Chapter

Resilience of Irrigated Agriculture to Face the Challenges in Mediterranean Climatic Conditions (Iberian Peninsula)

António Canatário Duarte, Amparo Melián-Navarro and Antonio Ruiz-Canales

Abstract

Climate change scenarios in Mediterranean basin point to a decrease in the amount of annual rainfall and the increased frequency of drought. In this framework of greater water scarcity, an increase in irrigation costs is expected, so its rational and efficient use is an unavoidable issue in modern irrigated agriculture. In the last 60 years in Portugal, it had a great increase in the efficiency of water use in agriculture, accompanied by a great increase in energy consumption, and the variation was 15,000 to 6000 m^3/ha.year and 200 to 1500 kWh/ha, respectively. The rational application of fertilizers is a priority, to prevent the contamination of superficial and subterraneous waters, and the process of soil salinization in semi-arid conditions. The pressure of water demand by agriculture implies the use of other water sources. For example, in 2010, the volume of unconventional water resources in Spain rose to 4.540 hm^3/year. Of the total used in agriculture, 450 hm^3 of water comes from the reuse of treated water, and 690 hm^3 comes from desalination. The use of modern/smart technologies in irrigated agriculture, like information and communication technologies, allows the rapid share of information between all the system components and can promote optimized answers at different scales.

Keywords: resilience of irrigated agriculture, Mediterranean climate change, water scarcity, water-efficient use

1. Introduction

Agriculture plays a vital economic role in the Mediterranean region. It employs more than a fifth of the population in 50% of the countries and contributes >10% of Gross Domestic Product (GDP) in eight countries alone [1]. The Mediterranean region in this study refers to the 21 countries surrounding the Mediterranean Sea in addition to Portugal. Mild winter temperatures and long hot dry summers that are characteristic of this region make it ideal for growing a diverse range of crops including olives, citrus, vineyards, and cereals, as well as high-value horticulture.

As precipitation across the region is subject to high inter-annual and seasonal variability, irrigation is an essential component of production for many farmers as it supports crop diversification, helps assure yield and quality, and helps to stabilize food supplies [2]. Water scarcity and droughts are frequent, widespread phenomena that affect more than 100 million people and around a third of the European territory. Global change (climate change and change in land use) is expected to aggravate this situation, especially in Mediterranean countries, such as Spain and Portugal [3].

Climate change is a diffuse and gradual phenomenon. Several factors intervene in it, although we can synthesize it in two in particular: that referred to the natural variability of the climate itself (with recurring events throughout history, famines with droughts due to temperature rises and a decrease in rainfall) and the actions of man who affect it (anthropic effects). Along these lines, the United Nations Framework Convention on Climate Change (UNFCCC) defines it as "a climate change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is added to the natural variability of the climate observed during periods comparable time periods [4]. Another aspect of climate change that particularly affects irrigation is the increase in the frequency of extreme events: torrential rainfall and droughts. The recent DANAs (Isolated Depression in High Levels) have caused important floods in the Spanish Mediterranean in recent dates (like 2019), and in the Ebro, with social, economic, and environmental losses. At the same time, periods of drought have occurred with excessive frequency in both countries. Both phenomena entail significant social and economic costs to deal with them. Crops are essential to mitigate desertification and temper climate change. They contribute to avoiding or at least cushioning the succession of extreme phenomena. The concentration of CO_2 eq (CO_2 equivalent) in the atmosphere has not stopped increasing, since in 1880 it was about 280 ppm and today it reaches 408 ppm [5]. Irrigated crops are in a greater proportion than rainfed crops as they produce more biomass.

Agriculture defends itself from drought by improving the efficiency of water application in irrigation and with improved management. Obviously, irrigation requires significant energy consumption in most cases. For this reason, water stress reduces the productivity of crops, and avoiding water stress is the reason for the practice of irrigation, as old as agriculture itself [6].

