3. IRRIGATION ENGINEERING AND FOOD PRODUCTION

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1. Introduction

The present chapter will focus on the water use in agricultural activity, under Mediterranean edaphoclimatic conditions, with very particular characteristics, such as climatic irregularity, the absence of precipitation in the summer months, and, in many years, much rainfall in the winter months, that can require the installation of drainage systems. Despite these climatic adversities, these climatic conditions are very good, many times the best conditions, for some crops, like olives, tomatoes, grapes, dry fruits, some vegetables, and others less important (Neira et al, 2024). Considering the importance of water in these climatic conditions, this chapter will look at three realities in three different countries in the Mediterranean basin, Portugal, Spain, and Italy, which highlight the importance of using water to obtain qualified agricultural production and high yields for farmers (Zagaria et al, 2023). In addition, climate change is altering precipitation patterns, leading to longer and more frequent droughts, as well as flooding during short periods (Canatário-Duarte et al, 2022). Overexploitation of aquifers and contamination of water sources has led to a reduction in the availability of freshwater, raising serious concerns for agricultural production (Rojas-Downing et al, 2017).

The Mediterranean region is known for its agricultural diversity, where the production of crops such as olives, grapes, citrus fruits, and vegetables is essential for the local economy and the culture of the countries that comprise it. However, this region also faces significant challenges related to climate change, which affect water availability and, consequently, agricultural production. Agriculture is a key component of food security, which refers to access to sufficient, safe, and nutritious food to meet the dietary needs of a population. As the global population and food demand continue to grow, more intensive agricultural production approaches are required, especially in the Mediterranean region, where agriculture is vital for local economies. In a context where the population continues to grow, efficient water management becomes crucial to ensure food security and the sustainability of agriculture in the Mediterranean basin (FAO, 2020). Water is a vital resource, not only for crop growth but also for the livelihood of rural communities that depend on agriculture as their main source of income. Also, water is fundamental for photosynthesis, nutrient transport, and temperature regulation in plants (World Bank, 2016).

2. Irrigation and food production around Mediterranean basin

2.1. Spain, water scarcity, and sustainable and resilient water use

In the Mediterranean region, namely a great part of the mainland of Spain, where precipitation is irregular and drought is a recurrent phenomenon, the availability of water for irrigation becomes a determining factor for agricultural success. The climatic characteristics of this region, with hot, dry summers and mild, wet winters, make irrigation a necessary practice to ensure crop production and quality. Table 1 summarizes the main crops grown in the Mediterranean region and their respective water requirements.

Table 1: The main crops in the Mediterranean region (Adapted from Pereira et al., 2015).

Crop	Average Water Requeriment (mm/year)	Main Growing Season
Olives	600-800	April to October
Grapes	500-700	April to October
Citrus Fruits	800-1,200	April to November
Vegetables (e.g. tomatoes)	600-1,000	Year-round

In the period 1965-2023, the total cultivated area in Spain was reduced by 18%, although dry land was reduced by 30%, while irrigation increased by 207% compared to 1965 (provisional data for 2023). This means that dry land loses 5.7 Mha (million hectares), of which 1.9 Mha are transformed into new irrigation and 3.8 Mha are abandoned (Berbel et al, 2024). The greatest transformation is directed towards the cultivation of woody crops, which also require investments in localized irrigation. The table 2 summarizes the water balance in Spain by territorial areas.

Table 2: Water balance in Spain by territorial areas. Adapted from MITECO (2020) and Juana and Sánchez (2024).

Crop	Surface (km2)	Rainfall (mm)	Consumptive Demands hm3 (Horizon 2021)				
			Urban supply	Agricultural use	Industrial use	Others	Total consumptive uses
North and Galicia	53,780	1,429	804	413	274	5	1,496
Duero	78,960	625	263	3,485	46	8	3,802
Tagus	55,810	655	864	1,973	61	39	2,937
Guadiana	60,210	537	167	2,019	82	3	2,271
Guadalquivir	63,240	591	400	3,328	43	0	3,771
South	17,950	530	540	1,573	91	45	2,249
Segura	19,120	383	194	1,487	10	41	1,732
Júcar	42,900	504	482	2,385	153	14	3,034
Ebro	85,560	682	383	8,379	217	0	8,979
Catalonia	16,490	734	531	377	100	0	1,008
Baleares	5,010	595	139	103	3	8	253
Canarias	7,440	302	205	226	13	25	469
Spain	506,470	684	4,992	25,750	1,093	189	32,024

The current demand (MITECO, 2020) (Table 2) is estimated at 32 km3, of which 25,7 km3 (80%) is for irrigation, 4,9 km3 (16%) for supplying populations, and 1,1 km3 (3%) for industry. A distinction was made between the demand that consumes the resource, consumptive demand, and demand that only uses it. In this sense, it was estimated that 80% of that destined for irrigation was consumptive (the other 20% would return to the river network) and 20% of that destined for supplies and industry (80% would be returned).

