month in which, in the northern regions, rainfall, low temperatures and fog affected the ripening of the rice

(Seabra, 1938: 44), making it unsuitable for cultivation in the north. Thus, in the northern districts of Coimbra and Leiria the varieties selected were mainly *Allorio* and *Novelli*, which have a shorter growing cycle of between 135 to 145 days and lower productivity (Seabra, 1938: 41-2; Silva, 1956: 21). In the district of Aveiro, where the weather is even wetter and colder, new varieties were not introduced until the 1940s (Seabra, 1938: 44). There, the *arroz da terra*[9] variety, as it was called, continued to predominate. At the same time, it was the less productive and the less commercially valued rice, but it had an extremely short growing cycle, between 120 to 130 days, which gave a better chance of a successful harvest around the Vouga River (Seabra, 1938: 41-2).

4. A NEW MAP OF RICE PRODUCTION

All the public measures described had a profound impact on Portuguese rice production. On the one hand, they allowed a significant increase in production and productivity. On the other hand, the geography of rice farming changed with an increase in production in the districts of the central and southern regions and a decrease in those of the north, with the exception of the district of Coimbra. Trends in national and regional rice production over the last century and a half confirm this. Graph 2 shows the growth of rice production in Portugal, especially since the 1930s, precisely when the first public irrigation systems began to operate, the incidence of malaria was greatly reduced until it was eradicated, and the introduction of foreign selected seeds began. Between the late 1950s and the early 1970s, production peaked at around 200,000 tonnes per year.

Despite a fall in production after the end of the dictatorship regime (1974), rice production remained at high production levels, even after Portugal joined the EU and the CAP. Indeed, the strategic position of Portuguese rice in European agriculture meant that it continued to be supported, unlike other cereals such as wheat, rye and barley. Over the last decade, rice has become the second most important cereal produced in Portugal, with an average annual production of around 175,000 tonnes over the last decade, surpassed only by maize (Faísca, Freire & Viana, 2021).

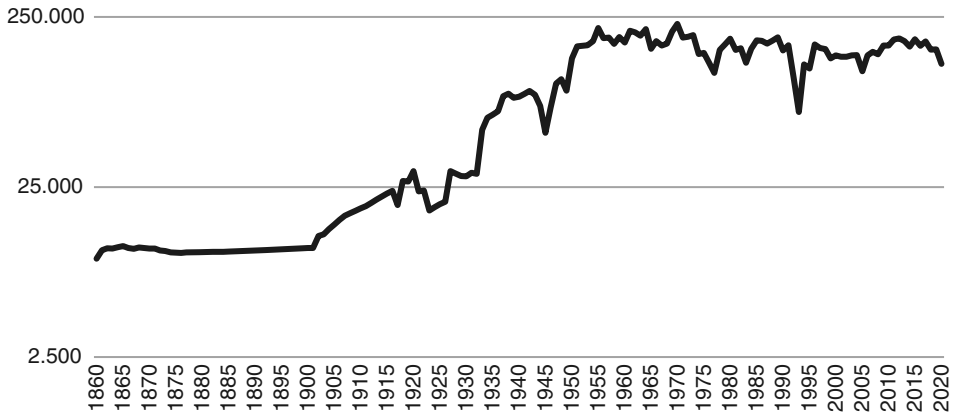
However, this pronounced growth conceals numerous regional differences. For example, in the second half of the 19th century, when the first quantitative data is available, the northern districts of Aveiro and Coimbra, the central district of Santarém and the southern districts of Lisbon/Setúbal accounted for more than 83% of the national rice pro-

9. Literally translated, it means "land rice". It is probably a local rice that was also identified in the few remaining rice fields in the Tagus estuary in 15th and 16th centuries. See Custódio (2016).

duction. A detailed analysis shows that the district of Lisbon/Setúbal stands out, with 41.09% of the national production, with a great preponderance of the Sado rice fields[10]. This is followed by three districts with similar proportions: Santarém (16.9%), Aveiro (14.0%) and Coimbra (13.0%). This group is followed by another made up of the districts of Leiria (6.0%) and Faro (4.1%), while the districts of the southern interior regions (Évora 2.3%, Portalegre 1.8% and Beja 1.0%) are still of little importance.

