A Qualitative Assessment of Water in Alentejo's Agriculture: Challenges and Paths Forward

Dissertation written under the supervision of Professor Nuno Moreira da Cruz

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Title: A qualitative assessment of Water in Alentejo's Agriculture: Challenges and Paths Forward.

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Abstract

Water is the most critical production factor for competitive agriculture. Besides increasing farmers' economic benefits, it promotes population settlement in rural regions and environmental sustainability. Alentejo is the most critical farming region in Portugal due to water scarcity, and its water demands have been increasing for the last few decades, mainly because of irrigation. At the same time, environmental uncertainty brings challenges at the strategic decision level, namely for farmers and policymakers.

The research examines the main factors, attributes, challenges, and opportunities related to water management scarcity in Alentejo. Since collaboration between countries, agencies, and the population is critical to fighting water scarcity in the short term, the research is examined through the lens of the Sustainable Development Goals, shared-value creation, and governance literature. To empirically evaluate the research questions related to water management scarcity, ten semi-structured interviews were conducted with leading primary and secondary stakeholders from the agriculture sector in the region. The qualitative data analysis used Leximancer, a text analytics software that performs an automated content analysis based on relationships between terms that frequently co-occur within interviews.

Findings suggest that new solutions to cope with increasing water necessities to more easily detect flaws in irrigation perimeters and a clear water governance public policy plan, must be made accordingly with agriculture stakeholders' interests for agriculture to maintain its attractiveness and sustainability. Theoretical and managerial implications are provided, along with directions for future research.

Keywords: Agriculture, Water scarcity, Sustainability, Irrigation, Governance, Water transfers.

Título: Análise Qualitativa à Disponibilidade de Água na Agricultura Alentejana- Desafios e Cenários de Futuro.

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Resumo

A água é o fator de produção mais importante para uma agricultura competitiva. Para além dos benefícios económicos para os agricultores, promove também o estabelecimento de populações em zonas rurais e a sustentabilidade ambiental. O Alentejo é a região agrícola mais importante em Portugal e as suas necessidades hídricas têm vindo a aumentar nas últimas décadas, principalmente devido ao regadio. Ao mesmo tempo, a instabilidade ambiental traz novos desafios ao nível das decisões estratégicas.

Esta dissertação pretende avaliar os principais desafios que a agricultura moderna alentejana enfrenta em relação à sua disponibilidade e uso de água. De forma a avaliar empiricamente as perguntas de pesquisa, foram conduzidas dez entrevistas semi-estruturadas com os *stakeholders* principais e secundários do setor agrícola. Os dados qualitativos foram submetidos ao Leximancer, um software de análise de texto que executa um estudo de conteúdo baseado nas relações de proximidade dos conceitos num texto corrido.

Os resultados deste estudo mostram que a falta de água em Portugal é uma realidade centenária, mas agora, mais do que nunca, a intensificação agrícola sustentável exige soluções rápidas e capazes de capacitarem a agricultura com água. Foi claro pela análise dos resultados que é necessária a elaboração de um plano para a governança da água a longo prazo que esteja de acordo com os interesses dos agricultores de forma a manterem o setor sustentável e atrativo ao investimento.

Keywords: Agricultura, Escassez de água, Sustentabilidade, Regadio, Governança, Transvases de água.

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List of Abbreviations

ANPROMIS: Associação Nacional de Produtores de Milho e Sorgo

APA: Agência Portuguesa do Ambiente

APRH: Associação Portuguesa dos Recursos Hídricos

CEO: Chief Executive Officer

CNA: Concelho Nacional da Água

EEA: Agência Europeia do Ambiente

EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization

EDIA: Empresa de Desenvolvimento e Infra-estruturas do Alqueva

ETC: Culture Evapotranspiration

FAO: Food and Agriculture Organizations of the United Nations

GDP: Gross Domestic Product

INE: Instituto Nacional de Estatística

IPMA: Instituto Portugês do Mar e da Atmosfera

NGOs: Non-Governmental Organizations

RQ1: Research Question 1

RQ2: Research Question 2

RQ3: Research Question 3

UAA: Utilized Agricultural Area

USGS: United States Geological Survey

Ha: Hectares

hm^3: Cubic hectometers

m^3: Cubic meters

m^2: Square meters

1. Introduction

1.1 Water Cycle- Increasing Demand vs Globalized Production

Water is the center of life, and its renewability has been jeopardized. Water is an indispensable natural resource necessary to complete to what is known as the water cycle. The flow of water starts with evaporation of sea and surface waters, then it precipitates directly to oceans or inland. Finally, from land, it drains back to the ocean through superficial runoff seen in rivers and brooks. Throughout this process, water has many uses such as agriculture irrigation, industrial use, and domestic consumption.

Population growth, higher life expectancy rates and socio-economic drivers are amongst the many reasons for the increase in human necessities, which has been contributing to an over-exploitation of our planet's resources (Fischer & Heilig, 1997). With the rising levels of water use every year, the planet hasn't been able to cope with the demands coming from the massive use of water, leading to insufficient storage, especially in more fragile regions such as the Mediterranean basin. The strongest pressure on water as a natural resource is agriculture which represents 70% of the total worldwide water extractions (Bordignon, 2016).

In Portugal, agricultural production is responsible for 85% of food self-provision i.e., many products must be imported in order to feed the whole population. While in some categories, Portugal registers a production surplus, such as olive oil (160%), tomato (175%), vegetables (155%), butter (139%) and wine (125%) most products must be imported from other countries. These include cereals (20% of auto-provision), meat (80%), fruits (79%), potato (48%), cheese (65%) (INE, 2020). A turnaround in the Portuguese agriculture is needed so that the product supply dependency can be replaced by the country's own production capability. However, the adequate strategy to change this trend is not immediate due to pressing limitations such as water scarcity. According to Wallace (2000, p.1) "*water scarcity and limited arable land will force production increase to come from growing more food on existing land and water*".