Spanish irrigation has already begun to take measures to adapt to and mitigate climate change. The first of these has been related to the improvement of irrigation efficiency through the modernization processes of irrigated areas. This has meant that in the period 2002–2016 there have been significant savings both in total consumption (112.5%) and in unit consumption 118.24%). The installation of control networks has also contributed to this through the installation of agrometeorological stations, (e.g. SIARI Network to determine ETo values), such as that of irrigation water quality control networks (for example RECAREX in Extremadura to estimate the degree to which irrigation pollutes water masses). Irrigation is regarded as one of the main adaptations to support crop production in response to climate change and population growth [2]. However, any increase in irrigation demand will correspondingly impact energy consumption and greenhouse gas emissions suggesting potential conflicts in terms of mitigation and adaptation policies [7].

The availability and reliability of water resources is a limiting factor for economic development in many water-stressed countries. The Mediterranean region is one of the most water-scarce regions globally. Water is particularly scarce in Southern and Eastern countries and in some catchments in the North, such as Southeast Spain and the Ebro Depression, where the expansion of irrigated production, coupled with tourism and urbanization has created significant water supply challenges [8]. The improvement of agricultural water management, through irrigation systems modernization and application of information and communication technologies to increase crop productivity and reduce the influence of drought and promoting water conservation is one of the main objectives of current irrigated agriculture in Mediterranean countries [9]. Another challenge in intensive agricultural systems, such as irrigated agriculture, is the necessary compatibility of soil and water as natural resource and as well production factors [10].

2. Approaching the problem from a technical perspective

One of the most important problems brought by climate change in irrigated agriculture, particularly in Mediterranean basin, is the increased variability of weather patterns and a higher frequency of extreme weather events [11]. For the management of water resources, Water Authorities (WAs) have to make decisions before knowing the weather conditions they are going to face. So, every year, due Water Authorities are less able to make decisions consistent with the weather pattern of the following season due to the decreased predictability of events and the less relevant use of past records to make future decisions. As a consequence, current water management decisions are often a compromise between the outcome determined by all the weather states that could emerge. On the other hand, considering the necessary effort to reach convenient water use and management, the rehabilitation of the irrigation project structures, and the modernization of irrigation systems are a priority [12].

2.1 Modernization of the irrigation systems

In the first third of the 20th century, an ambitious plan of agricultural development works began in Portugal and Spain, which included some public irrigation schemes of considerable area, and which still are in operation as a result of adaptation and rehabilitation works of their infrastructures [13]. It should be noted that most of these irrigation schemes never had high levels of adherence, for various reasons, namely the incentive to farmers for the new reality of land use. The high cost of agricultural production factors (including fuel and electricity costs), combined with the volatility of agricultural product sales prices, has been a disincentive to investment in agricultural activity, in particular in irrigation. In recent years, we have witnessed a resurgence of interest on the part of farmers, mostly young people, in irrigated agriculture, greatly encouraged by the country's new irrigation schemes aided by modern technologies. In the last half-century, we can see a significant increase in efficiency in the use of water in agriculture, from 15.000 m^3/ha.year in 1960 to 6.600 m^3/ha.year in 2014 (**Figure 1**) [14], mainly due to the modernization of irrigation systems. This has corresponded to the replacement of traditional irrigation systems with water distribution by gravity, by automated systems equipped with pumping systems that require energy for their operation. Thus, energy consumption has increased sharply in the same period, from 200 kW.h/ha in 1960 to 1.534 kW.h/ha in 2014 (**Figure 1**) [14]. On the other hand, the economic productivity of irrigation water (Gross Added Value/m^3 of water, calculated at constant 2006 prices) has increased in the last decade by more than 30% [15].

