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Irrigation water tariffs: lessons for Portugal

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Abstract

This article aims to provide a comprehensive review of the empirical literature on irrigation water tariffs in several countries, particularly in Mediterranean European countries, and to offer insights into the Portuguese status quo. We analyze a wide variety of tariffs, and the largest differences among them are discussed. In various countries, in those regions with a higher demand for water, irrigation water tariffs are more complex and higher, varying from country to country and, within the same country, from region to region. Large differences in irrigation water tariffs among different water-use associations were found, mostly because each one has its own objectives. A SWOT analysis was performed for Portuguese irrigation water tariffs. It concludes that there is much to do to enact the proposed strategies, including recovering operation and maintenance costs and promoting the efficient use of water and efficient water allocation. Furthermore, the farmers' position in the value chain must be improved along with their ease of access to credit, thus increasing the added value of the produced goods.

Keywords: International best practices; Irrigation water tariffs; Portuguese irrigation water tariffs; SWOT analysis

Highlights

- This research is based on a literature review of irrigation water tariffs in Portugal and in other countries that have similar climate characteristics to Portugal.
- A SWOT analysis was performed for Portugal, where it was found that there is much to be done.
- The farmers' behaviors have to be changed in order to promote the efficient use of water.

Introduction

One of the greatest challenges facing agriculture today is to ensure food security for the world's population (FAO, 2016a). The FAO (2002) defined food security as 'a situation that exists when all

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people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.'

Without water, it would be impossible to provide food for the planet's fast-growing population (Keremane & McKay, 2006). A water resource system may be characterized in terms of four components: the water resources *in situ*, whether surface water or groundwater; the abstraction of the resource, whether diversion of surface water or pumping of groundwater; the conveyance of water from the point of abstraction to the area of use; and the local distribution of water to end users within the area of use. In the case of urban water use, there are often several other components related to drinking water quality. The main difference in distribution and treatment make urban water a different commodity, and a much more expensive one than agricultural water. Up to 70% of available water resources goes into agricultural irrigation, about 30% is used in urban applications (domestic and industry). As water becomes increasingly scarce, competition for water among agricultural and urban sectors will inevitably increase. Also, the growing urbanization will have an impact on the volume and quality of water available for agriculture, especially in periurban areas. Competing demand from other sectors and public demands for environmental amenities will limit the development of surface and groundwater for agriculture in many regions. This, in conjunction with the impact of climate change, will require investments in measures that enhance the adaptation of agriculture and ensure the availability of water for food security (FAO, 2017).

Water tariffs are under the responsibility of various jurisdictions, according to each country's conditions, and water is managed primarily by the public sector. Water pricing is a complex issue due to the different types of tariffs related to the availability of water resources, and to related social, economic and environmental externalities (Marques & Miranda, 2020). Urban water is provided by public utilities; however, irrigation water is usually managed by irrigation districts, and water pricing in both sectors is regulated by different government agencies.

There are often large differences in water tariffs for irrigation within the same country depending on the objectives, the irrigation water source, the degree of water scarcity, the irrigation technologies, the type of farm, the socioeconomic objectives, and the management model (FAO, 2004). Due to all these characteristics, water policies are constantly changing, thus giving more and more importance to the control of and demand for water efficiency and to increasingly applying irrigation tariffs and creating water markets.

Different policies and strategies for establishing water tariffs have different theoretical objectives. According to FAO (2004), these are divided into service delivery objectives (covering everything from operation and maintenance costs to total water supply costs), control objectives (demand management, efficient water use and reduction of pollution levels) and social objectives (creation of benefit tax and equity access). However, in practice, the most common objectives in these policies are the operation and maintenance cost recovery and the efficient use of water. The main objectives of irrigation water tariffs in Portugal are, indeed, the operation and maintenance cost recovery.

Policy makers are therefore increasingly interested in using economic incentives for water demand management to address cost recovery, efficient water allocation and water governance (Bar-Shira *et al*., 2006). Therefore, they should also be prioritized in the water-related public policies in Portugal.

Efficient water allocation and appropriate water governance are growing objectives, with intense debates taking place in several parts of the world, such as France (Murgue *et al*., 2015), Australia (Lee *et al*., 2012), Ghana (Aidam, 2015), Pakistan (Watto, 2013), Syria (Yigezu *et al*., 2013), Portugal (INE, 2011), the European Union (Ferragina, 2010) and Brazil (Araújo *et al*., 2015).

In a perfectly competitive market, prices adjust through the interaction between buyers and sellers, and the optimum allocation of water is automatically reached. However, concerning water, several researchers claim that irrigation water demand is inelastic below a threshold price and elastic beyond it (Varela-Ortega *et al*., 1998; OECD, 1999).

As García Mollá (2002) suggests, water should be thought of as a productive input, where the elasticity of demand depends on three factors: the elasticity of substitution of water for other inputs, the price elasticity of demand for the good that is being produced, and the percentage that water costs represent in irrigators' total costs. In Portugal, the irrigation water is still an input with a very low cost compared to the other inputs.

The aim of this paper is to understand the different irrigation water tariffs around the world, particularly in the Mediterranean European countries with similar climate, and to explain why water tariffs in Portugal differ so much from those in other countries and even within the country itself. It also concludes about the lessons that can be learned and the best practices to be adopted.

After this brief introduction, the paper is organized as follows. In section *Water tariffs*, the variability of water tariffs applied in various countries and the reasons for their use are discussed. Section *Irrigation water tariffs in countries with similar climate classification* comprises an analysis of irrigation water tariffs in several countries, such as Spain, France, Italy and Greece in Europe, and United States, and Australia. Section *Irrigation water tariffs in Portugal* describes the irrigation water tariffs adopted in Portugal. In section *Discussion*, a SWOT analysis is developed for the Portuguese case study. The last section provides some concluding remarks.

Water tariffs

In the early 1970s, the International Commission on Irrigation and Drainage (ICID) drew up a questionnaire on irrigation water use and distributed it throughout the world. After the data gathered through this questionnaire had been processed and analyzed (Bos & Nugteren, 1974), the ICID decided to proceed with a second questionnaire in 1980, which asked more detailed questions about water charges.

In 1980, the Economic and Social Commission for Asia and the Pacific (1981) published the 'Proceedings of the expert group meeting on water pricing' and noted that only in one country, the Republic of Korea, did farmers pay the full annual operation and maintenance costs. They also observed that in other countries, water charges were assessed based on land productivity, area of irrigated land, season and kind of crop.

In 1982, the FAO published a paper entitled 'Organization, operation and maintenance of irrigation schemes,' (FAO, 1982) which noted that there were several methods for setting irrigation tariffs and that these were based on different economic theories. At that time, it was thought there were three main methods of calculating the water rates charged to the farmer: payment per unit of water used (volumetric method), payment per hectare or acre of irrigated land and payment by a fixed share (percentage) of harvested crops. Beyond these three main methods, monomial and binomial rates were applied. The monomial rate was a single amount paid for the water received and the binomial rate had two components: a fixed rate, which was constant for a number of years, and a variable rate, which changed from year to year. Some countries also applied a block rate, which used the volumetric method.