The most recent reports on climate conditions show evidence of higher average temperatures in the last decades and decreasing levels of precipitation, both essential for a competitive agriculture (Nascimento et al., 2004). To break this trend, Portugal must start producing with the limited and already highly exploited water resources in a competitive way, agriculture must turn to *Sustainable Intensification*. In other words, using an innovative approach to ameliorate agricultural productivity on existing land and with positive social and environmental impacts. Such an approach allows overcoming the dilemma of intensification and water usage via a change in the technological model of modern agriculture. Thus, allowing to produce more per hectare without needing to increase the use of water inputs (Santos, 2016).

1.2 Problem Statement, Objectives and Research Questions

In Portugal, agriculture is the industrial sector that requires the most water consumption (Dias & Correia, 2020). Either by precipitation or superficial runoff (rivers and water streams), the total amount of water that reaches the country has been decreasing (Nascimento et al., 2004). Finding efficient alternative solutions for agricultural irrigation seem to be a key topic for the near future. At the same time, agriculture has changed from subsistence family farming to a competitive sector in a globalized economy. Therefore, the research problem focuses on understanding the reality behind water scarcity in Alentejo, how Portuguese farming companies are managing and adjusting to this new reality, and how well is national legislation adjusted to their day-to-day issues to improve water governance.

The environmental changes registered in the past decades along with an increased demand for water in Portuguese agriculture, have led to an over-exploitation of water resources. The objective of this dissertation is thus, to analyze the relationship between the decreasing volume of water available and the increasing demand for water used in agriculture.

To analyze the research problem statement in more detail, three research questions (RQs) are addressed:

RQ1: How is water scarcity impacting the agricultural sector in Alentejo?

RQ2: How will farmers deal with water scarcity in the short-term future?

RQ3: In the long run, how can the Portuguese Government have a crucial role in developing effective water governance to cope with agricultural water demands?

1.3 Academic Relevance

This research contributes to the existing academic knowledge by involving *key governance leaders* from the Portuguese agriculture sector. Moreover, this study aims to analyze what trends are being followed to cope with water scarcity by farmers and agricultural experts in southern Portugal, where water scarcity is more evident. Since the current pressure on the resource in agriculture is evident, and the demand for food and water continues to increase, how water, as a natural resource, is used needs to be re-assessed. Between new ways to source water and new technologies that allow farmers to use water more efficiently, many underdeveloped techniques can help the sector. To understand the problem more thoroughly from an academic standpoint, analyzing of some of the current environmental indicators will help better understand the current production methods. Additionally, by focusing on sustainable development goal (SDG) # 17 – *Partnership for the Goals*, the present research sheds light on current governance practices employed by Portuguese agriculture in an attempt to manage water more efficiently. A qualitative research method using semi-structured interviews is used to properly analyze the reality of relevant professionals in the field and address the research questions posed above.

1.4 Managerial Relevance

Representing 1,6% of Portugal's GDP (INE, 2020) and employing 2,6% of the Portuguese population, the agriculture sector is being threatened by rising demands for water and food while the environmental conditions are getting less favorable for a competitive agriculture. More precisely in Alentejo, agriculture is responsible for 8,8% of the GDP in this region (Pordata, 2022).

This research project delivers practical insights and managerial implications on how farmers manage the water crisis and how do they conduct their activities to achieve a more sustainable environmental and economic future. From a broader point of view, practical insights indicate how government leaders may guide water governance if they want to help and respond to the needs of agricultural professionals.

1.5 Dissertation outline

The second chapter provides a review of the literature on the various sub-topics related to the research problem and how Portuguese farmers must deal with within the next decade to meliorate water usage in agriculture. It provides an understanding of the water distribution globally and some of the technologies that have been developed to increase the availability, and the efficient use of water. After, the third chapter describes the methodology and data collection employed in this research via de use of semi-structured interviews. The fourth chapter focuses on analyzing the data and reporting the results using Leximancer. This qualitative research software application correlates words and sentences resulting from the interviews. The fifth chapter presents the analysis and discussion of the primary data. Specifically, it provides the findings obtained through the semi-structured interviews conducted with agriculture industry professionals, which help to answer the research questions. Finally, the sixth and last chapter summarizes the main conclusions of the dissertation and presents theoretical and managerial implications, limitations, and suggestions for future research.

2. Literature Review

2.1 The Blue Planet

According to Shiklomanov (1993), the earth has about 1,4 km^3 of water in, on and above the surface. Out of this massive number, 97% is salt water and 3% is sweet water in liquid, solid and gaseous state. To narrow it down, it is estimated that only approximately 0,8% of earth's water is liquid fresh water that can be used for human consumption, agriculture, and industrial use present in rivers, lakes and underground (Water Science School, 2019).

Throughout the ages, humans have always tried to create and improve ways to manipulate and use fresh water. The demand for water resources is heavily impacted by population growth, government policies on food and energy, and globalization/increase in consumption. The three main uses of water are Agriculture, with 70% consumption of water resources worldwide, 22% for Industry, and 8% for Domestic use (Bordignon, 2016). Regional drought varies considerably across the globe. The unevenly distribution of water allows some countries to have surplus on their reserves of the resource while, on the other hand, over two billion people live in highly water-stressed areas (Oki and Kanae, 2006). In the same way, interannually, precipitation varies with latitude and other climate factors making it often scarce when needed and abundant when not (Fragoso and Marques, 2006).