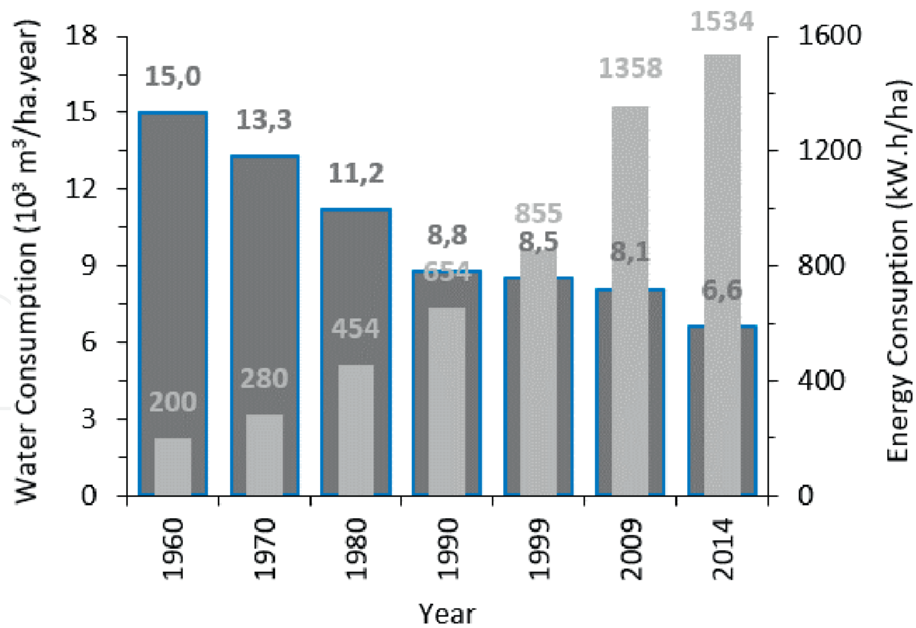

Figure 1.
Evolution of water consumption and energy in Portugal, in irrigated agriculture (Adapted of [14]).

It is foreseeable that in the coming years the efficiency of water use in irrigation will continue to increase, driven by operational programs, financial incentives, and the use of innovative technologies [16]. As mentioned above, irrigation farming is unavoidable in the summer months in most of the Iberian Peninsula, especially in the south of this territory, where there are climatic conditions to enhance the productive capacity of the crops. The climatic variables that influence evapotranspiration (solar radiation, temperature, relative humidity, and wind) reach comparatively more favorable values in the south of the Iberian Peninsula, which determine high rates of that indicator of the physiological activity of plants [17]. It is evident that the productive potential of the crops is not only expressed through the convenient supply of water but also through other cropping practices allowed to obtain good production, such as adequate levels of fertilization, the effective fight against pests and diseases, among others [9]. In the context of climate change, in many aspects already confirmed, the Intergovernmental Panel on Climate Change (IPCC) has been alerting to the scenario of a drier climate determining less available water resources, less production of hydropower energy and losses of 25% of volume water intended for agriculture activity [18]. In this context of greater water scarcity, the greater pressure in its demand for irrigation and other activities should lead to an increase in the costs of irrigated agriculture [19].

2.2 Information and communications technologies

Adaptation and mitigation are the two pillars facing climate change. In this regard, weather and climate services can help decision-makers in making informed decisions to improve adaptation capacity by assessing and forecasting existing and emerging risks. Since all adaptation actions depend on the availability of adequate information, the rapid diffusion of Information and Communication Technologies (ICTs), such as mobile phones and the internet, poses new opportunities to face climate change by improving access to information and consequently by improving the information environment under which water suppliers and water users operate [20]. The availability of ICTs might contribute to mitigating the moving-target problem by providing timely information on future climate and weather conditions, thereby reducing uncertainty before and during the irrigating season. Overall, the ICT-informed decision process of water management could help irrigated agriculture by reducing losses from climate shocks and taking advantage of favorable years. The potentialities of ICTs for the management of water resources in agriculture motivate many studies normally with the objective of quantitatively estimating economic benefits from the ICT-informed decision process of water management in agriculture at the Water Authorities (WAs) level. Some authors developed theoretical models based on insights from the Bayesian Decision Theory [21–23]. It assesses the economic benefits brought by new pieces of information, influencing WA's perception of uncertain events with direct consequences on its strategic decisions.