Dating back to the 1980s, numerous methods have appeared, each one with its own objectives.

Currently, there are often large differences in tariffs and their mechanisms within a single country, reflecting different objectives, different water sources, different degrees of water scarcity and irrigation schemes with different technologies, farm types or socioeconomic objectives.

To achieve efficient water allocation and appropriate water governance objectives, tariff models might be categorized into three major groups, respectively: fixed tariffs, water budget charge and water markets (Figure 1).

Fixed tariffs (€/ha) are the most widely used charging structure and are adequate where the sole objective is cost recovery. In this kind of tariff, the bill does not depend on the quantity of water consumed, and the marginal price of irrigation water is zero. Nonvolumetric water charges are simpler to administer than volumetric pricing, as there is no requirement for extensive metering and continuous field recording. In some cases, this may vary according to crop type, with higher charges for more water-demanding crops. The fixed component or the flat charge is levied to ensure that the high capital costs of providing water services are fully covered (Grafton *et al*., 2020).

Volumetric water pricing or tradable water allocations (quotas) are used where the objective is to reduce or limit water use in the agricultural sector. Under a volumetric tariff system (€/m^3), the bill depends on the volume of water consumed and the marginal price that farmers pay is equal to the price per unit of water, providing an incentive to save water (FAO, 2004). Volumetric pricing has a significant effect on farmers' water consumption patterns, positively affecting their water use efficiency, but it may cost 10–20 times the price required for full cost recovery in order to affect water demand, since water represents a very low charge of the agricultural inputs and farmers disregard the amount of water used. The most typical volumetric charging to improve irrigation water-use efficiency is rising block tariffs, where all units falling into certain bounds have the same price. It is usual to apply a combination of low rates for initial entitlements with very high rates for additional water beyond a set threshold, leading to a low total cost and a high marginal price. This tariff structure is impracticable in many countries due to the installation complexity and high installation costs of the necessary infrastructure (meters) required to regularly measure the volume of water consumed. According to Grafton *et al*. (2020), the increasing block pricing structure intends to provide incentives to use water carefully.

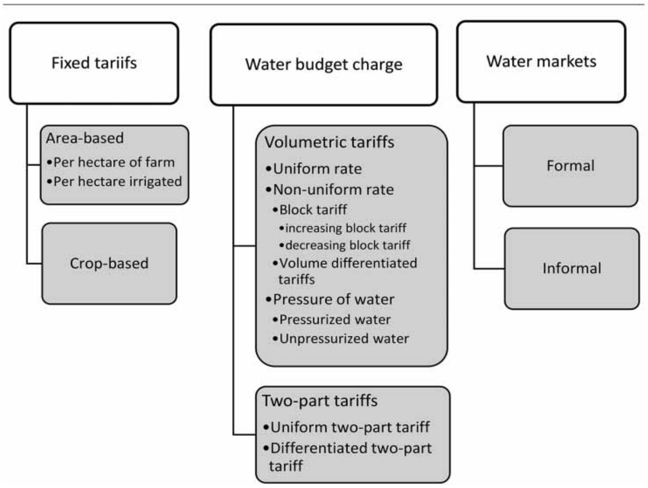

Fig. 1. Water tariffs most commonly used (*Source:* authors).

Where the metering infrastructure does exist, a two-part tariff (with a fixed element to cover the fixed costs and a variable element to reflect consumption) offers the benefit of ensuring a more predictable basic income stream. The two-part tariff comprises a variable charge intended to reflect the marginal costs of providing an additional cubic meter of water for the user and a fixed charge intended to cover the fixed costs of production and distribution (Joskow, 2005). The fixed charge usually recovers only part of the total fixed costs, since they are quite high.

Water markets facilitate the trading of water between two parties: a buyer and a seller of water entitlements. The buyer faces a water deficit and is willing to pay to meet its water demand. And the seller holds an entitlement that is surplus to its current water demand. In the international literature, water markets are often defined as formal and informal (Easter *et al.*, 1999). In the informal water market, only the right to use a given volume of water for a certain period of time is traded. The negotiation often takes the form of simple agreements between irrigators and requires little administrative input. The formal markets demand more complex institutional and administrative arrangements because rights must be registered and defined and their use monitored and measured (Bjornlund & McKay, 2002), something not possible in many developing countries (Appelgren & Klohn, 1999). There are two types of formal water markets: permanent and temporary trade. The permanent trade is a transfer of the water entitlement to the purchaser on a permanent basis. The purchaser will retain the parcel and receive any allocation granted upon it from the date of the transfer indefinitely or until the time at which they sell the entitlement. Temporary trade is a transfer of water specifically for irrigation, whereby the water is transferred to the current irrigation season and the purchaser is the beneficiary of any increase in allocation from the date of the transfer (DAWE, 2019).

The tariffs presented in Figure 1 are applied in several countries (Dinar, 2015). For example, in the United States, Brazil and Mexico, most farmers pay a volumetric water charge. Five of the six Australian states have a two-part tariff, as do French, Spanish and Portuguese farmers. In Greece and Italy, there is only a fixed charge per hectare of irrigated land. On the other hand, there is no irrigation water pricing in Chile; however, agricultural producers face the opportunity cost of water through markets for water-use rights.

Irrigation water tariffs in countries with similar climate classification

Overview

The European territory spans from north of the Arctic Circle to south of Parallel 38. European agriculture uses 44% of the European Union's territory and is extremely variable as a result of geographic and climatic diversity, ranging from the temperate climates in the north to the arid climates around the Mediterranean Sea (Berbel *et al.*, 2007). In Mediterranean countries, irrigated farming accounts for a large share of total water withdrawals (87.83% in Greece, 68.19% in Spain, 44.17% in Italy and 78.7% in Portugal), while it represents less than 10% in Northern European countries, as in France (FAO, 2016b). At the same time, there is a wide variety of farming patterns, crop types, farm sizes and contents of water laws across the countries of the community.

European Directive no. 60/2000 integrated European Union environmental principles, such as the 'polluter pays' principle, and a high level of environmental protection within a single document ratified by all European Union members (European Council, 2013).

Historically, the Common Agricultural Policy (CAP) included heavy subsidies for production, export and import restrictions, and indirect subsidies, such as on energy and irrigation costs (European Commission, 2018).

Several regions have Mediterranean climate characteristics similar to those of Portugal, with a *Csa* and *Csb* climate classification: Spain, France (in the south), Italy, Greece, the United States (California) and Australia (Western and Victoria states). However, irrigation water tariffs differ from country to country and within the same country.

Spain

Irrigation experiences in Spain date to the Iberian Peninsula's occupation by the Arabs, starting in the 8th century, and the further development of Roman irrigation techniques. This explains the diversity of irrigation techniques across regions and even among neighboring irrigation areas. Spain's irrigation water demand has been slowly increasing over the last decades and is expected to continue growing with a tendency toward reaching stabilization (Margat, 2002).