Recent climate change circumstances and the increase in water withdrawals due to trends in socio-economic drivers are the two main factors influencing future water stress regions, which lead to serious water management challenges (Alcamo et al., 2007; Sailer, 2013). Additionally, since water consumption has increased over the last few decades, it has led to higher competition for the use of this natural resource while opening an avenue of research to find more sustainable and efficient ways to manage it (Fragoso & Marques, 2006).

2.2 Portugal: Water vs Agriculture- A Review of Environmental Indicators

A study developed by the Portuguese Environmental Agency- APA (2015) shows that the agriculture sector is responsible for 75% of the total water withdraw in Portugal. This is due to the irrigation technologies that have been developed in agriculture to cope with the high levels of evapotranspiration registered in the summer. The United States Geological Survey (USGS) defines evapotranspiration as the sum of all processes that induce water in a liquid state to vaporize and reach the atmosphere (Water Science School, 2018).

According to the National Water Council- CNA (2014), the main sources of freshwater in Portugal are precipitation, surface runoff from hydrography basins and underground water that infiltrates. In the same way, the Portuguese Institute of the sea and atmosphere known as the *Instituto do Mar e Atmosfera* (IPMA) characterizes Portugal as having a temperate climate with rainy and cold winters while summers are hot and dry.

This offset created between temperature and precipitation is felt more aggressively in Portuguese southern regions (below Tajo River) and has made it crucial to find ways to store water annually so it can be used when it's needed the most. Rain distribution is quite heterogeneous across the country. Northern regions have high average annual precipitations, around 2000 mm/year (1 mm = 1 liter/m^2), while the southern regions register annually averages of precipitation bellow 500 mm (Portal do Clima, 2000). A study developed by Nunes et al. (2017) uses five precipitation models applied to the future between 2071 and 2100 compared with 1961-2000. Findings show that a decrease in the rainy season will lead to a drop in the average annual precipitation of 20 to 40%. Rain will drop 15% in the north region and over 30% in the south.

As for temperatures, these are higher in the southern districts. According to IPMA, the average temperature registered south of the Tajo River between 1971-2000 on the hottest month (August) was 24,1ºC, while the northern districts registered 19,5ºC that month for the same period. Aggravating this fact, all scientific models that refer to different possible climate scenarios predict a substantial increase in the average temperature in all Portuguese regions, felt more aggressively in the interior and south of the country, states the Climate Change Post (Raimundo, 2018).

As Doorenbos and Pruitt (1977) define, crop water requirements is the amount of water needed by plants to match their water loss through evapotranspiration. Consequently, the struggle on water requirements felt by farmers in the south is considerably higher than other farmers located in northern districts. The unbalance between north and south in water use requirements has implications on several metrics such as how the water distribution and intensity affect all agricultural practices. So are precipitation and temperature as the climate conditions that have the most significant impact on Portuguese agricultural management. Crop water requirements are at their maximum in the dry season. Therefore irrigation becomes essential to increase productivity and create a competitive sector (Water Science School, 2018).

The increase in demand for water resources in irrigated agriculture and the gradual decrease of annual precipitation in Mediterranean countries are the two main factors changing the reality for modern agriculture, which significantly impact how Portuguese farmers adapt to the new environment observed.

2.3 Irrigation on a Competitive Agriculture—A Global Sustainable Development Goal

As aforementioned, irrigation becomes essential to create a competitive agriculture and lead the sector to a broader economic growth. Accordingly, irrigation has become a crucial production factor for governments and private agribusiness companies to promote agricultural productivity, combatting food insecurity and boosting overall growth. The rapid change between water demand and supply brings unbalance on water resources. Enhancing water use efficiency as well as increase water availability is a priority (Salman et al., 2019).

It has been a very common topic this last few decades amongst scientists, farmers, and politicians that water resources are slowly decreasing in many parts of Europe, especially in the south. On the other hand, driven by population density, socio-economic activities and climatic conditions, the overall water requirements are increasing. The European Environmental Agency - EAA (2022) confirms that: "*Between 1990 and 2017, annual renewable freshwater resources decreased in southern Europe from 2,800 to 2,400 m*^{3} *per person*".

However, in the near future, collaboration between countries, agencies and population will be key to fight water scarcity. These collaboration schemes fall under sustainable development goal (SDG) 17 – also known as *Partnership for the Goals*. The sustainable development goals (SDGs)were introduced in 2015 by the UN and set under the 2030 Agenda for Sustainable Development (United Nations, 2015). The SDGs are a strategic call for action to stimulate economic growth and social and environmental well-being. Recognized by developed and developing countries in a global partnership, SDGs aim to promote synergy between governments, businesses, and society to act together for a better future. The UN General Assembly agreed to define SDGs as a roadmap across all countries to positively impact people and planet in a conjoint effort with specific targets and indicators to be achieved by 2030. Currently there are 17 SDGs, 169 targets and 231 indicators. The present research focuses on SDG #17, more specifically on target 17.16 and 17.17 that relate the importance of *multi-stakeholder partnerships*, such as:

17.16 Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology, and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries (United Nations, 2015).

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships (United Nations, 2015).

Despite SDG 17 being the focus, other SDGs are also affected by implications of the present research, namely SDG 15 – *Life on Land*, SDG 13 – *Climate Action*, or SDG 3- *Good Health and Well-Being*. In this line of reasoning, Portuguese agriculture and all its stakeholders are operating at full speed and under what is known as the decade of action, which requires that countries, governments, industry sectors, and all stakeholders take immediate action to be able to meet (most of) the goals by 2030.