Background in agriculture, some models using ICT investigate the role played by information in supporting WAs to rationalize the management of water resources and the prevention of extreme weather event impacts. Because decisions on land and water allocation are sequential across the season and influenced by one another, the methodology accounts for the passing of time in the decision process to assess how the time of information provision affects its usability [21]. Great potential is found for such technologies in contributing to food security and climate change adaptation in the agricultural sector. Qualitative studies showed their benefits for both developed and developing countries. Among these, [24] identified the following: (i) promoting economic performance, (ii) raising efficiency, and (iii) fostering innovation. Nevertheless, reference [25] suggested that ICTs impacts on decision outcomes are highly variable. One reason for this variability lies in the findings of the authors in [26]; according to them, ICTs are successful only when key information needs are addressed. In addition, many ICTs projects do not reach the expected success because developers take useful information for granted. As a consequence, ICTs developers tend to poorly consult end users on their information requirements and the resulting ICTs may turn out to be inapplicable in their decision process.

The elements characterizing information and determining its value are: (a) content of information: the WA must be able to implement the additional information in the decision process; if the WA is not able to act upon information, it has no value for it; (b) accuracy of information: the more accurate the information is, the smaller the risk of failures and the higher the VOI (Value of Information); imprecise information is not capable of inducing any change in WA beliefs; (c) timing of information provision: information must be provided at the right time in the decision process; late messages have no value. The timing factor (c) plays a key role in influencing the accuracy of information (b). Usually, information provided well in advance of the occurrence of an event might condition strategic decisions but it will not be so accurate. If information is provided in a short advance, the decisions influenced by the information will not be so strategic, but the information will be likely more accurate. This is typically the case with emerging information, such as weather forecasts.

Developing and applying a method to assess the economic value of ICTs seems to be an interesting topic for agricultural and resource economists. Moreover, considering the growing societal demand for climate services, together with the limited budget available, this topic is of high policy relevance.

3. Approaching the problem from policy, economic and institutional perspective

Since antiquity, the use of water in agriculture has been a basic element for the survival and economic and social progress of humanity. This explains why, since then, the irrigated area of the world has not ceased to grow [27], making irrigation a key element for feeding the planet. All over the world, Asia is irrigating 41% of the total cultivated surface, America 13%, Europe covering 9%, Oceania is irrigating the 7%, and Africa the 5%. The authors in [28] estimate a total irrigation potential of some 402 million hectares in developing countries, of which half is currently in use. In this way today, although the extension of global irrigation is limited since it represents only 7% of the world's useful agricultural area, this type of agriculture is a key element for feeding the planet [29]. Irrigation contributes exceptionally to social cohesion and stability since it generates a strong demand for labor and favors the commercial exchange of products and supplies, with the consequent economic flows (of consumption and savings) [30]. From north to south (Mediterranean area) the natural scarcity increases, being greater in the area of the Region of Murcia and Almería (Andalusia). They are the most productive irrigation but also the most deficient. In addition, this famine is aggravated by recurrent extreme events (droughts and floods) [31], that force us to think about management measures to prevent their effects and consequences [32]. Climate change projects a decrease for the year 2027 between 2 and 11% in the average contributions of the peninsular basins, whose effects will be greater in the most limiting or sensitive areas. The need for irrigation and its efficiency is indisputable [33].

3.1 Politic, economic and institutional aspects

The role of water in the economy covers various aspects from the analysis of the uses of water and its impact on the different economic sectors to economic instruments in the planning and management of water resources. In the first approach, the economics of water advocates determining the volume that is used, the forecast of future demand, its elasticity in relation to variations in other parameters, and the productivity of the different uses. The second focuses on the instruments of economic content that public authorities use in the planning and management of water resources. The National Agrarian Accounting Network of Spain indicates that for the year 2017 [34] the annual value of the production of an average hectare of irrigated land in Spain is 5.4 times higher than one of rainfed land (€5.576 compared to €1.030). Irrigation, in addition to promoting higher income, also makes it more secure by favoring the diversification of production and not depending on rainfall. In line with the greater profitability of the irrigation activity is the land value of the irrigated land. The transformation into irrigation on average multiplies by three the value of the land. In fact, in 2018 the average price of rainfed land for the whole of Spain stood at €9.447/ha, while irrigated land reached €28.444/ha [34]. Irrigated agriculture contributes more than half (64%, 16,000 million euros) to the value of the Spanish Final Agricultural Production, using less than a quarter (22.5%) of the national cultivated area (**Table 1**). The profitability and economic productivity of water are also different depending on the type of crop. 80% of irrigation water has returned between 0.02 and 0.60 €/m^3. It stands out that 19% of the volume used in irrigation is used for crops with very low profitability (less than €0.02/m^3. And only 1% for crops with returns greater than €3.00/m^3 [36].