Irrigation techniques, such as drip irrigation and sprinklers, are widely used to optimize water use. Drip irrigation, in particular, is very effective in this region, as it minimizes water waste by directing it straight to the roots of the plants. However, its implementation can be costly and requires regular maintenance, posing a challenge for small farmers in rural areas.

As climate change continues to alter climatic conditions, irrigation systems must adapt to face the uncertainty of water availability. This involves not only adopting more efficient technologies but also rethinking water management strategies and cultivating varieties of plants that are more drought-resistant.

In response to water scarcity, aggravated by the climate change projected conditions, it is crucial to implement sustainable and resilient water management strategies in the face of climate change. Integrated water resource management policies become essential to balance the needs of agriculture, human consumption, and environmental conservation. To address these challenges, various sustainable irrigation strategies are being adopted in the Mediterranean region. One of these is the implementation of precision irrigation technologies, which enable farmers to apply the exact amount of water needed for each crop based on their specific requirements (Döll and Schmied, 2012). These technologies utilize sensors, climate data, and predictive models to optimize water use and reduce waste. By integrating data on soil moisture and plant water needs, farmers can significantly reduce the amount of water used. Table 3 lists some innovative irrigation technologies and their benefits for Mediterranean agriculture.

Table 3: Irrigation technologies for Mediterranean agriculture (Own elaboration from CIHEAM, 2016 & Pereira et al. 2015).

Irrigation Technology	Description	Benefits
Drip Irrigation	Delivers water directly to the root zone through a network of pipes and emitters.	Highly efficient, reduces water waste (30-50%), increases crop yield and reduces weed growth.
Smart Irrigation Systems	Uses sensors and automation to optimize water delivery in real-time.	Reduces water waste (20-30%), prevents over-irrigation, improves plant health, and reduces labor costs.
Subsurface Drip Irrigation (SDI)	Burying drip irrigation lines below the soil surface to water roots directly.	Minimizes evaporation, prevents runoff, improves crop health, and is ideal for vineyards and orchards.
Precision Sprinkler Systems	Advanced sprinklers that control water pressure and droplet size for specific areas.	Reduces evaporation, delivers water uniformly, and benefits row crops like vegetables and cereals.
Drones for Irrigation Monitoring	Drones with multispectral cameras monitor plant health and soil moisture.	Detects water stress reduces over – or under-watering, saves labor, and improves large farm management.
Soil Moisture Sensors	Devices placed in soil to measure moisture levels and trigger irrigation automatically.	Optimizes water use, prevents over-watering, reduces water consumption (up to 50%), and enhances drip systems.
Solar-Powered Irrigation	Uses solar panels to power irrigation pumps, reducing reliance on grid electricity.	Environmentally friendly, reduces energy costs, suitable for remote areas, and ideal for small-to medium-sized farms.
Desalination for Irrigation	Desalination processes treat seawater to provide fresh water for irrigation.	Provides alternative water sources, supports drought-prone coastal agriculture, and reduces groundwater extraction.

Mulching and Cover Crops	Organic or synthetic materials cover the soil to retain moisture.	Reduces evaporation, improves water retention, reduces irrigation needs, and protects soil structure.
Aquifer Recharge & Water Harvest-ing	Captures rainwater and recharges aquifers for future irrigation use.	Increases groundwater availability, ensures sustainable water use and reduces.
Rainwater Harvesting	Collects and stores rainwater	Reduces reliance on groundwater improves resilience

Additionally, crop rotation and the use of cover crops are practices that can improve soil health and optimize water use. These strategies not only contribute to the sustainability of the ecosystem but can also enhance agricultural productivity in the long term (Pimentel and Pimentel, 2008). Agroecology presents itself as a viable alternative, promoting agricultural practices that mimic natural ecosystems and can better adapt to changing climate conditions.

2.2 Southern Italy, irrigation, agricultural production, and economic stability

In Italy irrigation is crucial in the agricultural sector, particularly in southern Italy, significantly impacting production and economic stability. The key points are:

• Dependence on Irrigation: Approximately 75% of agricultural production in Southern Italy relies on irrigation, making water a vital resource for farmers (Fais, 2006).

• Water Scarcity and Competition: Water is relatively scarce and unevenly distributed in Southern Italy, leading to intense competition between agricultural, urban, industrial, and tourism sectors (Fais, 2006).