Concerning agriculture and water use in particular, better management systems must be in place to meet some of these requirements. Public and private efforts and capital must be aligned in the same direction, and a strategy needs to be outlined to prioritize investments by importance. In the Portuguese scenario, it is crucial to underline the low economic power of local farmers. Hence, public, and public-private entities significantly influence crucial decisions to orient agriculture to a brighter future. Furthermore, strategic partnerships between private companies can create a lobby effect and increase their demand power over national policy-making institutions such as the agricultural ministry. For competitive agriculture in a country such as Portugal, it becomes essential to measure and evaluate specific key performance indicators over the main topic of water. To better understand them, we divided water use into two main paths.

The first path compares actual water availability with potential water resources, i.e., how local farmers can increase storage capacity and what other water sources are not exploited that could increase the quantity of water available for irrigation (or even industrial and domestic use). In this topic, it is also studied the possibility of transferring water from surplus regions to other regions in shortage.

The second path studies the performance of water used i.e., how local farmers and institutions are using the water that reaches their lands and crops. Irrigation performance is, therefore, a key aspect of the overall water management.

2.3.1 Path 1: Water Availability and New Sources of Water

2.3.1.1 Water Storage Capacity

National water reservoirs have a total capacity of 10 000 hm^3 of water equivalent to only 20% of the total yearly flow from the main 10 river basins in the country (APA, 2015). In other words, 80% of the water running in Portuguese rivers is not utilized nor stored, and eventually wasted in the ecological flow from rivers to the Atlantic Ocean. This is linked to a small capacity to storage the water that reaches our country, either by rain or by superficial runoff from Portuguese-Spanish river basins. Water that can't be stored during rainy season is wasted to the sea.

Table 1- Useful Storage Capacity from the 10 main river basins in Portugal (Source: APA, 2015, p. 59)

River Basin	Current Yearly Flow (hm^3)	Useful Storage capacity (hm^3)	Useful storage capacity in % of flow
Lima	**3 000**	**355**	**12%**
Cávado	**2 300**	**1 142**	**50%**
Douro	**18 500**	**1 300**	**7%**
Vouga	**2 000**	**88**	**4%**
Mondego	**3 350**	**361**	**11%**
Tejo	**12 000**	**2 355**	**20%**
Guadiana	**4 500**	**3 244**	**72%**
Sado	**1460**	**444**	**30%**
Mira	**330**	**240**	**73%**
Algarve Streams	**400**	**230**	**58%**
TOTAL	**47 840**	**9 759**	**20%**

In agriculture, the problem of water waste is essentially due to a deficient plan and conception of public infrastructures for irrigation, that are often the most appropriate for agriculture use (Branco 2018). As we can see on **Erro! A origem da referência não foi encontrada.**, the 5 hydrographic basins from Alentejo (Tejo, Guadiana, Sado, Mira and Ribeiras do Algarve) have a total yearly flow of 18 700 hm^3. Although this, only 6513 hm^3 are stored which is equivalent to 34% of yearly flow. Tejo River also supplies a vast territory outside Alentejo.

The most important infrastructure in Alentejo is Alqueva dam (Guadiana Basin), ending in 2004 with a full capacity of 4 500 hm^3 of water. Currently, the Alqueva's irrigation perimeter supplies a total of 130 000 ha, equivalent to 4,1% of Alentejo Region.

Capturing only 20% of the water that reaches our rivers, one may question why this problem was not a priority for Portuguese agencies to increase storage capacity.

2.3.1.2 Water Transfers- Connecting the country

The transfer of water consists in creating water highways between places where it is abundant to other regions where it may be scarce. According to the president of the Portuguese Association for the Water Resources (APRH), Teresa Leitão[1], water transfers consist in a viable option for Portugal. Building infrastructures that allow to transfer water to more needy places is an initiative that promotes good management of the resource. According to (Almir Cirilo et al., n.d.) Portugal has two small pipelines connecting different water basins, one from Douro basin to Tejo river and the second one connecting Guadiana basin (Alqueva) to Sado River.

2.3.1.3 Desalination of Sea water

Regarding the water crisis that has been felt in many parts of the world, some countries have shifted their attention to new sources of water. Water is very abundant in the planet but, as we previously saw, most water can't be used in human activities. Amongst different ways to obtain water, technology has been showing progress on new efficient processes of desalination.

Desalinization consists in removing the salts and other suspensible particles from the water existent in seas and oceans. To date, there are two common ways to desalinize saltwater. Some water purification facilities combine these two technologies (Silva and Gómez, 2022). The first one has been used since mankind and it's called distillation process (thermal energy), consisting of boiling salt water and capture the steam resultant. Although this, water has a high point of vaporization and therefore it requires high quantities of thermal energy to turn liquid water into gas. It can be created by burning fossil fuels, using renewable energy or by direct action of the sun (Younos & Tulou, 2005). The second process, called Reverse Osmosis, is based on membrane technologies and it has become increasingly common in most countries (Silveira, 2015 cited by Bordignon, 2016). In this process, water is forced by pressure to pass through a

[1] Consulted: https://www.dn.pt/arquivo/2005/transvases-sao-solucao-para-agua-615365.html

series of porous that hold salt and other undesirable molecules while water passes clean (Silva & Gómez, 2022, and American Water Works Association, 1999 cited by Younos & Tulou, 2005). As one may expect, applying such amounts of pressure requires intense energetic use (Middlecamp et al., 2016 cited by Bordignon, 2016).

Worldwide, 95 $m^3$of water is desalinized every day in over 15 thousand facilities (United Nations University, 2019 cited by Iberdrola, 2019). When discussing desalination, it is essential to mention the progress made by some Middle Eastern and Northern African countries such as Israel, Saudi Arabia, Tunisia, Morocco) accounting for approximately 50% of the total desalinized water. According to David Balsar, General Manager of Innovation and Ventures of Mekorot, 80% of drinking water supplied in Israel is desalinated.