GRAPH 2

Portuguese rice production in tonnes in a semilogarithmic scale, 1860-2020



Source: Faísca, Freire and Viana (2021).

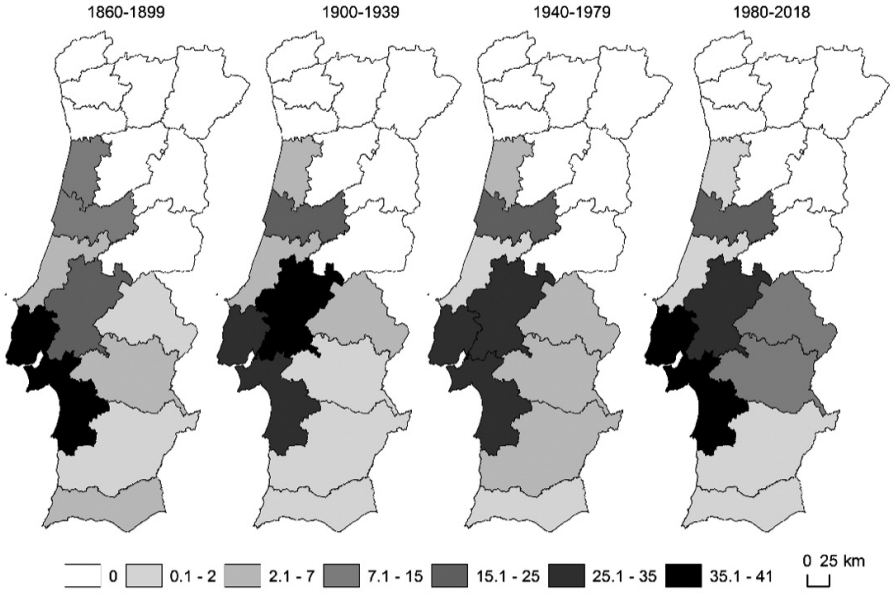
The beginning of the 20th century established the main regional trends that have continued to the present day. The most notable was probably the rapid decline of the district of Aveiro to its current state of insignificance. Similarly, in the districts of Leiria and Faro, this period marked the beginning of the disappearance of rice, which is now almost non-existent. Conversely, from the middle of the 20th century, the southern interior districts of Portalegre and Évora began to become important as public irrigation extended to the

10. The district of Setúbal was only created in 1926, when it was split off from the historic district of Lisbon, and is therefore referred to in this paper as the district of Lisbon/Setúbal. It is located in the southern region and is connected to the Sado River, although Lisbon is actually the central region and is connected to the Tejo River. However, since most of the rice produced in these two districts is located in Setúbal, this small inconsistency does not invalidate the assumptions and conclusions. For example, in 1930, the district of Lisbon produced 278 tonnes of rice, while Setúbal reached 9,903 tonnes. In 2018, the difference was between 1,560 tonnes in Lisbon and 82,134 in Setúbal.

southern areas. Among the districts with the highest rice production, the increase in the share of Santarém is of note, which is beginning to challenge the predominance of the district of Lisbon/Setúbal. Finally, Coimbra has always had a more or less stable share of between 13% and 18% of the total Portuguese rice production.

The main changes in the regional rice production are therefore linked firstly to the relative growth of the central and southern regions, such as the southern interior districts of Portalegre and Évora, or the increase in production in Santarém; and secondly to the relative loss of the share of the northern regions, such as Leiria and especially the district of Aveiro, with the exception of Coimbra. It should also be noted that the level of regional concentration of national rice production has always remained fairly stable (Fig. 4 and Table 2).

FIGURE 4
Change in the share of rice production in Portugal by district, 1860-2018



Source: Universidade de Lisboa, Instituto de Ciências Sociais (2021).

With warmer temperatures and government intervention, permanent water supplies, foreign, selected and hybrid seed varieties and local technical support, rice production in the central and southern regions of Portugal became increasingly important (Fig. 5). These are the effects of the three factors that make up the framework of agricultural production: human action, represented here in particular by public policies; local agroecological con-

ditions, in the case of rice in particular temperature and water supply; and the genetic characteristics of the seeds.