• Economic Impact: Irrigation is essential for the economic viability of agriculture in the region. For instance, irrigation of arable crops in Southern Italy and the islands has increased farm income by about 12% (Capitanio et al, 2015).

• Challenges: The region faces several challenges, including groundwater overexploitation, increasing salinization, and the impacts of climate change (Dono et al, 2019). Additionally, using brackish water for irrigation due to seawater intrusion exacerbates soil salinity issues, necessitating careful management to maintain soil fertility (Phillips et al, 2008).

• Water Management: The management of water resources is highly fragmented, involving multiple local consortia and regional governments, which complicates efficient water use (Fais, 2006). Improved governance and technological solutions are also needed to optimize water use (Fais, 2006; Allouche et al, 2006).

• Climate Change Adaptation: Deficit irrigation strategies are being implemented to cope with limited water availability, particularly in citrus cultivation, which is a significant crop in the south of Italy (Bartolini et al, 2007).

In this context, Water Use Efficiency (WUE) is crucial for optimizing water resources in agriculture. It involves measuring the water delivered to irrigated plots and the amount taken from sources. Recent advancements have allowed for satellite imagery to estimate crop water consumption (Jia and Zheng, 2014).

Efficient irrigation management and scheduling are essential for improving WUE. This includes determining the optimal amount and timing of water application based on crop needs, soil characteristics, and meteorological conditions. The goal is to maximize the beneficial water use component, which is the fraction of water that can be utilized by plants. While several methods have been developed to improve WUE, their adoption is often restricted by cost, installation time, and maintenance challenges. Improving water use efficiency in irrigation can contribute to reducing environmental impact and increasing sustainability. Moreover, increasing water use efficiency can lead to higher productivity and profitability of agricultural land it can also contribute to improving the economic competitiveness of agricultural production systems (Carlesso et al, 2009).

Another critical aspect to underline is a notable dualism between the north and south of Italy regarding irrigation efficiency and management. The north, particularly the Padano district, shows lower efficiency in irrigation management for cereals and fruit compared to the more efficient practices in the southern districts like Appenino Meridionale (Capitanio et al, 2015; Dono et al, 2019). Thus, the main irrigated crops in Italy vary by region, reflecting the diverse agricultural practices and climatic conditions across the country.

The following crops are identified as significant in terms of irrigation:

Maize: Particularly in the Po Valley plain in northern Italy, maize is a major irrigated crop, covering almost 30% of the agricultural land in the region (Bechini and Castoldi, 2009).

Rice: Italy is the leading producer of rice in Europe, with traditional paddy fields primarily located in the north-western regions (Gharsallah et al, 2023; De Marco et al, 2018).

Tomato: In the Apulian Tavoliere, one of the largest irrigated districts in Southern Italy, processing tomatoes are a representative irrigated crop (Palumbo et al, 2011).

Vegetables: Various vegetable crops such as lettuce, tomato, melon, fennel, cucumber, endive, and cauliflower are grown in irrigated systems, particularly in central and southern Italy (Campanelli and Canali, 2011; Lonigro et al, 2015).

Fruit and Citrus: Fruit farming, including citrus, is also a significant part of the irrigated agricultural landscape in Italy (Bartolini et al, 2007; Bazzani et al, 2005).

Olive: In the Apulian region, olive groves are a major irrigated crop, with remote sensing techniques used to monitor irrigation practices (Matarrese et al, 2023).

These crops highlight the diversity and regional specificity of irrigated agriculture in Italy, reflecting the country's varied climate and agricultural practices. The environmental impacts of irrigated crop production in Italy are significant. Using irrigation with saline water can lead to seawater intrusion into groundwater, soil salinization, and nitrogen leaching, which poses a severe environmental threat (Campanelli and Canali, 2011). Additionally, the adoption of conservation agriculture (CA) can lead to a reduction in yield in the early years of transition from conventional to CA, but it also improves soil fertility, reduces management costs, and enhances soil carbon sequestration, thus contributing to environmental sustainability (Borsato et al, 2020). Reusing purified wastewater for irrigation can supplement water availability and limit withdrawals from groundwater, contributing to sustainable water management in agriculture across Italy (Lonigro et al, 2015; Bartolini et al, 2007).

The adoption of water conservation and saving technologies (Deficit Irrigation, DI) by Italian farmers can improve the resilience of the agricultural sector and enhance water sustainability in water-scarce locations (Bazzani et al, 2005; Matarrese et al, 2023).