For instance, Portugal has projected a new facility in Algarve to desalinize 8 million $m^3$of water per year. The estimated water cost for the projected facility is 35 to 50 cents per m^3 which is ten times higher than the average cost of conventional water capture. The initial investment runs around 45 million euros. According to some experts, this investment is not justified since the annual water waste is 20 times superior. As the president of the environmental association "ZERO", Sara Correia, mentioned to Rádio Renascença (Lima, 2022), "*Portugal must be more efficient with the water we have already before thinking of investing in new sources*."

At the current energy efficiencies, one may also ask in what circumstances it is reasonable to pay ten times the price for water.

2.3.2 Path 2: Improve Irrigation Performance

Agriculture is much more than producing the highest possible yield. Farmers are the number one interested party on improving production efficiency to enhance profitability, protect water resources for long-term sustainability and cut the use of inputs (such as water) thanks to new technologies and up-to-date information. Lamaddalena *et al*. (2019) suggest that by 2030 the world's irrigated land will increase 34% while water resources will increase by only 14%, meaning an improvement in the efficiency of the water used. Performance can be measured as the ratio between the water absorbed by the plants and the total amount administered. Reducing this gap is, therefore, key in agriculture and can be done by knowing the exact amount of water needed by crops and adequately supplying it to the surface.

2.3.2.1 Irrigation Efficiency

FAO (2020) says that there is not a best irrigation system for agriculture. The fit between a crop and the way water is administered depends on several factors like climate, soil texture, crop types, energy prices and sources, labor, technology.

The first irrigation system used by mankind was surface irrigation (or by gravity/flood) distributed in open-sky channels. It consists in applying high volumes of water on one end of the field and let it horizontally runoff trough the land, providing water to the rest of the plants. This system is still used today despite registering the lowest efficiency of the three main irrigation types mainly because of deep infiltration. Water is wasted once it reaches higher depths than crops' roots or when it exits the field through surface runoff at the tail end of the land. Although surface irrigation varies with the structure and type of soil, average technical efficiencies fluctuate between 30 and 70% (Gilley & Watts, 1977; Taghvaeian, 1996; Wallace, 2000b).

Some cultures with higher plants density per unit of area such as cereals pastures and vegetables, are usually irrigated through sprinkles, either set or flexible (center-pivot). Sprinkle Irrigation has proven to have technical efficiencies of 60 to 90% (Schneider, 2000; Gilley and Watts, 1977; Lamaddalena et al., 2019).

The most modern type of irrigation is called localized irrigation or drip. Drip irrigation continuously supplies water on the surface directly above the root system, perfectly adaptable to water fruit orchards and other types of perennial crops. Low quantities of water for long periods (e.g., 2 liters per hour) allow the plant to keep absorbing water as it needs without letting it infiltrate in higher depths. Thus, it can reach high technical efficiencies, such as 90% to 99% (Gilley & Watts, 1977).

In 2019, 15,9% of Portugal's Utilized Agricultural Area (UAA) was irrigated (INE, 2021). The study made by Gulbenkian Foundation (2020) revealed that 65% of farmers are using drip irrigation (corresponding to 71% of the irrigated land in the survey), 35% of them use sprinkle irrigation (48% of the irrigated surface), and only about 16% use gravity irrigation (corresponding to 9% of the irrigated surface). The overcount is due to some farmers having multiple irrigation systems.

These numbers reveal that there has been a transition to more sustainable systems in terms of water use; nevertheless, whether it is sufficient to fight against water scarcity in a world demanding more water and where remains to be determined.

2.3.2.2 Avoid Deep Percolation

Deep percolation consists of water infiltration to depths not reachable by plants roots. To avoid this, farmers must know how much water is needed by crops (ETC) so that only that amount is supplied. Any quantity above the ETC will be lost as underground infiltration by the simple fact that the plant is not able to absorb it (Rocha et al., 2011).

To estimate crop needs it is crucial to study the historical values of temperature and precipitation in the region and its effects on the crop we want to produce. At the same time, it is important to monitor the water amount present in the soil so that the estimations can be adjusted along the crop lifecycle. Despite its importance, the Portuguese reality seems to be different. According to a study conducted by the Gulbenkian Foundation (Dias & Correia, 2020), which involved several interviews with the biggest Portuguese farmers, the sample size was equivalent to 84% of the total irrigated land in the country. Accordingly, only 30% of farmers use soil moisture probes to monitor the amount of water in the soil, while only 23% work with environmental and historical values to estimate crop necessities of water. The rule has it that the most common practice is to water crops by eye. Farmers turn on the faucet and let it soak the land until it's visible. As Joaquim Cano revealed in one of the interviews- "*when we do it (water crops) by eye, we often water in excess*".

In the oversupply of resources, such as water, crops cannot absorb it at the rate it is supplied; eventually, it infiltrates in depth to regions inaccessible by the crop's roots, counting as wasted.