As Spain's annual average rainfall of 611 mm occurs mostly outside the crop-growing season, irrigation is a major feature of Spanish agricultural production. Surface waters are highly regulated, contrary to groundwater (20% of irrigation water). According to the Köppen–Geiger classification (Köppen & Geiger, 1936), there are three different climate zones in Spain: the southwestern and southern region (*Csa* climate), the western and northwestern coastal region (*Csb* climate) and the Basque country of Cantabria, Asturias and Galicia, which has a *Cfb* climate.

The irrigation sector in Spain contributes to covering water service costs through two instruments: the charges applied by the River Basin Authority for services upstream, and the charges of the water-use associations (or irrigation districts) that cover 100% of self-management downstream distribution costs.

Approximately 70% of all Spanish irrigated areas are serviced by irrigators' communities or districts. In addition to management of the resources and infrastructure, they share water among irrigators and play a very important role in water management at the River Basin Authority and district levels. The irrigators' communities are active members in the planning and governing boards and have permanent seats in the Basin Assembly of Users.

Farmers pay a 'regulation levy' and a 'water use tariff' to the River Basin Authority through the irrigation district, as well as an additional 'levy' to cover the costs of the irrigation district itself. Irrigation districts that abstract their water directly and do not use publicly developed infrastructure only pay the regulation levy and their own pumping, transport and operation and maintenance costs.

Spain's irrigated areas have chosen one of the following pricing schemes (MAPA, 2001):

- A fixed per-hectare tariff, calculated as the total costs borne by farmers divided by total irrigated area. This is the most common option in the traditional districts served by surface water resources. In all, fixed rates are applied across 82% of the surface water irrigated acreage in Spain;
- A volumetric tariff, more frequent in districts served by groundwater and/or incurring energy costs, is applied across 13% of the irrigated hectares. Volumetric tariffs are applied (1) as an amount per m^3 served, (2) with rates for each time a hectare of land is irrigated, and (3) with rates per hour of irrigating time;
- A two-part tariff that combines a volumetric rate, to cover variable costs, with a fixed charge per hectare rate, for investment and management costs, is applied across 5% of the irrigated acreage. Two-part tariffs are more prevalent in private and modern publicly developed districts, where metering devices exist and energy costs are substantial.

A study at the Júcar Basin (MMA, 2004) indicates that approximately 80% of all expenses related to surface water and groundwater are not controlled by river basin authorities, but by the private economy.

France

In France, rainfall remains at approximately 840 mm, being relatively high, and evapotranspiration is low. As in Spain and Portugal, individual River Basin Authorities carry out the resource planning for the whole country. According to the Köppen–Geiger classification (Köppen & Geiger, 1936), the southern coastal areas of France can be categorized as *Csa* climate.

In southern France, farmers pay a two-part tariff comprising a fixed tariff per hectare and a volumetric charge. In general, water tariffs in France have increased over time across all irrigation units. According to Duchein (1997), the criteria used to set charges vary substantially across basins, depending on diverse characteristics (probability of drought, type of user, capital costs, ownership, etc.). The pricing systems range from 'average cost' to 'marginal cost,' which are used with systems of quotas. According to the French Water Law of 2006 (Law no. 2006-1772 (2006)), River Basin Authorities establish the final rate applied in each river basin. As Chohin-Kuper *et al.* (2003) observed, the charges cover operation and maintenance costs as well as part of the capital costs.

Italy

Similarly to other Mediterranean countries, Italy has asymmetrically distributed water resources: abundant in the Po valley (north) but scarce and unpredictable in the south. Hydroelectric use controls the regulation of surface water in Italy, with its average annual rainfall of 942 mm. Italian climate is classified as *Csa* climate, according to Köppen & Geiger (1936).

In Italy, metering irrigation water is relatively unusual, and the levy for water abstraction is based on the area of irrigable land. Italian farmers pay much less than other users. Charges cover only some of the operation and maintenance costs. Investment or depreciation costs are excluded (Chohin-Kuper *et al.*, 2003). Xiloyannis & Dichio (2001) found large water consumption differences for the same crops between two districts: one using a fixed charge per hectare and another using a block rate system.

For example, in the case of the Consorzio di Bonifica and Irrigazione del Canale Lunense (northern Italy), which supplies water under pressure, there is a binomial tariff: (a) per hectare and (b) volumetric charge. At the same time, payment for drainage services is proportionally charged according to the benefit attained and based on the hectares serviced.

Greece

Greece has an annual average rainfall that varies between 400 mm, in Athens, and 1300 mm, in the Greek Islands. The climate of Greece is classified as *Csa* climate (Köppen & Geiger, 1936).

Access to water resources has not yet been fully regulated, and the water management agencies and water suppliers are essentially managed and governed by the civil code. Irrigation water demand has slowly increased in the past decades with a tendency to stabilize, because the irrigation supply has achieved the optimization level and there are few new opportunities to expand irrigation in agricultural land (Margat, 2002).

Private initiatives, which currently represent approximately 60% of the total irrigated acreage, are mostly equipped with sprinkler or drip technologies. The remaining 40% of the total irrigated acreage

(532,000 ha) comprises cooperative irrigation projects jointly undertaken by the Local Land Improvement Boards, which manage water allocation, collect farmers' fees and manage collective facilities, and the National Land Improvement General Boards, semigovernmental organizations that finance works affecting more than one Local Land Improvement Board.

United States

According to Köppen & Geiger (1936), the western states of the United States, such as California, have a *Csb* climate classification, as in the northern Portugal.

Much of the irrigation water in the western United States is managed and delivered by state or federal agencies, such as the U.S. Bureau of Reclamation and the state-level departments of water resources. They make contractual arrangements with irrigation districts (water user associations) that represent groups of farmers (Burt, 2007).

In California, the riparian water rights are also common, but they are not managed by the U.S. Bureau of Land Management, because the riparian water right is a right to use the natural flow of water on riparian land (private land). Under a riparian right, water cannot be stored during a wet period for use during a drier period. When these markets do not exist, there may be an incentive to overuse water in relation to what is actually required (CWB, 2020).

Current irrigation prices in western states reflect both the historical implications of long-term contracts for water projects developed by the U.S. Bureau of Reclamation and the more recent views of the U.S. Congress and several state governments regarding the need to recover larger portions of the cost of building and operating irrigation projects.

In many areas, charging the full cost of providing irrigation water would reduce net farm income in ways that might not be desirable from a social welfare perspective. Water laws and allocations were established a long time ago in the arid western states, given the region's climate and the tendency for water demands to exceed water supply in many areas. Water policies and prices pertaining to surface water often differ from those related to groundwater. Many western states regulate surface water supply very carefully, while groundwater withdrawals are not subject to close regulation.