The economic implications of irrigated crop farming in Italy are influenced by the introduction of green payments and the impact of climate change on farm income. The introduction of green payments may have significant negative effects on gross margin, especially for farms specialized in maize production (Cimmino et al, 2015). Farm net revenues are very sensitive to seasonal changes in temperature and precipitation, with different responses from livestock and crop farms, as well as rainfed and irrigated crop farms (Bozzola et al, 2018).

The great challenges in the irrigation of crops in Italy include the need for efficient irrigation management to prevent soil salinization and seawater intrusion into groundwater, as well as the trade-offs between human needs and the conservation of natural capital in sustainable irrigation practices (Campanelli and Canali, 20115; Matarrese et al, 2023).

Irrigation significantly impacts Italian food production, particularly in rice cultivation in the north-western part of the Padana plain (Corbari and Mancini, 2023). Moreover, the replacement of traditional flooding with water-saving irrigation techniques, such as Alternate Wetting and Drying (AWD, a type of Deficit Irrigation), has brought economic benefits to farmers and reduced irrigation needs without significantly affecting rice yield or quality (Corbari and Mancini, 2023). The use of treated wastewater for irrigation can supplement water availability and limit withdrawals from groundwater, contributing to the sustainability of Italian food production (Buttinelli et al, 2024). Deficit irrigation (DI) has been found to have contrasting effects on crop yields and irrigation water utilization efficiency (IWUE) for processing tomatoes in Mediterranean Italy, with variable results depending on climate and soil parameters (Francaviglia and Di Bene, 2019).

Regarding environmental implications of irrigation, the reuse of purified wastewater for irrigation can mitigate water shortage, support the agriculture sector, and protect groundwater resources in Southern Italy (Libutti et al, 2018). However, using treated agro-industrial wastewater for irrigation may pose challenges related to soil and product contamination, requiring careful assessment of health risks and microbiological safety (Libutti et al, 2018).

The economic and environmental analyses of different irrigation systems used in Italian beet sowing seed production identified advantages for localized irrigation, including reduced total irrigation costs and water footprint (Assirelli et al, 2023). To achieve the so-called precision irrigation, the adoption of 4.0 technologies, such as sensors for constant field monitoring, has been shown to improve water management and reduce water consumption in Italian agriculture, with positive economic implications for farmers (Stefanini et al, 2023). Implementing water conservation strategies in the tomato processing industry has resulted in considerable water savings, contributing to environmental sustainability (Eslami et al, 2024).

2.3 Alentejo Region-Portugal, modern irrigation systems, and technologies

In Portugal, this chapter will focus on the importance of a large irrigation project in the south of Portugal (Alentejo region), equipped with modern infrastructures and technologies for managing the water distribution, and precision irrigation systems, for promoting efficient water use and protecting de environment.

The Alentejo region, in the south of Portugal, corresponds to around 1/3 of the territory of mainland Portugal. It is a region with a low population density, only 5% of the population, with high rates of human desertification and aging. Its Gross Domestic Product per capita is below the national average, and it also has a large rainfall deficit. The lack of water in this region has, over the years, been one of the main constraints on its development, preventing the modernization of agriculture and the sustainability of public supply. The Alqueva Irrigation System (EFMA, acronym in Portuguese), located in the Alentejo Region (Portugal) (Figure 1), is a project centered on the Alqueva dam, the largest strategic water reserve in Europe, whose aim is the economic and social development of the region in which it is located, by guaranteeing the water resource. This hydro-agricultural development is a project based on the concept of multiple purposes, where the Alqueva dam is the center of the largest water reserve in Europe, with a total capacity of 4,150 million cubic meters. It has the size, scope, and modernity of infrastructures that make it possible to irrigate the largest Portuguese hydro-agricultural perimeter, produce hydroelectric power in reversible mode, enabling total complementarity with other renewable energies such as photovoltaics, public and industrial supply, preservation of the environment and heritage and land use planning. The Alqueva Irrigation System (EFMA) has a direct impact both on the municipalities covered by the Alqueva reservoir and on those that benefit from the installation of new irrigation perimeters or are served by public water supplies (EDIA, 2023).