2.3.2.3 Reduce losses on Storage and Distribution Channels

During storage, losses can be registered by direct evaporation to the atmosphere or by underground infiltration. Dams built in river basins hold significant amounts of water at a certain point. Similarly, farmers build reservoirs in their properties and artificially fill them with water. Bos (1985, cited by Wallace, 2000) estimated that approximately 30% of irrigation water is lost in storage. The first reason is the sun's direct evaporation of water into the atmosphere since they are usually open-sky reservoirs. With time, reservoirs create cracks and leaks that can lose water for depth percolation, which leads to the second reason related to the age and characteristics of the infrastructure. Distribution channels are built to transport water from reservoirs to the croplands by a network of channels. These channels transport water at a low speed from reservoirs at higher altitudes to lands. Thus, the steady flow of water for an extended time wears out the walls and bottoms of these channels and eventually opens cracks and leaks. At the same time, channels directly impact the sun, leading to high losses in water on both ends, with the most recent studies indicating significant benefits from having underground pressurized tubes as a means of distribution (Liotta, 2015). Maintenance and new technologies are among the many ways to reduce storage losses; therefore, not only adequate infrastructures are needed but governance as well, as reviewed next.

2.4 Water Governance

Governance, on a broader term, designates a group of laws, processes and practices by which an agency must live when exercising power over a common resource, promoting responsibility, transparency, coherency and efficiency (CCE, 2001). Actions that lead water governance towards sustainability need to be understood in a complex manner where many drivers play their role. Therefore, it becomes crucial to understand the agents involved, how they interact and what are the results of their interaction. A study done by Homobono *et al.* (2022) utilized a social-ecological framework to "*grasp the complexity of issues related to the sustainable use of public goods such as water*" in the southern part of Portugal. They concluded that local policies promoting communication and collective actions between researchers, local organizations, public administration, and farmers are missing.

In the same way, Esgalhado & Guimarães (2020, p. 1) found that in the southeast Portugal a "*picture of a depopulated territory, impacted by ill-adjusted policies to its harsh conditions, including little water availability and continuous depopulation*". Two development paths were found. On one side there is the local farming, prioritizing traditional and ecological crop systems, usually rainfed and multicultural (different crops). As for agricultural companies, the necessity for profitability requires water resources as mean to increase productions and create economically sustainable businesses, often monoculture (one crop for a vast area) while promoting population fixation and agricultural intensification.

Water can be seen as a shared resource, and the lack of governance will eventually and certainly lead to its depletion. In a study by Garrett Hardin (1968) on the *Tragedy of the Commons*, unowned resources are vulnerable to over-use by interest parties. These parties, or farmers for current research purposes, will satisfy their self-interests regardless of the impact it can have on others. At the same time, any attempt to improve the resource's use or maintenance would benefit every stakeholder at the expense of only one party; therefore, improvement is discouraged.

Although water resources for agriculture are managed by public agencies whose goal is to encourage sustainable practices and promote business settlement in rural and depopulated areas, governments and public agencies become crucial in a long-term water governance strategy, especially in irrigation perimeters. Public agencies that manage national irrigation perimeters, such as NGOs, are responsible for creating the best opportunities for agricultural businesses to strive. At the same time, the government and its surveillance entities must maintain pressure over social and environmental standards that companies must fulfill, hold them accountable for any issues brought up by their activities, and highlight the financial risks for any firm whose conduct deviates from the acceptable (Becher, 2022; Porter & Kramer, 2006). Thus, to understand the strings involving water governance, it is helpful to analyze the business concept of creating shared value (CSV) introduced by Porter and Kramer (2006) that changes the orientation of profit maximization in a short-term strategy to a broader perspective of long-term sustainability for all stakeholders (Høvring, 2017 cited by. Becher, 2022). Stakeholders can be defined as an individual or a group of individuals that that have an influence or are influenced by a business and form a mutually dependent relationship with the organization running the business (Freeman & Dmytriyev, 2020).

There are two types of stakeholders - primary and secondary stakeholders. Primary stakeholders are those that directly impact or are impacted by the business. Within the agriculture context, are those who have a direct relationship with water use such as farmers, business unit managers or employees. Secondary stakeholders are those that indirectly influence or are indirectly influenced by the business operations, such as trade associations, academics, and special interest groups such as environmental activists or public officials. Evaluating primary and secondary stakeholders' farming practices, their opinions, and inputs is of utmost importance to gain a deep understanding of the current situation regarding water usage efficiency and the technologies employed to increase water availability in agricultural practices in the Alentejo region.

3. Methodology

The objective of this dissertation is to study the reality of the agricultural sector in terms of water management, in southern Portugal, namely in the Alentejo region. A review of the literature provided a big picture in terms of the technical problems that water scarcity brings to the agricultural sector in Alentejo. Yet, questions remain to be analyzed to fill the gap related to water management scarcity, namely how do primary stakeholders such as farmers look at water scarcity? Also, how can secondary stakeholders such as the government and policy makers promote effective legislation policies that comply with the agricultural sector's needs? What measures should be undertaken at the public and private governance level to attain long-term ecological sustainability and economic feasibility? Is there effective communication between stakeholders to foster efficient cooperation between them while creating synergies to make the use of water more efficient and available to all? These are some of the underlying questions used in the semi-structured interviews used for the empirical purposes.

3.1 Research Methods

The methodology chosen consisted of 10 semi-structured interviews with different stakeholders from this industry. Interviews were conducted in Portuguese and then translated and transcribed to English. All of them were recorded as it was agreed by all participants.

All information regarding interviewees or associated companies were kept confidential as required by the General Data Protection Regulation (GDPR).

Freeman (1984, cited by. Becher 2022) first defined stakeholder theory as the inevitable interconnections between different groups of people resulting from any industry's activities. For better understanding the opinions of different levels of stakeholders and following the stakeholder segmentation mentioned in the previous section, the data was segmented into two groups of primary and secondary stakeholders.

The qualitative data obtained from open ended questions reached a saturation, hence revealing to be sufficient to draw conclusions in a grounded theory process. Glaser and Strauss (1967) define grounded theory as an analysis type in which the researcher develops theories after data is collected. This type of data collection aims towards understanding the situation involving a certain topic through the point of view of a specific group of people in which the researcher observes and interprets the interviewees' experiences. Data saturation consists of increasing the sample size until no new relevant entails are obtained, no new themes are identified, and no new issues are brought up by each new interview regarding a certain matter.