Contribution of irrigation in Spain	Irrigated crops	Rainfed crops
Economic contribution		
Production value (€/ha)	5.576	1.030
Agriculture net income (€/ha)	2.328	484
Land value (€/ha)	28.444	9.447
Aid CAP/Agriculture net income (%)	24.2%	47.3%
Final Agricultural Production Contribution (%)	64%	36%
Social contribution		
Employment generation (Agricultural Work Unit (AWU/ha)	0.109	0.024
Net Value Added/AWU (€/AWU)	31.782	25.516

Table 1.
Economic and social contribution of irrigation in Spain (year 2017) [35].

In Spain and Portugal, an important part of irrigation is supplied by surface water, coming from the reservoirs of the great Iberian rivers. Therefore, it is from these river valleys, both those that flow into the Mediterranean and, mainly, those that flow into the Atlantic, that supply three-quarters of the Iberian irrigation. Irrigation is associated with high energy consumption. This makes irrigation communities especially vulnerable to energy prices with consequences on their economic situation [37–39]. Some prices are appraised and have a political component. Until a few years ago, there was a subsidized electricity rate for irrigation in Spain. For example, in the Segura Hydrographic Confederation for 2018, the different prices paid by the final user of water for irrigation are barely €0.033/m^3 for river water, €0.10/m^3 when water comes from the transfer (between river valleys), or €0.5/m^3 if it comes from a water treatment plant [40]. In Portugal, great variability is also observed in the form of water pricing. The cost of water in most irrigation communities is based on area, and soil quality, because in some areas the hydrants do not have water meters; the most modern irrigable areas already have them and in these cases the water will be paid for the volume spent. Among those communities that charge water considering the irrigation area, they also differentiate their price considering the crops, and supposedly the water will be more expensive for the most profitable crops and with better soils. Thus, for example, the cost can vary between €77.5/ha (Cova da Beira Irrigation District) and €556.8/ha (Alqueva Irrigation District) on land cultivated with corn [41]. These prices include utilization fees and maintenance fees.

Special mention in Spain requires the cost of the Tajo Segura Transfer water. It is an aqueduct that transfers water from the Tagus River in an amount of 421 hm^3 per year to the Segura River and therefore allows to reduce the scarcity of water in the Spanish southeast, where it is used with great efficiency. As a note to indicate that a few years the agreed total has been transferred and the transferred water covers not only irrigation needs but also other uses (urban). For some provinces of the Spanish southeast, the impact of the transfer is very high. It is enough, for example, to indicate that 62% of the agricultural area of the province of Alicante corresponds to areas that can be irrigated by transfer, while in Murcia it is 55% [42]. Transfers, like any other water policy measure, present economic costs, as well as environmental ones, which must be compensated. The total invoiced for the transfer represents 20% of all the income from fees and tariffs that are produced in all the Hydrographic Confederations of Spain, despite the fact that the transferred water is only 3% of the total water used for irrigation in Spain [43]. As of 2017, a modification has been introduced in the rate that obliges water users to cover the construction costs, as well as the fixed costs of the infrastructure (of the entire infrastructure despite not transferring all the water agreed), increasing average costs.

3.2 Unconventional waters use

The scarcity of water determines and even forces the search for other non-conventional alternatives such as desalinated water or water treatment effluents so that water from treatment plants or desalination plants is used for irrigation, mainly mixed with well or surface water. Agriculture is the main user of reclaimed water and is reported to be used for this purpose in around 50 countries, on 10% of all irrigated land [44]. The main difficulty lies in the price, too high to be supported by farmers, and in the characteristics of the water obtained, due to the excess of salts, with the problems involved by the aquifers and soils. However, improving the quality of effluents is essential for their subsequent use, since water is a reusable resource that can have an almost unlimited life if it's well managed [45].