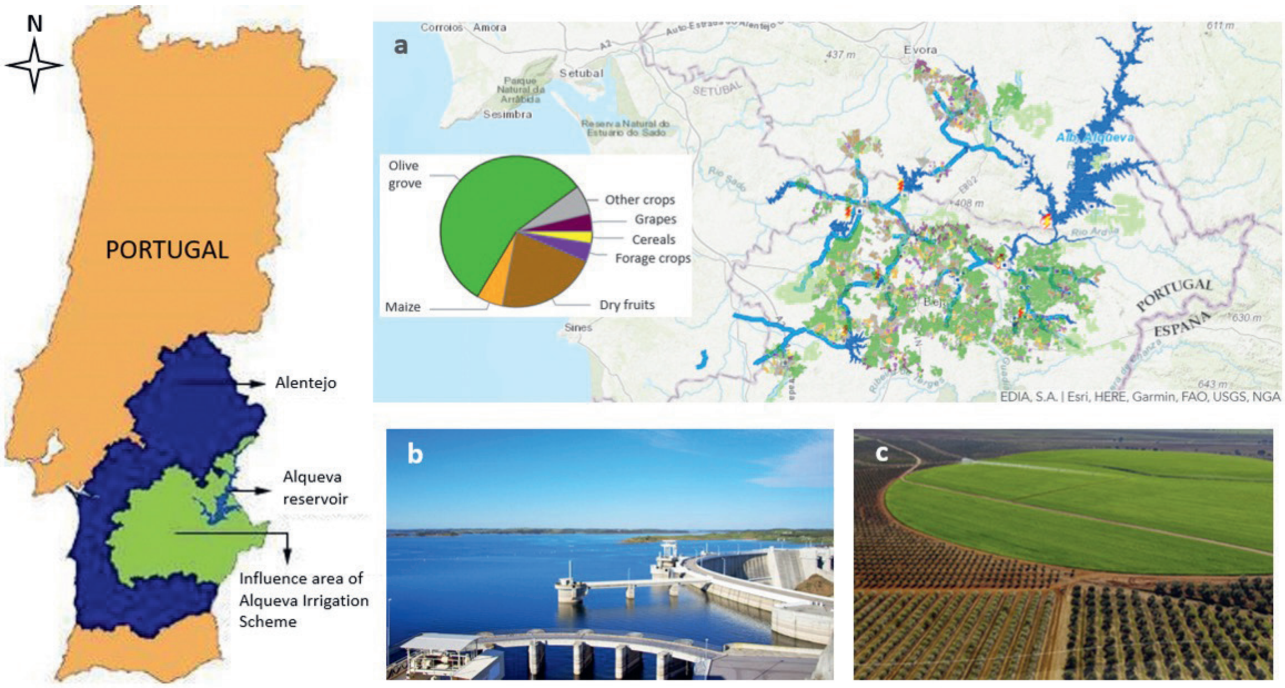


Figure 1: Location of Alqueva Irrigation Scheme influence and respective reservoir, in the Region of Alentejo (Portugal) (Rosa, 2020), actual expansion of beneficed area (a) (EDIA, 2024a), aspect of the dam and reservoir that supply the irrigated area (b) (EDIA, 2023), and example of crops in the irrigation scheme (olive groves with drip irrigation, and maize with center pivot machine) (c) (EDIA, 2023).

The Alqueva Global Irrigation System consists of 72 dams and reservoirs, 2,078 km of canals and pipelines, 48 pumping stations, 5 mini-hydro plants, and 1 photovoltaic plant, and is divided into three subsystems according to the different water sources, namely Alqueva, Ardila and Pedrógão (EDIA, 2024a).

The Alqueva subsystem, whose water originates in the Alqueva reservoir, is developed from the Álamos Pumping Station. This infrastructure allows water to be raised to a height of 90 m, through a forced pipeline 850 m long and 3.2 m in diameter, to the Álamos reservoirs, which guarantee the distribution of water to the entire Alqueva subsystem, which has a total irrigated area of around 75,000 ha (EDIA, 2024a).

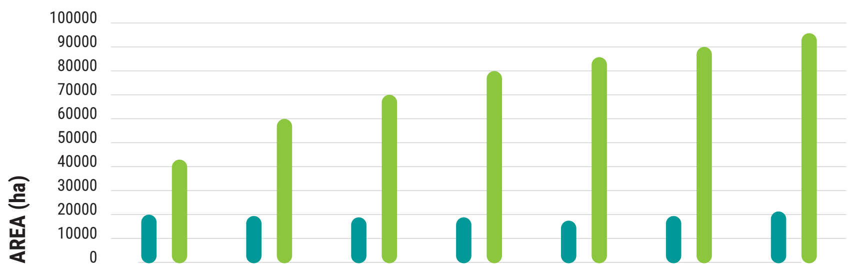
The Ardila River subsystem, with its water source in the Pedrógão reservoir and its pumping station, is made up of a set of 15 dams or reservoirs. It stretches over 60 km of primary network and has around 270 km of pipelines in the secondary network, 6 pumping stations, and a mini-hydroelectric power plant, including several irrigation schemes located on the left bank of the Guadiana River in the municipalities of Moura and Serpa, covering a total irrigated area of 30,000 ha (EDIA, 2024a).