Australia

Agricultural water users in Australia can be divided into two categories: those supplied from a water supply scheme and those supplied from private infrastructure. In the past, the operation and maintenance costs of water supply schemes were heavily subsidized by the government, often reflecting broader policy objectives around regional development. More recently, there has been a shift to increasing the charges paid by farmers to the irrigation infrastructure manager.

The 2004 National Water Initiative (COAG, 2004) required that the actors involved in water management should (1) promote economically efficient and sustainable use of water resources, water infrastructure assets and government resources, (2) ensure sufficient revenue streams to allow the efficient delivery of required services, (3) facilitate the efficient functioning of water markets, and (4) enact the user-pay principle and achieve pricing transparency in respect to water storage and delivery in irrigation systems and cost recovery for water planning and management.

Western Australia is dominated by a *Csa* climate classification (Köppen & Geiger, 1936). Irrigation activity in Western Australia is restricted to the southwest and the far northwest. The southwest water tariffs are more complex, in part because the region must recoup funds from users to pay the Water Corporation for storage and dam safety services. Payment for these services is included within the fixed component of fees (service charge), as is a surcharge for access to pressurized supply via a pipeline. A variable charge also applies and is based on volumetric use (water use charge). The Water Corporation is the main supplier of water services in Western Australia, it is owned by the State Government, and accountable to the Minister for Water and is a regulated monopoly (Water Corporation, 2019).

The Murray–Darling Basin Authority facilitates fair, consistent and transparent water trade across the Murray–Darling system which is the most important of the country. The New South Wales, Queensland, South Australian and Victorian governments are primarily responsible for managing water markets, and each state has its own process and rules for allocating water.

According to Köppen & Geiger (1936), Victoria has a *Csb* climate classification. There are four water corporations that provide rural water services across Victoria for irrigation, stock and domestic, environmental and recreational purposes. Goulburn–Murray Water is Victoria's largest rural water provider, storing, managing and delivering about 70% of Victoria's stored water and around 50% of its groundwater supplies. In this irrigation district, there is a service cost per account, a fixed cost (per unit area), a variable cost (per water used) and various drainage components costs (GMW, 2019).

Many of the largest irrigation supply organizations in New South Wales are located in the Murray–Darling basin, and the Independent Pricing and Regulatory Tribunal (IPART) of New South Wales sets WaterNSW prices (IPART, 2017). WaterNSW currently levies a two-part tariff, comprised of a fixed charge and a usage charge. The fixed charge is an annual charge that is applied to the share component specified on each water access licence ($/ML of general security and high-security water entitlement or unit share). The usage charge is applied to the quantity of water recorded as taken for a water access licence in the billing period ($/ML of water take or 'usage').

In Queensland, the majority of water for irrigation purposes is supplied by a State government-owned corporation working closely with the Queensland Competition Authority (QCA) and State agencies. The Queensland Government sets the price of irrigation water supplied by Seqwater in South-East Queensland and Sunwater elsewhere in Queensland. Irrigation prices generally take the form of a 'two-part tariff': fixed tariff (according to the amount of water access entitlements that irrigators hold) and a volumetric tariff (per ML of actual water use by irrigators). The government provides a subsidy known as a community service obligation payment to Seqwater and Sunwater from the Queensland budget when prices are set below the level necessary for Seqwater and Sunwater to meet the operating, maintenance and refurbishment costs to supply water for irrigation.

The majority of South Australia's irrigation sector is managed through privately owned irrigation trusts. Charges comprise a fixed service fee and a volumetric usage fee. The usage fee varies according to the time of use and the pressure associated with delivery.

Irrigation water tariffs in Portugal

Overview

Portuguese geography is a blend of Atlantic and Mediterranean influences (Ribeiro *et al.*, 1991), with the Atlantic ones dominating the northern part of the country and the Mediterranean climate seen in the southern part, with an impact of different climate, flora and fauna. These atmospheric characteristics, together with relief dissymmetry, are responsible for the decrease in rainfall from north to south (Brito, 1994). The average annual rainfall for the whole country is 820 mm, but regional values range from less than 400 mm to over 3000 mm.

There are two major climate zones in Portugal (Figure 2) according to the Köppen & Geiger (1936) classification: the northern region has a *Csb* climate characterized as a warm, temperate, moist forest climate, with wet winters, dry summers and the warmest month below 22 °C on average; the southern region has a *Csa* climate characterized as a warm, temperate Mediterranean climate with dry, warm summers and moderate, wet winters with the warmest month above 22 °C on average. A small region in the south of Alentejo, in the south of Portugal, has a *BSk* Climate characterized as a cold, dry climate with a dry summer and annual average temperatures under 18 °C.

The Portuguese Water Law combines public and private ownership of water resources. The State's role in promoting irrigation projects in Portugal has been generally very limited. Traditionally, water abstractions were free of charge; however, major institutional and legal progress has been made recently in terms of implementing water charges for public projects.

The Portuguese charge system is based on two fiscal instruments:

1. A water resource levy, created in 2008 through Decree-Law no. 97/2008, to be applied to all water services and activities and covering abstractions including self-consumption and groundwater across the whole country. Revenues from the water resource charge currently go toward the National Environment Fund (50%) and the Portuguese Environment Agency (50%).
2. A cost recovery of water infrastructure management through tariffs on water use, with the goal of increasing cost recovery (operation and maintenance charges and conservation charges).

Irrigation farmers in Portugal pay for water used in irrigation following the starting date of irrigation, that usually is in March/April, at the end of the civil year, and have no idea about how many cubic meters they actually used in one day. In Portugal, which is located in the Northern Hemisphere, the civil year starts on 1 January and ends on 31 December.

Water resource charges

The Portuguese Water Law (Law no. 58/2005 of December 29 (2005)) defined the payment of a water resource fee stemming from the negative impact of authorized activity on water resources once the title of water use is provided.

Water resource charges are established in accordance with the economic and financial legal regime of water resources approved by Decree-Law no. 97/2008, amended by Decree-Law no. 46/2017, formulating the principles that are at the origin of the Water Law and upon which the management of national water resources is based: the social, environmental and economic value of water.

According to Decree-Law no. 97/2008, the water resource charge is an economic and financial instrument designed to compensate for the benefits resulting from the private use of the public water domain, the environmental cost inherent in activities that can have a significant impact on water resources, and the administrative costs of the planning, management, supervision and assurance of the quantity and quality of water.

The water resource charge taxable base comprises six components: A, E, I, O, U and S.