3.1.1 Empirical Analysis of the Portuguese Agriculture

In the first Research Question **(RQ1:** How is water scarcity impacting the agricultural sector in Alentejo?), we want to analyze what problems are brought up by water scarcity in light of each interviewee's reality. We focus on understanding their crops, the growing systems chosen, and the origin of their water resources.

The selected interviewees were chosen as they are top of the line in terms of innovative and sustainable farming practices. For that reason, it was felt the need to understand first what the environment that surrounds them is. For that, it was often asked if their practices are also adopted by the general population of farmers in their region or if they belong to a high-end niche with extreme means for water preservation and impeccable responsible behaviors. To illustrate, some of the addressed questions included: Is water scarcity alarming? Is it a recurring event or it only happens from time to time? From where do you supply your property? Is it an expensive asset in the overall economic balance of the production? How has been the evolution of water availability in your region?

3.1.2 Identifying problems and solutions

For the second Research Question **(RQ2:** How will farmers deal with water scarcity in the short-term future?), we started by identifying the main problems involving water scarcity and the underlying reasons. After that, we wanted to find out what new solutions are being used to cope with this new environment. That is since the selected professionals are dealing with a changing environment, it is important to understand how their choices have been impacted by this scenario.

Finally, since there are many techniques to face issues brought about by water scarcity, it becomes important to collect stakeholders' expertise on which solutions must get prioritized for achieving an environmentally, socially, and economically viable sector.

3.1.3 Long term water plan

In our third Research Question (RQ3: In the long run, how can the Portuguese Government have a crucial role in developing effective water governance to cope with agricultural water demands?), we wanted to dig dip into farmers' opinions on how the Government should align their policies to answer to water scarcity crisis. These professionals should have the best experience in water technology management. Therefore, their feedback is essential to identify opportunities to move the agricultural sector forward. Some underlying questions were: Do famers have a voice in decision making processes? Is there a communication channel between all stakeholders such as local organizations (producers' associations and NGOs), water management companies and the government? Does the lobby effect have an impact on policy making?

3.2 Interviewees

As aforementioned, the interviewees were divided into primary and secondary stakeholders. As shown on Table 2, each interviewee was tagged with a Greek letter to be identified in the rest of this dissertation. Their field of action and regions were also identified.

Table 2- Interviewees and their occupations

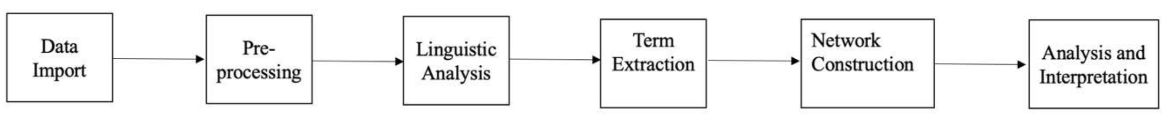
Tag	Professional Activities	Region
	Group 1- Primary Stakeholders	
α	Farmer	Beja, Benavente
β	Farmer and President at a cereal producer's association	Redondo
γ	Viticulture manager at a wine company	Reguengos
δ	Marketing director at a vegetables production company	Odemira
Δ	Farming director at an almond production company	Viana do Alentejo
	Group 2- Secondary Stakeholders	
ε	College professor, agribusiness consultant	Lisbon,
θ	President of a cereal association	Lisbon
μ	CEO at a public water management company	Lisbon, Beja
π	CEO at a forest industry association, former College Professor, founding partner at an agribusiness consulting firm, farmer and former state secretary of forestry and rural development.	Lisbon, Benavente
ρ	President of the National Irrigation Federation and farmer	Coruche, Torrão

3.3 Data Analysis

Krippendorff (1985) states that "*in open-ended interviews, participants are allowed to speak freely and in their own terms. To explore the conceptions that are manifest in such conversations, researchers need to perform what amounts to content analysis on the transcripts of these conversations*". In this way, the conversations between the author and our industry experts followed an unstrict script whose only function was to maintain the conversation on track. Personal answers and opinions were encouraged along the interviews so that we could extract the truest possible views on the subject (Areias, 2020).

To properly analyze the output of the interviews, it was used a software system that performs a conceptual analysis of text data, Leximancer software 4.5. Leximancer is a text analytics software that uses a technique known as automated content analysis to extract meaningful insights from large volumes of text data (Biroscak et al., 2017). It aims to discover and visualize the key themes, concepts, and relationships present in a given interview output. By understanding patterns in respondents' answers and drawing correlations between words and thesaurus concepts, Leximancer can rapidly quantitatively analyze large amounts of text, identify word tags, and draw conceptual maps from it (Harwood et al., 2015; Smith, 2003). More specifically, the steps involved in analyzing the interviews using Leximancer software are as follows (Table 3):

Table 3 - Sequential steps involved in automated content analysis by Leximancer



In the next chapter, is shown the conceptual maps of the data. As for the interviews full text, it can be supplied upon request. As an example, we leave two interviews in Appendix 1 and Appendix 2 with professor ε and farmer β, respectively.

4. Data Analysis and Results

4.1 Global Data Analysis

The content analysis using Leximancer allowed us to build two concept maps differing in the type of tags filtered. The first map (Fig. 1) shows the output of correlations from the whole sample of interviews, i.e., without the distinction between primary and secondary stakeholder. These map results interesting as it allows to take conclusions from the broad perspective of the whole agricultural sector.