The Pedrógão subsystem, which also draws its water from the Pedrógão reservoir and has its own pumping station, comprises a total of 9 dams or reservoirs, 3 pumping stations, more than 42 km of primary network, and adits on the right bank of the Guadiana River, and benefits an area of 24,500 ha (EDIA, 2024a).

Close to the new Aldeia da Luz, there is a 593-hectare irrigated area, that pumps the water directly from the Alqueva reservoir.

This project currently operates an area of 130,000 hectares, with an adherence rate, i.e. use of the irrigation infrastructures, of over 95%. Meanwhile, the expansion of Alqueva's irrigation perimeters is underway, covering an area of around 40,000 hectares, and demand has increased, both from farmers and from investors wishing to set up in Alqueva or establish partnerships. The investment in this multi-purpose project, now managed by the Alqueva Infrastructure Development Company (EDIA), has enabled a progressive change in the agriculture system of Alentejo, traditionally based on rainfed land, which now, with the guarantee of water from Alqueva, generates new opportunities for irrigated crops and provides opportunities for agro-industries. The irrigation perimeters of the Alqueva subsystems, equipped with modern remote management techniques, offer farmers a guarantee of water, but also the possibility of obtaining information in real-time and adapting the irrigation periods and irrigation depths to their needs at any given moment. EDIA also provides users with a tool to simulate water consumption and estimate the associated cost. The Irrigation Tariff Simulator is a simple tool that is prepared to calculate the cost associated with water consumption, depending on the location and type of supply, the crop's year of installation, the volume of water planned for the crop and the respective area benefited (EDIA, 2024b).

The Alqueva Irrigation Scheme is a national benchmark for its large area of olive groves, but also for its diversity of annual and permanent crops (Figures 2 and 3). The different soil and climate conditions, found throughout all areas of EFMA, provide good conditions to produce a diversified portfolio of crops.



	2017	2018	2019	2020	2021	2022	2023
Annual	19504	19504	18890	18592	17958	19374	20614
Permanent	42837	59172	69692	79321	84305	90007	94603

Annual   Permanent

Figure 2: Evolution of land occupation by annual and permanent crops in Alqueva Irrigation Scheme (EDIA, 2023).

Olive groves are, to a large extent, Alqueva's most important crop and, in a way, the symbol of the region's new irrigated agriculture. Around 50% of the olive presses in the Alentejo region are in the Alqueva area, which demonstrates the importance of olive groves for this region and the economic importance of the olive oil sector in Alqueva.

As a result, the Portuguese olive sector has greatly increased its productivity. To technically characterize this sector, a study was produced to understand the true economic, social, and environmental impacts of this crop and to identify the conditions for promoting its sustainability. This study, coordinated by EDIA, points out that modern irrigated olive groves can be developed in a sustainable and ecologically positive way, depending on the cultural practices used. Good practices such as the preservation and promotion of pockets of biodiversity in the middle of the crop (riparian galleries, groves, isolated Quercineae, temporary ponds, living hedges, and multifunctional inter-rows), or the preference for biological pest control play a decisive role. However, in recent years other crops have expanded greatly in the Alqueva Irrigation Scheme, such as almonds, corn, and vines, which have had a more or less significant impact on regional and national production. The crops that had the greatest impact on regional production were almonds, table grapes, corn, tomatoes for industry, and olive groves, with an increase in area of 92.3%, 91.1%, 69.4%, 51.6%, and 35.3%, respectively (Table 4). In the national context, the crops that contributed most to the increase in crop area were melons, almonds, table grapes, walnuts, and olive groves, with an increase in the area of 85.3%, 37.4%, 23.8%, 19.6%, and 18.7%, respectively (INE, 2022 and EDIA, 2023) (Table 4).

Table 4: Most representative crops in EDIA, in the context of Alentejo (EDIA, 2023) and Portugal (INE, 2022) production.

Crops	Cropped area in Portugal (ha)	Cropped area in Alentejo (ha)	Cropped area in EDIA (ha)	Average production in EDIA (ton/ha)	Authorized Application Depth in EDIA (mm)	Cropped area of EDIA versus Alentejo (%)	Cropped area of EDIA versus Portugal (%)
Olive grove	379565	201298	71035	8–9 (vase) 12–14 (hedge)	280 (vase) 340 (hedge)	35.3	18.7
Grapes wine	173518	25391	5447	08-Oct	210	21.5	3.1
Maize grain	74639	10369	7197	14-16	780	69.4	9.6
Almonds	63884	25857	23859	2-3 (kernel)	570	92.3	37.4
Wheat and Triticale	31046 15354	22766 13798	1434 338	04-May	300	6.3 2.5	4.6 2.2
Citric fruits	21765	1806	576	15-20	600	31.9	2.7
Tomato-industry	15193	1888	974	90-100	670	51.6	6.4
Dystic Barley	11932	9667	1422	4	260	14.7	11.9
Sunflower	7668	5951	1216	4	450	20.4	15.9
Walnuts	5492	1950	1077	02-Apr	700	55.2	19.6
Grapes table	2273	593	540	25-30	520	91.1	23.8
Melon	1730	------	1476	25-35	500	------	85.3
Onion	1574	------	342	20-30	760	------	31.7