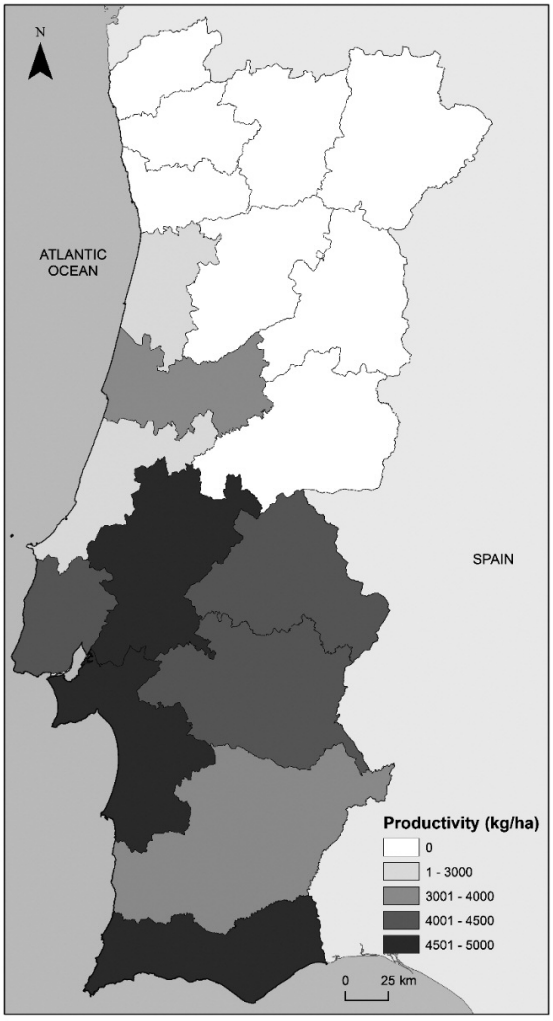
TABLE 2
Change in the share of rice production in Portugal by district, 1860-2018

District/Region	1860-99	1900-39	1940-79	1980-2018
Aveiro	14.0%	7.3%	2.2%	0.2%
Coimbra	13.0%	15.1%	15.4%	18.2%
Leiria	6.0%	2.4%	1.5%	1.4%
Northern Region	33.0%	24.8%	19.1%	19.8%
Santarém	16.9%	34.2%	32.7%	25.6%
Central Region	16.9%	34.2%	32.7%	25.6%
Lisbon/Setúbal	41.1%	34.7%	37.7%	38.4%
Portalegre	1.8%	2.2%	5.0%	7.5%
Évora	2.3%	1.9%	6.9%	7.2%
Beja	1.0%	0.9%	3.3%	1.1%
Faro	4.1%	3.1%	1.1%	0.5%
Southern Region	50.3%	42.8%	54.0%	54.7%

Source: Universidade de Lisboa, Instituto de Ciências Sociais (2021).

In fact, in the northern regions of the districts of Leiria and Aveiro, rice production was maintained until the mid-20th century for social reasons, rather than economic, reasons. From a share of almost 20% of the national production in the second half of the 19th century to less than 4% in the mid-20th century, agronomists stated that this crop continued to exist because it generated significant employment that was relevant for feeding the local population, mainly through subsistence agriculture (Rodrigues, Russo & Melo, 1953). Smallholder and family farming predominated in these regions, especially in Aveiro, which facilitated this development (Baptista, 1993: 130). The situation seemed so economically unsustainable that several local agronomic reports predicted the short-term substitution of rice for fodder or other crops (Rodrigues, Russo & Melo, 1953: 155). Even the introduction of foreign rice varieties in the 1940s, such as *Allorio* and *P6*, was not sufficient to change this scenario, as Aveiro was the only region with a negative gross income from rice production (Baptista, 1993: 132). In this case, the way the three factors that make up the framework of agricultural production came together was not sufficient for rice production to meet the success criteria advocated by agronomists.

FIGURE 5
Regional productivity of rice in Portugal, 1970-89



Source: Silva (1995, 147).