Component A refers to the private use of water in the public water domain of the State. It is calculated by applying a base value (in €/m^3) to the volume of water abstracted, diverted or used, multiplied

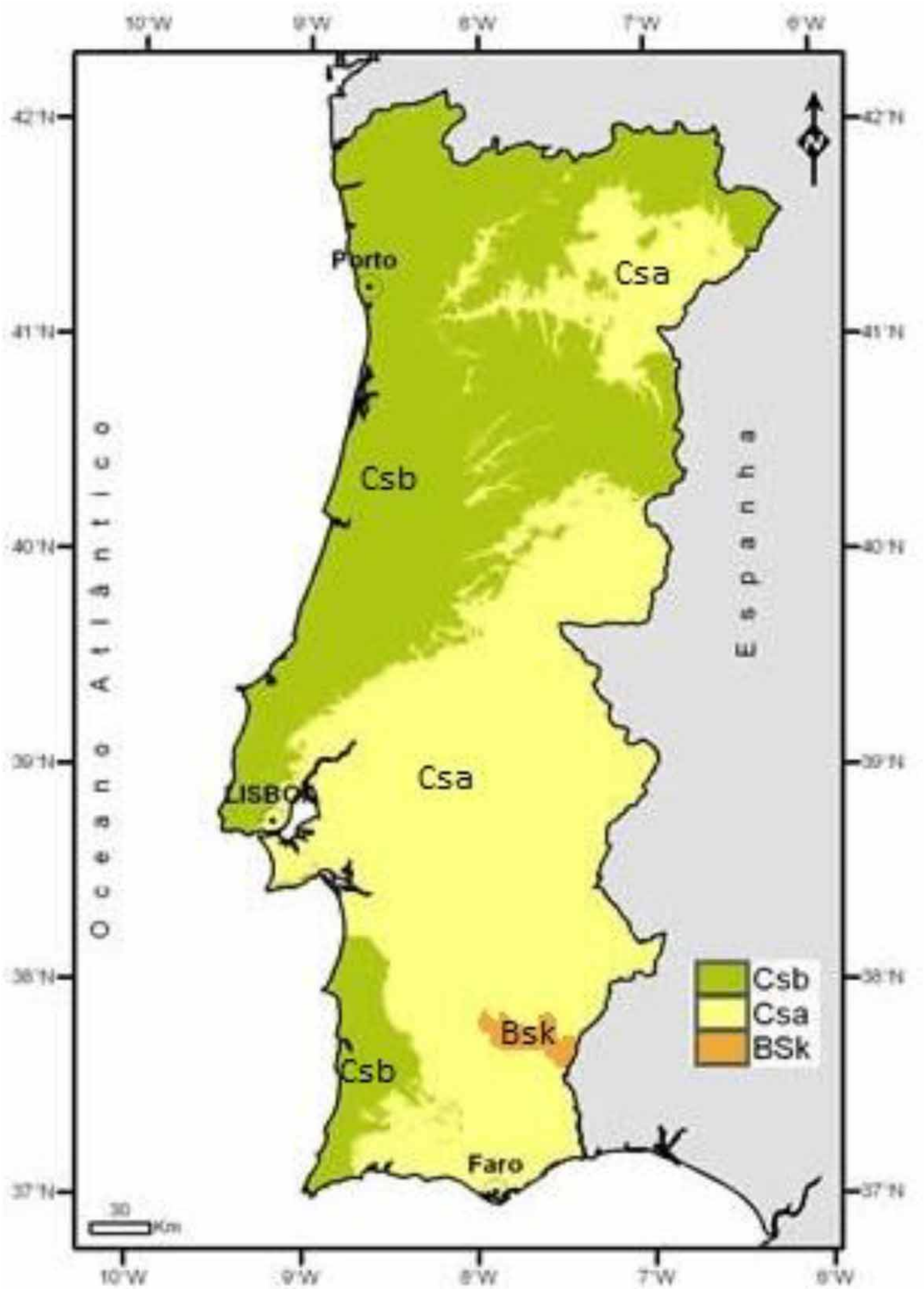

Fig. 2. Portugal Köppen–Geiger climate classification (IPMA, 2019).

by the **scarcity coefficient** (Figure 3), when it is not marine water. This component can be reduced in different situations, one of which is the use of water for thermal regulation of agricultural crops, as is rice, where there is a 90% reduction of component A.

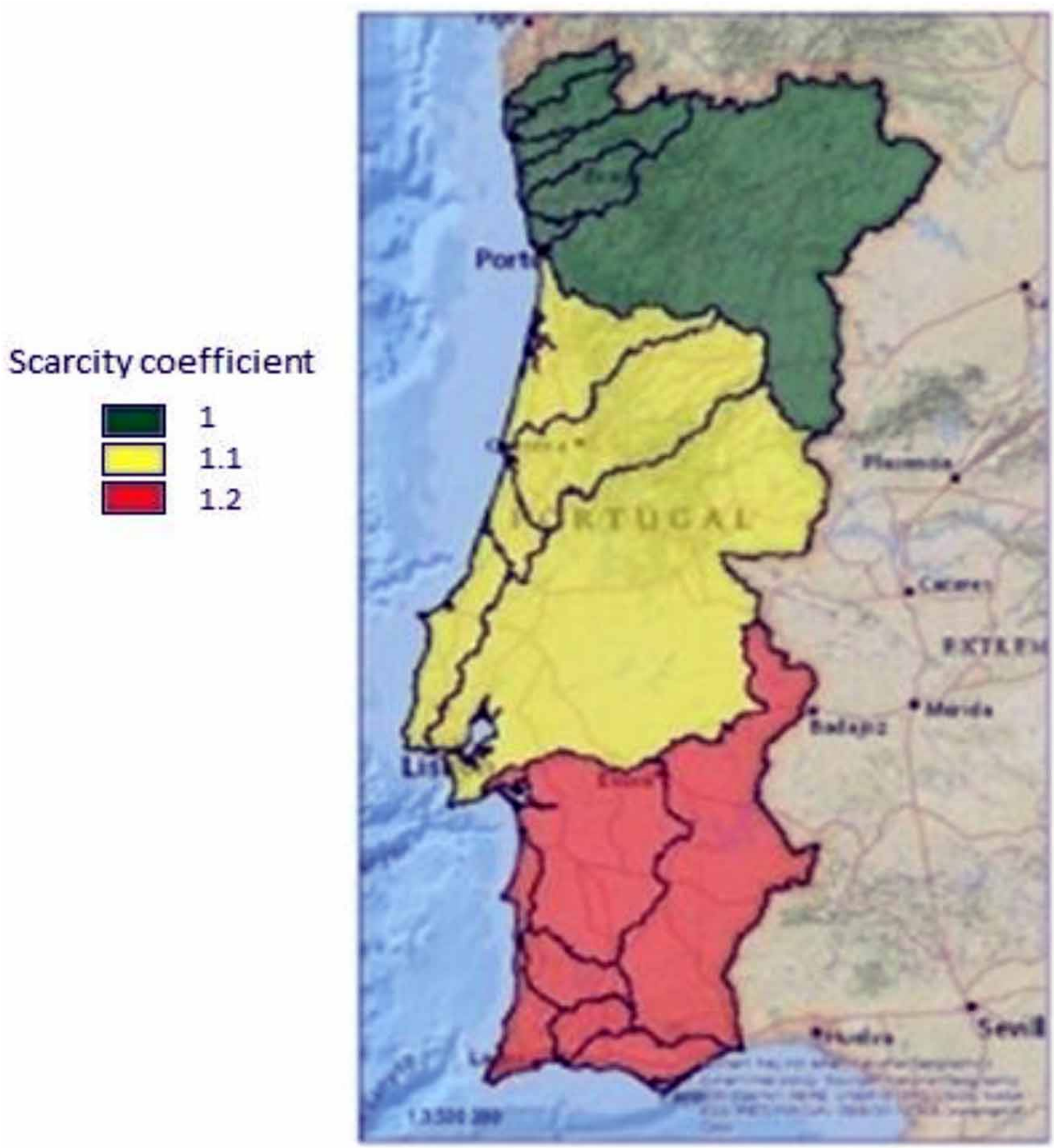

Fig. 3. Scarcity coefficient values.