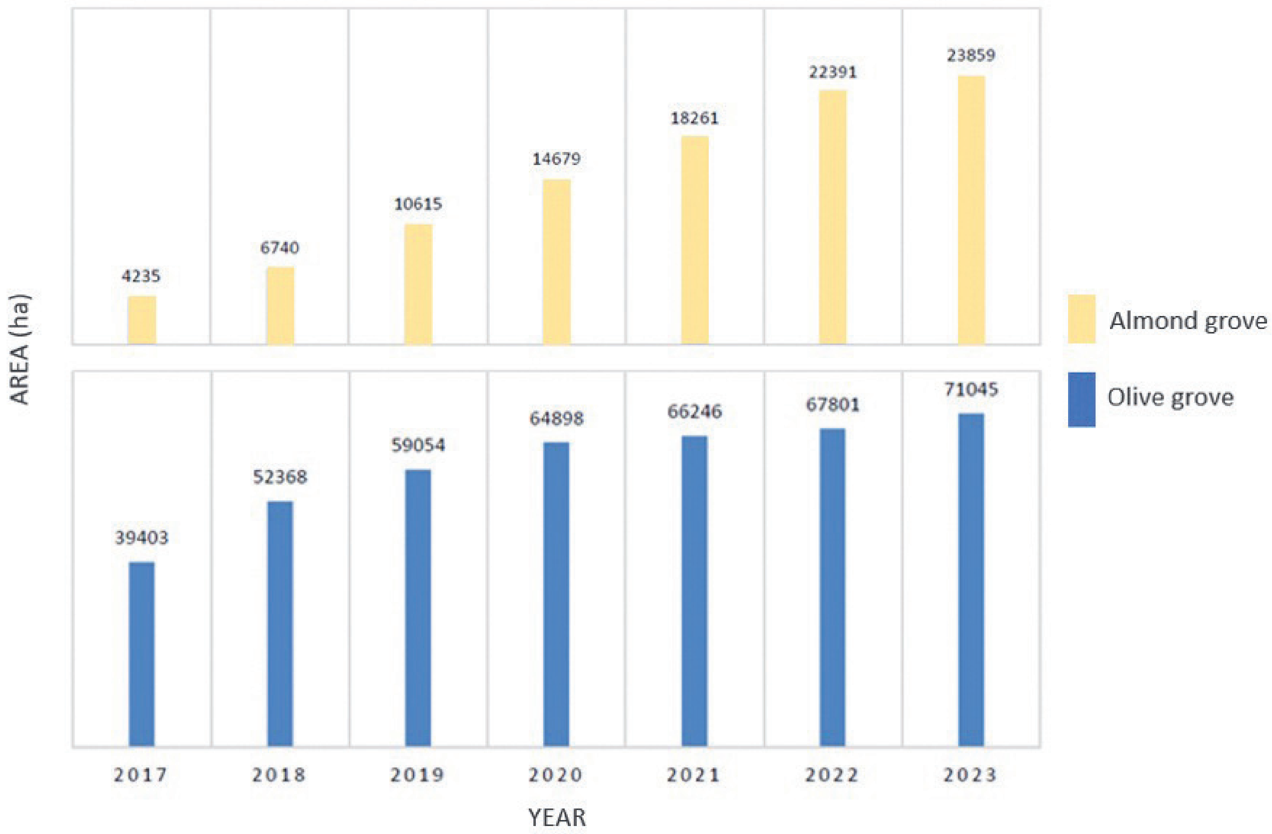


Figure 3: Evolution of land occupation by almond and olive groves (2017-2023) (EDIA, 2023).

In 2022, EDIA the water price for irrigation in the subsystems of the Alqueva Global Irrigation System, was the following. The Conservation Rate is defined as the fee applied to all owners benefiting from irrigation, even if they don't use the water for irrigation, and the Operating Rate is defined as the fee applied to owners of areas benefiting from irrigation who actually use the water for irrigation. Precarious users are those who irrigate areas outside the benefited areas, with water from the irrigation scheme (Government Order 3025/2017, 11 April 2017).