In 2010, the volume of unconventional resources in Spain rose to 4.540 hm^3/year, of which, those with effective use would add 450 hm^3 of water coming from the reuse of treated water and 690 hm^3 coming from desalination [46]. This amount has only grown and there are currently some 1.000 desalination plants in Spain with an installed capacity of 1.205 hm^3/year and 2.530 treatment plants that treat a flow of 3.375 hm^3/year, although their capacity is 30% higher [3]. Reclaimed water is one more resource within water management, and although it cannot be considered a conventional resource, it does have a key role in comprehensive water planning [47]. Despite this, its importance, at a quantitative level, is still very low, representing around 3% of the total available water resources. Although in practice it's found that the use of treated water is limited in agriculture basically because of its price ranges between €0.6/m^3 and €0.8/m^3.

4. Approaching the problem from an environmental perspective

The rational use of water should imply its moderate and efficient consumption, and the conservation of its quality after use and release back into the water environment. This idea is a fundamental concern in the Water Framework Directive (Directive 2000/60/EC of October 23rd, 2000). Several authors point out that improving water management at the fields level is the most effective tool in reducing the impacts of irrigation on the environment [48, 49], is the achievement of this objective, inseparable from convenient management of water resources at the scale of irrigation district [16, 50]. Agricultural and livestock activity is one of the primary sources of non-point source pollution, occurring in extensive areas and highly dependent on its hydrological behavior, which leads to the water bodies substances previously deposited in the soil (fertilizers, phytosanitary products, organic matter) [51]. For this reason, the focus on controlling this type of pollution has been more on indirect instruments such as codes of good agricultural practice embodied in agri-environmental measures complemented with monetary incentives to farmers [52]. In the climatic scenario of water scarcity, a considerable increase in irrigation costs is expected due to the pressure of water demand, so its rational and efficient use, combined with environmental concerns, is an unavoidable issue in modern irrigated agriculture.

4.1 Rational application of fertilizers

The amount of nitrogen fertilizers incorporated into the soil should be in proportion to its removal by the crops, safeguarding unnecessary spending with excess fertilizer and situations of contamination of soil, water, and atmosphere [53], since, in more oxidized forms, nitrogen is very soluble and mobile, presenting itself as one of the most problematic substances in water pollution [54]. However, this desideratum has not been achieved in recent years in Portugal, and there has even been an increase in the excess of nitrogen fertilizers between 2000 and 2017 from 144.7 to 153.1 thousand tons, corresponding to an increase of 5.8% (**Figure 2**). It should also be noted the importance of gaseous nitrogen emissions from the application of fertilizers in agricultural activity, which in 2017 amounted to 36.3 thousand tons, with a considerable impact on air quality and the water cycle. Nitrogen losses to the atmosphere are volatilized in the form of elemental nitrogen, ammonia ammonium ion, and nitrous oxide, the latter having a very harmful influence on the greenhouse effect in the atmosphere [56].

Concerning the nutrient phosphorus, the amounts applied in fertilizations are much lower, and its mobility in the soil is lower than that of nitrogen and is preferentially loaded outside of agricultural fields together with sediments [57, 58]. Even considering the improvements that have been seen in the characteristics of fertilizers, particularly in the efficiency of absorption of this nutrient by plants, the excess phosphorus applied still has a very high value, contributing to the progressive saturation of the soil with this element. We can verify by reading the graph in **Figure 2** that the phosphorus balance had a significant decrease between 2000 and 2017 (35%), passing the surplus amount of this element from 36.6 to 238 thousand tonnes. In the same period, the situation regarding the nitrogen balance presents an opposite trend.