Component E is associated with the direct or indirect discharge of effluents into water resources, which may have a significant impact. It is computed by applying a base value (in €/m^3) to the quantity of pollutants contained in the discharge expressed in kilograms.

Component I concerns the inert extraction of the public water domain of the State. It is calculated by applying a base value (in €/m^3) to the volume of extracted inerts, expressed in cubic meters.

Component O refers to the occupation of land of the State public water domain and to the occupation and creation of water plans. It is determined by applying a base value (in €/m^2) to the occupied area, expressed in square meters.

Component U is associated with the private use of water, whatever its legal nature, subject to public planning and management, which may have a significant impact. It is estimated by applying a base value (in €/m^3) to the volume of water abstracted, diverted or used, expressed in cubic meters.

Component S concerns the private use of water, whatever its legal nature and regime. It is calculated by applying a basic value (in €/m^3) to the volume of water collected or used for public water supply systems, expressed in cubic meters.

The water resource charge is corrected by an **efficient coefficient** (0.75) in river basin regions and in multipurpose projects. This coefficient takes into account the adoption of measures for the efficient use of water and the economic sustainability that should be approved by the members of the Government responsible for the areas of finance, environment, agriculture and rural development. However, this coefficient remains a fixed value, regardless of whether farmers adopt more efficient measures or not.

The basic values used to calculate each component for the year 2017 are defined in Decree-Law no. 46/2017 and are subject to annual updating by applying the Consumer Price Index, published by Statistics Portugal (INE), in accordance with article 17 of that decree.

Water-use associations and operation and maintenance and conservation tariffs

Agricultural water tariffs are levied by water-use associations. Each water-use association belongs to a river basin (Figure 4) and defines, annually, the operation and maintenance, and conservation charges.

The water-use associations manage state irrigation projects of river basins according to Decree-Law no. 84/82.

In line with this legislation, State irrigation projects are constructed for the use of public domain water for the irrigation, drainage, drying and defense of agricultural land. The State irrigation projects' classification, design and construction, and operators are presented in Table 1.

Table 2 presents the river basins, the Group II State irrigation projects that belong to them and the corresponding water-use associations.

Project beneficiaries are required to pay a yearly set charge called operation and maintenance and conservation tariff, which includes a selection of no more than three of the following components: (a) a fixed charge per reclaimed or ameliorated hectare of land (ranging from 14 to 211 €/ha); (b) a fixed charge per irrigated hectare (ranging from 15 to 222.5 €/ha); (c) a volumetric charge per cubic meter, if metering is possible (ranging from 0.0093 to 0.0906 €/m^3); (d) a drainage fee, when drainage of excessive water is required (ranging from 42.55 to 235 €/ha); and (e) a crop-based fee applicable for specific crops and projects (ranging from 11 to 55 €/ha) (data obtained through personal communication with Portuguese water-use associations).

Some water-use associations compute their payable fees using various interest rates, with the rates varying according to the soil quality and crops. For example, in Caia water-use association, the

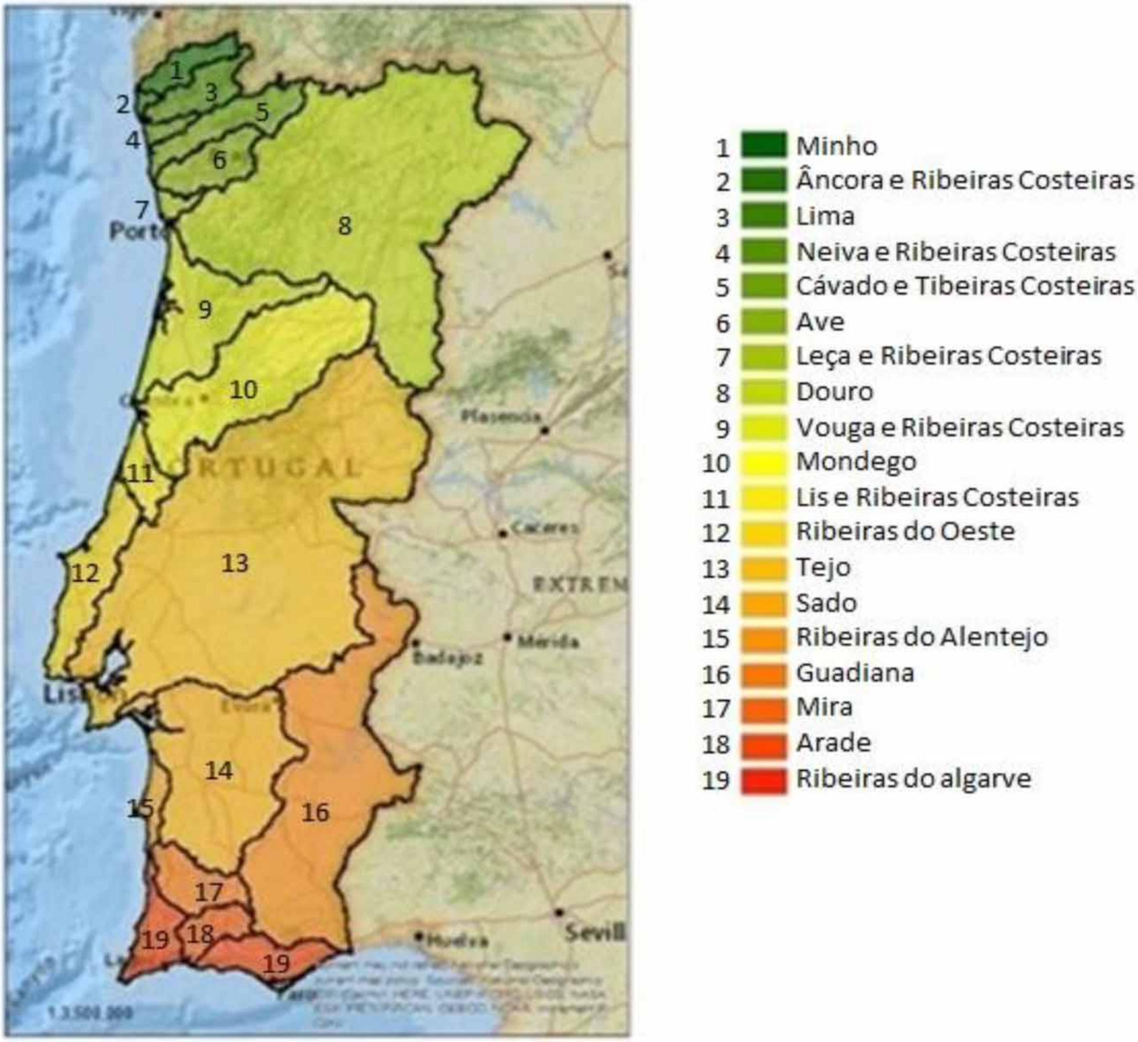

Fig. 4. Portuguese river basins.