In the north, Coimbra was the exception, with an early introduction of foreign varieties, irrigation and public technical support, but in this district public policy went even further. Recognising that climate conditions put Coimbra at a disadvantage compared to the districts in the central and southern regions, between the mid-1970s and 1980s the State granted a special regional payment for rice production (Silva, 1995: 32). The objective of maintaining rice production continued in Portuguese agricultural policy after the end

of the Estado Novo dictatorship and in the context of integration into the EU, in 1986. It is possible that abandoning a region that was –and still is– very important for Portuguese rice production could compromise this objective. In fact, following the CAP, the Portuguese government maintained special public support for rice cultivation. This is due to the autarkic tendency of the CAP, which since its inception in 1962 has aimed to make the EU self-sufficient in food supply, a stance that has not changed (Ferreira, 2015: 125-29). In the case of rice, the EU is very unbalanced between low production and high consumption, making this crop strategic for the objectives of the CAP (Barreiros, 2018). With Portugal being one of only eight rice-producing countries in the EU, public support was maintained, despite some fluctuations, which may help to explain the increased political effort in the district of Coimbra.

Nevertheless, the reasons for the continuation of rice production in the district of Coimbra should be explored in future research. Other motives outside the public sphere could be considered, such as the distribution of property and business organisation. It is known that large farms had the financial means to introduce new techniques, and these were a key factor in competitiveness from the mid-20th century onwards (Baptista, 1993: 130-32). In the central and southern regions, large farms were most common, while in the northern regions small farms predominated. Once again, in the north, Coimbra was the exception, especially compared to Aveiro, where family farming accounted for the majority of these farms. In 1968, for example, only three rice fields in Aveiro were greater than 50 hectares, while in Coimbra they were greater than 19 hectares (Baptista, 1993: 130). Coimbra's farm structure may have led the State to conclude that it was worth maintaining support for production in this district, but not for others in the north.

It is worth noting that, unlike in the United States, where the geography of rice production changed radically with the total replacement of the South Atlantic (North and South Carolina, and Georgia) by the Old Southwest (Louisiana, Texas, Arkansas, and later California) (Coclanis, 2011), the change in Portugal was less pronounced. In any case, the public policies implemented in the United States were largely similar to those in Portugal, but two or three decades earlier, starting in the 1880s. Thus, the rice geography of the United States was also transformed, based on biological innovations, technical support, mechanisation, the creation of agricultural organisations and other public support strategies. As in Portugal, the agroecological conditions and genetic characteristics of the seeds were again taken into consideration, starting with a focus on rice, since the climate and soil were not suitable for the production of the crops originally predicted (wheat and maize), but they were suitable for rice (Coclanis, 2011). Later, from the 1930s onwards, there was also regional specialisation, based on the characteristics of different varieties of rice.

Despite what has been highlighted, some regions where rice production was already very important in the 19th century remain so, but with considerable intensification. The Portuguese case seems to be more similar to that of Spain, based on similar actions within the same chronology, in which the rice-producing regions have maintained their relative importance over the centuries, and other regions, such as Andalusia and Extremadura, have emerged (Sáenz Jubera, 1954; Arteaga, 2005).

5. CONCLUSIONS

As a seed of tropical origin, the cultivation of *Oryza sativa* L. requires conditions that have historically been difficult to achieve in a European country such as Portugal. For this reason, rice production was initially limited to areas where there was also an adequate and stable supply of water in the warmer months, linked to the absence of low minimum temperatures. This meant that rice could not be grown in the northernmost regions of Portugal because of the low temperatures, nor in much of the inner central and southern regions because of the scarcity of water during the dry season. Thus, in the late 18th century, the first places where rice was persistently cultivated were near the permanent water lines south of the Douro River. This was still very clear in the second half of the 19th century, the first period for which statistical data are available. At that time, there were four important rice districts: Lisbon/Setúbal in the south, Santarém in the centre, and Coimbra and Aveiro in the north. Less important, but still significant, were the districts of Leiria and Faro, the latter in the south and the former in the north. In the southern hinterland, the districts of Portalegre and Évora were insignificant. In the remaining districts, rice production has always been relatively low or non-existent. The explanation for the first objective of this article is therefore that it was only possible to cultivate this Asian tropical seed in Portugal in very specific areas of the country.