4.2 Irrigation water quality and the problem of salinization

The high concentration of salts in the various compartments of its cycle, depending on its nature, may cause inconveniences to economic, environmental, and social order. This problem usually occurs under particular climatic conditions, being typical in irrigated areas where water with high salinity is used [59], frequently by downstream reuse of water that has already been used once or several times in irrigation [60, 61]. In a given agricultural system, the balance of salts is considered adequate when the level of soil salinization is compatible with the expected crop yield [62]. In a scenario of climate

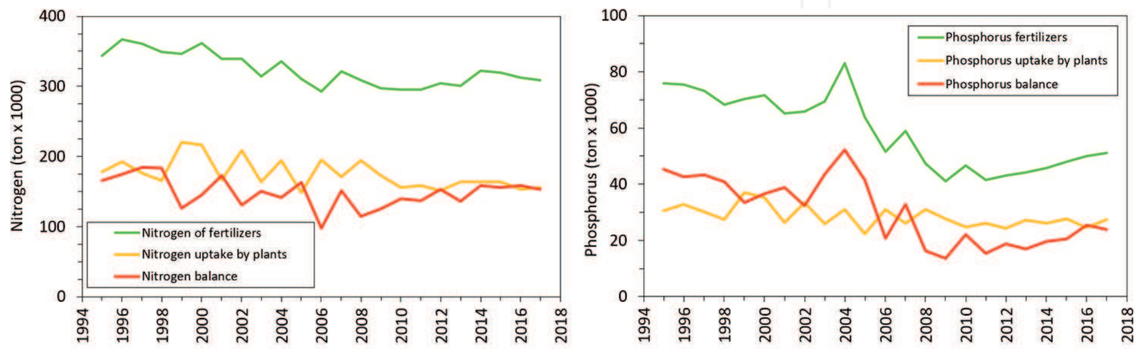

Figure 2.
Gross balance (incorporation – Removal by plants) of nitrogen and phosphorus from fertilizers applied in agricultural activity in Portugal (Adapted of [55]).

change for Portugal and Spain, where an increase in temperature is predicted, with a greater incidence of drought phenomena, and a decrease in total annual precipitation, especially in the south of the Iberian Peninsula, the problem of salinization may become an agro-environmental problem with some acuity, due to the decrease in the washing of salts from the soil and its evapoconcentration in the plant root zone [41]. Of particular concern are the areas of more intensive agriculture, with massive applications of fertilizers, namely the areas of irrigation perimeters in southern Portugal and Spain, and, for similitude of climatic conditions, the southern European countries [63]. In Portugal the estuarine zones of some rivers and other coastal areas, and in Spain, especially in the Ebro River valley and large areas between Almeria and Valencia, the soils are potentially affected by salinization. A significant problem is the particular case of salinization called sodization, currently affecting more than 50% of areas near the coast of Cadiz in Spain. Areas near the coast may be affected by the advancement of the seawater interface due to the intensification of groundwater abstractions [64].

In addition to the excessive application of fertilizers to crops, especially irrigated crops, the quality of the water derived for irrigated areas is also a determining factor in inducing salinity in soils [65]. This aspect is crucial when the water abstracted for an irrigation district already has return flows enriched with nutrients (salts) from several irrigation zones and portends a deteriorated quality [66]. If the irrigation water has of good quality, it is usually not degraded after being used and returned to the natural drainage network. To exemplify this idea, the results of two irrigation seasons observed in an experimental basin located at the Irrigation District of Campina da Idanha, in the center-eastern region of Portugal, are presented below. Indeed, it is possible to verify the low mineralization of the irrigation water derived from a distribution channel, whose quality refers to a category of excellent, and slight variation throughout the irrigation season, rarely exceeding the limit of 100 S/cm (**Figure 3**). On the other hand, the return fluxes from this basin also present a good quality regarding this parameter, not compromising its use downstream [68].

Once the problem of soil salinization is installed, some corrective measures can be adopted to improve crop yields, such as (i) adoption of rotations that include crops more tolerant to salinity and that ensure acceptable yields for farmers; (ii) paying particular attention to the crops tolerance to salinity in the emergence phase, practicing