Table 1. Classification, design and construction, and operators of State irrigation projects.

Classification		Design and construction	Operators
Group I	National interest	State initiative	Water-use associations
Group II	Regional interest		
Group III	Local interest, with a high collective impact	Municipalities' initiative and/or farmers' initiative	
Group IV	Other works of local interest		Farmers' board

Table 2. Portugal's river basins, respective Group II State irrigation project and water-use association (Inácio, 2018).

River basin	State irrigation projects	Water-use associations
Douro	Macedo de Cavaleiros	Associação de Beneficiários de Macedo de Cavaleiros
	Vale da Vilariça	Associação de Beneficiários do Vale da Vilariça
	Veiga de Chaves	Associação de Regantes e Beneficiários da Veiga de Chaves
	Alfândega da Fé	Associação de Beneficiários e Regantes de Alfândega da Fé
	Cova da Beira (B. Sabugal)	Associação de Beneficiários da Cova da Beira
Vouga	Burgães	Associação de Regantes e Beneficiários de Burgães
Mondego	Baixo Mondego	Associação de Beneficiários da Obra de Fomento Hidroagrícola do Baixo Mondego
Lis	Vale do Lis	Associação de Regantes e Beneficiários do Vale do Lis
Ribeiras do Oeste	Cela	Associação de Beneficiários da Cela
Tejo	Idanha-a-Nova	Associação de Regantes e Beneficiários de Idanha-A-Nova
	Vale do Sorraia	Associação de Regantes e Beneficiários do Vale do Sorraia
	Cova da Beira (excepto B. do Sabugal)	Associação de Beneficiários da Cova da Beira
	Minutos	Associação de Beneficiários da Barragem Dos Minutos
	Divor	Associação de Beneficiários do Divôr
	Alvega	Associação de Beneficiários de Alvega
	Loures	Associação de Beneficiários de Loures
	Lezíria Grande de Vila Franca de Xira	Associação de Beneficiários da Lezíria Grande de La Franca de Xira
	Veiros	Associação de Beneficiários do Perímetro de Rega de Veiros
Sado	EFMA	Associação de Proprietários e Beneficiários do Empreendimento de Fins Múltiplos de Alqueva
	Campilhas e Alto Sado	Associação de Regantes e Beneficiários de Campilhas e Alto Sado
	Vale do Sado	Associação de Beneficiários do Vale do Sado
	Odivelas	Associação de Beneficiários da Obra de Rega de Odivelas
	Roxo	Associação de Beneficiários do Roxo
Mira	Mira	Associação de Beneficiários do Mira
Guadiana	EFMA/EDIA	Associação de Proprietários e Beneficiários do Empreendimento de Fins Múltiplos de Alqueva
	Freguesia da Luz	Associação de Beneficiários da Freguesia da Luz
	Caia	Associação de Beneficiários do Caia
	Lucefecit	Associação de Beneficiários do Lucefecit
	Vigia	Associação de Beneficiários da Obra da Vigia
	Sotavento Algarvio	Associação de Beneficiários do Plano de Rega do Sotavento do Algarve
Ribeiras do Algarve	Alvor	Associação de Regantes e Beneficiários do Alvôr
	Silves, Lagoa e Portimão	Associação de Regantes e Beneficiários de Silves, Lagoa e Portimão
	Várzea de Benaciate	Associação de Regantes e Beneficiários de Silves, Lagoa e Portimão

conservation tariff is higher for farmers who have their holdings on higher class soils and lower for lower class soils. For example, in Idanha-a-Nova water-use association, the conservation tariff varies with the land-use capacity (higher for land with greater use capacity) and the operation and maintenance tariff varies with the crop and irrigation types, being higher for maize and lower for drip irrigation.

There are major differences in irrigation water tariffs among different water-use associations. The majority of water-use associations intend to minimize irrigators' costs, including operation and maintenance costs. However, in Alqueva (Alqueva State irrigation project or in Portuguese Empreendimento de Fins Múltiplos de Alqueva – EFMA), a political tariff is applied, approved by Decree-Law no. 36/2010, which states that the tariff should be approved by the joint order of the government members responsible for the areas of finance, agriculture and rural development and environment, on a proposal from EDIA (in Portuguese: Empresa de Desenvolvimento e Infra-estruturas do Alqueva) company.

In Alqueva, there is a tariff for the period ranging from 1 January to 11 April and a different tariff for the remaining months of the year. Within each period, the tariff system comprises a conservation tariff and an operation and maintenance tariff. Both vary with the water distribution pressure (high or low), type of user (precarious or not precarious) and type of water supply (direct abstraction or supplied by EDIA). The operation and maintenance tariff for water distributed under high pressure varies according to hourly cycles (peak or off-peak).

Discussion

There are several urban water saving strategies applied all over the world (NSW DLWC, 2000; Cool-California, 2019). Some of these strategies could be applied to promote irrigation water savings, such as

- Development of an irrigation water management and conservation plan considering each river basin;
- Audits should be carried out on water distribution companies and on the most important users;
- The potential for water pricing strategies should be considered to be used to both stimulate conservation and raise revenue to meet clean water needs. For example, using the increasing-block rates, applying higher prices during the peak demand period, charging a higher rate for consumption above the regional average or even using seasonal rates considering the availability of water;
- Reduce water usage in landscapes, using appropriate plants, installing smart landscape irrigation, using recycled water to irrigate landscape;
- Improving education programs with water users.

After analyzing the tariff systems of various countries with a Mediterranean climate classification (*Csa* and/or *Csb*), it appears that there are large differences between them. In Portugal, there are EFMA political tariffs (in Alqueva) and other water-use associations' tariffs. A SWOT analysis was undertaken to understand the strategies to be developed in order to improve the status quo and eventually create a nationwide tariff system for Portugal.

A SWOT analysis is a decision-making method widely used in business management. SWOT is a systematic and comprehensive strategy identification tool that considers factors relating to water resource systems, that is, internal and external factors. SWOT stands for categorized internal (Strengths and Weaknesses) and external (Opportunities and Threats) factors. It is also a combination of various effects, in which S and O have positive effects on the system, while W and T represent negative effects (Nagara *et al.*, 2015).

SWOT analysis has also been successfully applied in identifying and solving problems related to water resource management that often involve interdisciplinary issues difficult to quantify (Mainali *et al.*, 2011).