Since the early 20th century, when rice production increased sharply, this scenario intensified: the central and southern districts have become more important, while those in the north have become less so. This was not the case in the south, where rice disappeared in Faro and Beja, or in the north, where the district of Coimbra retained its importance. Public policy has been key to this development. Firstly, from the 1910s onwards, the importation of foreign seeds of rice varieties with better productive performances, but which could not be used in the same way all over Portuguese, exacerbated the regional differences in rice production. This led to an advantage for the central and southern districts, where temperatures allowed them to adopt the most productive varieties. Then, from the 1930s onwards, the construction of an extensive irrigation system, mainly in the central and southern districts, provided the southern regions with the water they had lacked

in the past, allowing them to exploit their climate advantages. This was a key factor, in that it allowed the full expansion of rice cultivation to the southern Mediterranean areas of Portugal, where there was a climate mismatch between rainfall and heat. As a result, rice fields in the districts of Setúbal and Santarém have expanded from their previous locations, and new rice areas have been created in the districts of Portalegre and Évora. Finally, from the late 1930s onwards, public technical support has been concentrated in the districts of Setúbal (south), Santarém (central) and Coimbra (north), even though its effectiveness has been questioned.

Taking this last district as an example, the history of rice cultivation in Coimbra can be considered a model of public policy influence on this crop. Located in the north of the country, outside the optimum temperature range for rice cultivation, the state has invested resources that have allowed Coimbra to remain an important production area. Foreign, selected and hybrid varieties of rice were introduced, a reasonably sized irrigation system was built and a public technical support service for rice cultivation was established. In addition, in the 1980s there was a public subsidy for rice production to compensate for the district's climate disadvantage compared to the other districts south of the Tagus River (Santarém and Setúbal). As a result, unlike the districts of Leiria and Aveiro, Coimbra still accounts for 18% of the national rice production.

It can therefore be concluded that the state aimed at increasing rice production in Portugal by favouring the geographical reorganisation of cultivation areas according to the agroecological conditions of the territory, with the exception of the district of Coimbra. By increasing the availability of water where it was scarce and by introducing more productive varieties that could only be grown in regions with better temperature conditions, public policies were clearly aligned with existent agroecological conditions. This was the case for centuries and until the beginning of the 21st century, following the guidelines and context of domestic policy, since rice was never intended for export, and after 1986, with the implementation of the European CAP.

Thus, with regard to the second objective of this article, it is demonstrated how public policies, agroecological conditions and the genetic characteristics of seeds have increased rice production in Portugal and, at the same time, shaped its geography. The constant readjustment of these three factors crucial for agriculture innovation can explain the history of rice production in Portugal. It is important to highlight two different phases of the Portuguese public policy on rice. The first phase, between the 18th and 19th centuries, is characterised by the relevance of a single promotion measure (protectionism), but also, since the mid-19th century, by the restriction of the expansion of rice fields because of their association with malaria. The second phase, from the early 20th century to the present day,

is characterised by the introduction of new and/or improved seeds, successful malaria control, the expansion of water supply, and regional differentiation according to the production potential of each region. The same type of guidelines were followed in both the United States and Spain, also with a strong impact on rice production, changing the geography of those countries. In the first case, a radical change occurred, while in the latter, as in Portugal, the warmer regions tended to be strengthened, not surprisingly given the agroecological similarities between the two neighbouring countries. The framework used in this article makes it possible to take proper account of the factors that are crucial to analysing agriculture, and can therefore be employed in future studies of other crops (wheat, maize, potato, wine, etc.) across different geographies and time periods.

In addition, other conclusions can be drawn from this study. Despite other factors that have certainly contributed to the regional evolution of rice production, as in the case of the aforementioned ownership structure and/or agribusiness organisation, public policies have been decisive for the regional –and national– dissemination of rice in Portugal. This conclusion is all the more relevant for two reasons. Firstly, because the continuation of public support for rice production in Portugal has recently been discussed, along with agricultural –and other– public policies which are being decentralised in favour of regional and local governance. Thus, this study confirms the essential nature of public policies, whether central, regional or local, in Portuguese rice farming without which this crop would probably not have become so important in the country's agricultural setup. Secondly, with the foreseeable rise in temperatures in the coming decades, rice production may be a viable option for agricultural areas further north, even those that have never produced this cereal. Finally, the example of rice shows that public policies, if adapted to the specific local and seed characteristics, can contribute to the convergent development of countries on the European periphery. Future research exploring other crop trajectories and/or changing geographies may confirm or refute this hypothesis and contribute to the understanding of the historical role of the State, which is one of the main questions of economic development guiding historians and other researchers.

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