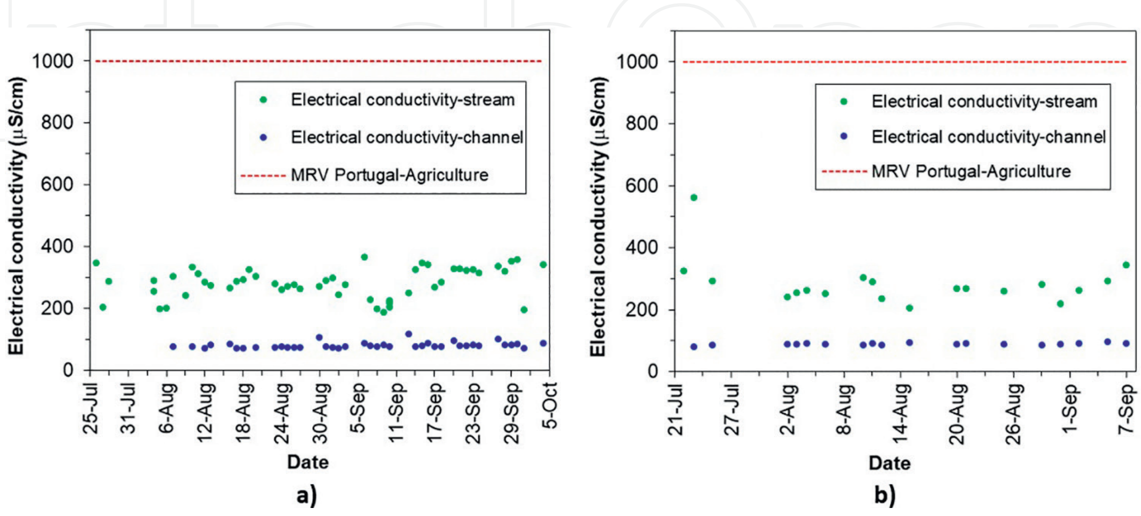

Figure 3.
Evolution of water quality (electrical conductivity) in a distribution channel of Idanha Irrigation District (Portugal), and the return fluxes of an irrigated small basin, in irrigation seasons 2004 (a) and 2005 (b), and the maximum recommended value (MRV) of irrigation water quality in Portugal (Adapted of [67]).

one or more irrigations to decrease the osmotic potential in the soil; (iii) more frequent irrigations than contemplate an adequate leaching fraction for the maintenance of an acceptable salinity level; (iv) adoption of localized irrigation systems, allowing to have high moisture contents in the humidified soil volume mitigating the salinity effect [67].

5. Conclusions

The edaphoclimatic particularities of the Mediterranean basin, namely in the Iberian Peninsula, determine that irrigated agriculture is unavoidable to guarantee the quality of agricultural products and levels of production to the necessary economic viability. However, this goal implies strong challenges, like the compatibility between agricultural activity and the conservation of natural resources.

The great increase in the efficiency of water use in agriculture was accompanied by a great increase in energy consumption, due the modernization of irrigation systems. In the last 60 years in Portugal, the variation was 15,000 to 6000 m^3/ha.year, and 200 to 1500 kWh/ha, respectively. The use of modern/smart technologies in irrigated agriculture, increasingly widespread in the last time, like Information and Communication Technologies, allow the rapid share of information between all the system components, according to the actual or forecasted situation, and using models and artificial intelligence, can promote optimized answers at different scales (irrigation systems in field, distribution water network in the irrigation project, water storage).

The alternative/unconventional sources of water to supply the necessity in agriculture, already quite contribute to the resilience of this activity in Spain. For example, in 2010, the volume of unconventional water resources in Spain rose to 4.540 hm^3/year. Of the total used in agriculture, 450 hm^3 of water comes from the reuse of treated water, and 690 hm^3 comes from desalination.

Nevertheless, the main difficulty lies in the price, too high to be supported by farmers, and, many times, in the characteristics of the water obtained. Special mention must be referred about the water transfer between regions under rules of equity, and periodically reviewed. An example in Spain is the water transfer from the Tagus River in a volume of 421 hm^3/year to the Segura River.

The rational application of fertilizers, in line with the crops needs, is a priority, to prevent the contamination of superficial and subterraneous waters, and to prevent the gradual process of soil salinization in semi-arid regions. Equally important is the evaluation of the water quality to irrigation and accounting the amount of nutrients that already contain.

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Conflict of interest

The authors declare no conflict of interest.

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