The strengths, weaknesses, opportunities and threats for irrigation water tariffs in Portugal are illustrated in Figure 5. The SWOT analysis was developed by the authors, in collaboration with some experts in the field.

As we can observe in Figure 5, there are numerous weaknesses and threats and many improvements to be made in Portugal. The strategies to be followed to address the problems highlighted in the SWOT analysis and to maximize the positive issues detected are summarized in Figure 6.

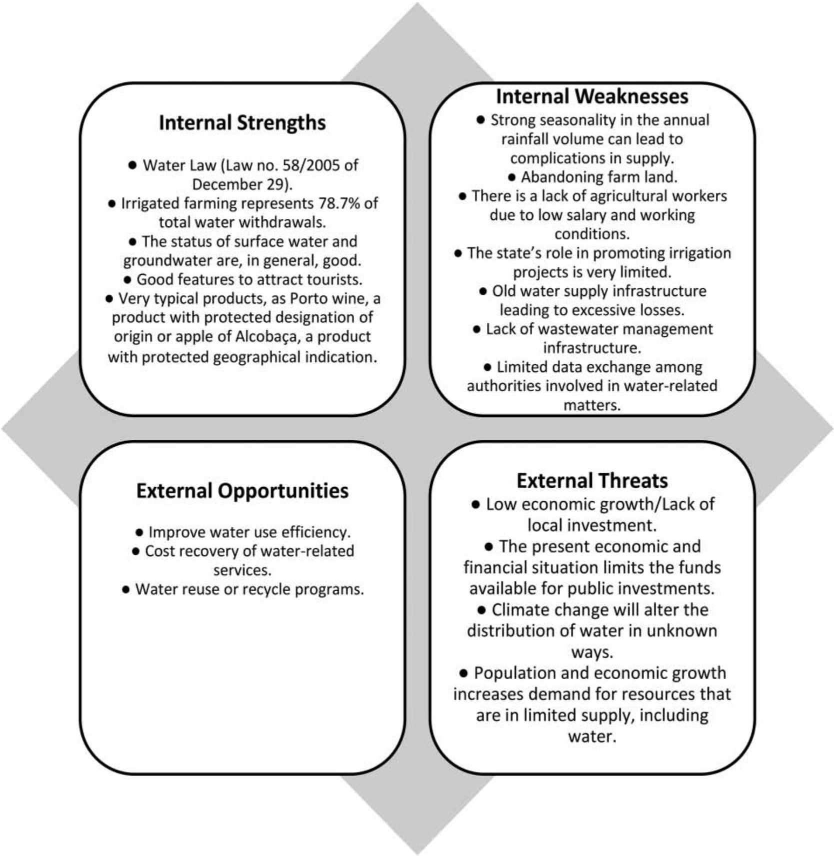

Fig. 5. SWOT analysis for irrigation water tariffs in Portugal.

The irrigation water tariff is very important in promoting these strategies, directly via water governance and efficient water allocation, and indirectly through farm income, operation and maintenance costs, improving rural areas to attract young farmers and adaptations to climate change.

An irrigation water tariff can lead farmers to select water-efficient crops, which is a climate change adaptation measure. These crop choices will promote efficient water allocation, with lower water consumption and, consequently, lower operation and maintenance costs and higher farm income.

In some regions, such as South Australia and California, where the tariff system is more complex, some of these strategies can already be observed. In Portugal, the measures implemented thus far are not reflected in the farmers' choices. This situation must change because, in the long run, it will not be sustainable either financially or in water-use efficiency.

Concluding remarks

This research is based on a literature review of irrigation water tariffs in Portugal and in other countries that, in some way, have similar climate characteristics to Portugal, such as Spain, southern France, Italy, Greece, California in the United States and Victoria in Australia.

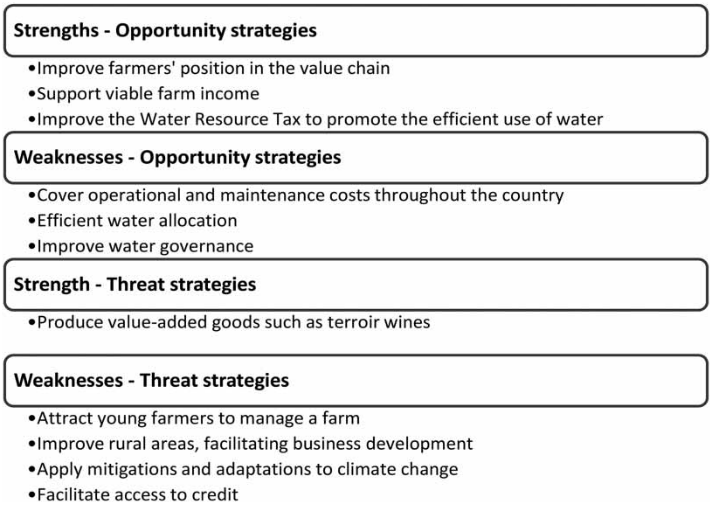

Fig. 6. Summary of the main conclusions.

There is great variability in irrigation water tariffs, which depend on economic, social and environmental objectives. There are four main groups of most commonly used water tariffs: fixed charge tariffs, volumetric charge tariffs, two-part tariffs and water markets. When the sole objective is cost recovery, fixed charges are used. Volumetric charges are adopted when the efficient use of water is considered. The two-part tariff is used when a commitment between fixed and volumetric charges is intended. Water markets are used in some developed countries, where water is tradable.

In Portugal, one of the aims of water-use associations is cost recovery. Water-use associations comprise farmers' irrigators, and they all aim at minimizing irrigators' costs. However, Alqueva (EFMA) applies a political tariff approved by Decree-Law of the national government. There are enormous differences in irrigation water tariffs among different water-use associations, because each one has its own objective.

In several countries, in regions with water scarcity and a high demand, irrigation water tariffs are more complex and higher. They can vary from country to country and, within the same country, from region to region, but quite a few similarities are observed in regions with analogous characteristics.

Following this literature review, a SWOT analysis was performed for Portugal, where it was found that there is much to be done to implement the proposed strategies. To be able to pay a 'fair and reasonable cost' for water, farmers' financial conditions should be improved through the production of differentiated products, attracting young farmers to manage the farms and facilitating access to credit. The efficient use of water and efficient water allocation should be promoted, water governance should be improved, operation and maintenance costs should be covered, and mitigations and adaptations to climate change must be applied.

In light of the above analysis, a possible future study would be on developing a tariff proposal suitable for the various regions of Portugal and for other countries with a Mediterranean climate.

It is important that restructuring the irrigation water tariff will promote farmers' behavior regarding more efficient water use. Behavior change can be achieved by using benefits or penalties. Therefore, the irrigation water tariff should reward the use of more water use-efficient crops and penalize less water use-efficient uses, always taking into account their financial profitability, with some exceptions as in rice production. By using various agricultural techniques for a given crop, farmers can become more or less efficient in utilizing water, and this factor should be taken into account when dealing with irrigation water tariffs.

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Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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