- Water taken directly from the primary network, with pumping provided by the farmers: 0.0305 €/m3;
- Water taken from the Secondary Network to supply high-pressure water to farms (≥ 3.0 bar):
- Conservation Rate: 55.91 €/ha;
- Operating Rate: 0.0599 €/m3;
- Water taken from the Secondary Network to supply low-pressure water to farms (< 3.0 bar):
- Conservation Rate: 20.33 €/ha;
- Operating Rate: 0.0325 €/m3;
- Precarious users:
- Water supply with high pressure (≥ 3.0 bar): 0.0783 €/m3;
- Water supply with low pressure (< 3.0 bar): 0.0387 €/m3.

The conversion from extensive to intensive farming, and from rainfed to irrigated farming, has led to a change in farming practices with greater use of resources and production factors, with repercussions for the environment and human health. In this context, EDIA has drawn up a Manual of Good Agri-Environmental Practices, as a tool to support and help all farmers of the Alqueva Irrigation Scheme, thus contributing to the adoption of correct and sustainable environmental behavior. The monitoring of the environment is also an important management tool, making it possible to characterize the reference situation and follow the evolution of the different environmental descriptors. EDIA's Environmental Management Program, approved in 2005, provides the promotion, coordination, and implementation of environmental monitoring programs, which ensure (EDIA, 2020):

- Monitoring and understanding the evolution of environmental variables in the influence area of the Alqueva Irrigation Scheme;
- Collect and compile data to support decision-making in the management and operation of irrigation scheme;
- Evaluate the effectiveness of the mitigation measures implemented in the various environmental areas and, if necessary, propose new measures;
- Assessing the status of surface and groundwater water bodies;
- Assessing the biodiversity of fauna and flora;
- Monitoring the evolution of properties that contribute to good soil health.

3. Conclusions

The Mediterranean edaphoclimatic conditions, with very particular characteristics, such as climatic irregularity, the absence of precipitation in the summer months, and, in many years, much rainfall in the winter months, are often climatic adversities, but, at the same time with the practice of irrigation, these conditions are very well, for some crops, like olives, tomatoes, grapes, dry fruits, some vegetables, and others less important.

So, irrigation and water management are essential aspects of agricultural production and food security in the Mediterranean region. The implementation of sustainable irrigation technologies, along with efficient agricultural practices, can contribute to a more responsible and effective use of water. Collaboration among different stakeholders, including farmers, governments, and non-governmental organizations, is crucial for developing policies and strategies that promote sustainability. Efficient irrigation is crucial for agricultural production in this context, as it allows farmers to maximize crop yields. However, the impacts of climate change, such as rising temperatures and decreased water availability, threaten this capability. Sustainable agricultural practices, coupled with efficient water management, are essential to mitigate the effects of climate change and ensure food security in the region. Crop diversification and the promotion of native varieties are strategies that can also help increase the resilience of agricultural systems to adverse climate conditions.

Normally, irrigation has both positive and negative impacts on food production, affecting yield, quality, the environment, and the economy. Adopting water-saving irrigation techniques and using treated wastewater for irrigation can contribute to sustainability, but careful assessment of health risks and economic efficiency is essential. Therefore, adopting advanced irrigation technologies can improve water management and contribute to environmental sustainability.

The main irrigated crops in Italy include maize, rice, meadows, winter cereals, fruit, vegetables, citrus, tomato, and processed tomato products. The environmental impacts of irrigated crop production are significant, with challenges such as seawater intrusion, soil salinization, and nitrogen leaching. The irrigation system contributes to sustainability by reusing purified wastewater and adopting water conservation and saving technologies. Key challenges in the irrigation of crops in Italy include efficient irrigation management and the trade-offs between human needs and the conservation of natural capital in sustainable irrigation practices.

In Portugal, the Alqueva irrigation project is exemplary in many aspects, related to water management and distribution to farmers, environmental monitoring and protection, water pricing, and the location of the chain value inside the region where are located the irrigation project. This irrigation project has a modern management system, based on remote sensing, to regulate the water distribution on the canals and pipes network, according to the water demand by the farmers. It is a very important question to save water in the irrigation project. The relatively low price of water allows the farmers to obtain profits more high, and become more competitive. The Alqueva Irrigation Project has a true concern with environmental questions, like control of fish species transference between different watersheds, control of invasive plant species (freshwater hyacinth), that can disturb the water flow in the canals, advice the farmers to rational use of water fertilizers. Inside the influence area of this irrigation project are located many agro-food plants to transform, process, and pack, the crop production of this great irrigated area.

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