Agriculture is not just made of primary producers like farmers, other industries and professionals have major roles as well. Players such as water industry leaders, producers' associations, academic professionals, and inputs' producers (phytopharmaceutical companies, fertilizer companies) are a crucial part of the global agricultural sector. With the input of the different points of view provided in the interviews, the software generated a global map showing semantic clustering according to the most recurring themes and concepts.

Exploring the map, the theme "Water" is at the center having three other themes with high percentage of correlation: "Energy", "Capacity" and "Agriculture". Farmers and government show on the upper end with a small percentage of overlap between the two as well as both with agriculture.

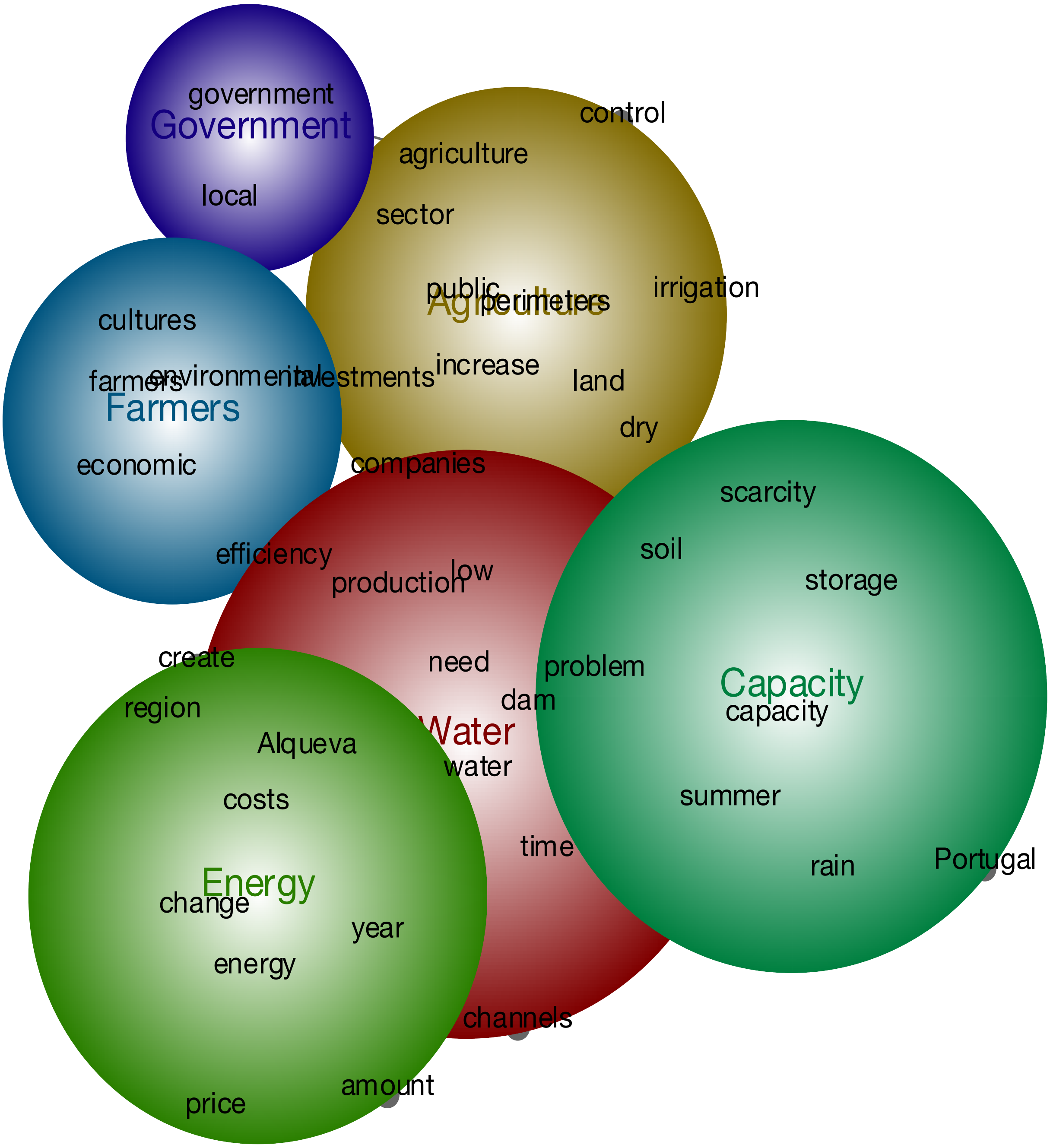


Fig. 1 - Concept Map- Global analysis of the interviews

Further, the software identified the word "Water" as the main topic of the data with 100% relevancy. Then, 9 more themes were identified with relevancies ranging from 10% to 19%, as shown in Table 4.

Table 4 - Leximancer's identification of main concept and themes based on content analysis

Main Topic	Relevance (%)
Water	100%
Themes	Relevance (%)
Need	19%
Agriculture	17%
Farmers	17%
Alqueva	16%
Irrigation	15%
capacity	11%
Public	11%
Increase	10%
Energy	9%

4.2 Stakeholder Data Analysis

The second analysis differs in the approach used. In this map (Fig. 2), the topics generated by the software are grouped by two tags, primary stakeholders, and secondary stakeholders. With this differentiation from the first map, we can see what topics and themes are more related with each group. For the primary stakeholders, the theme "Alqueva" and "Irrigation" are the most relevant points of conversation. As for "Water" and "Capacity", are topics that are more align with the secondary stakeholders.

One example on how to explore this second map, "Water" and "Irrigation" overlap and are closely connected, concepts such as farmers, efficiency and investments are clearly related with both themes.

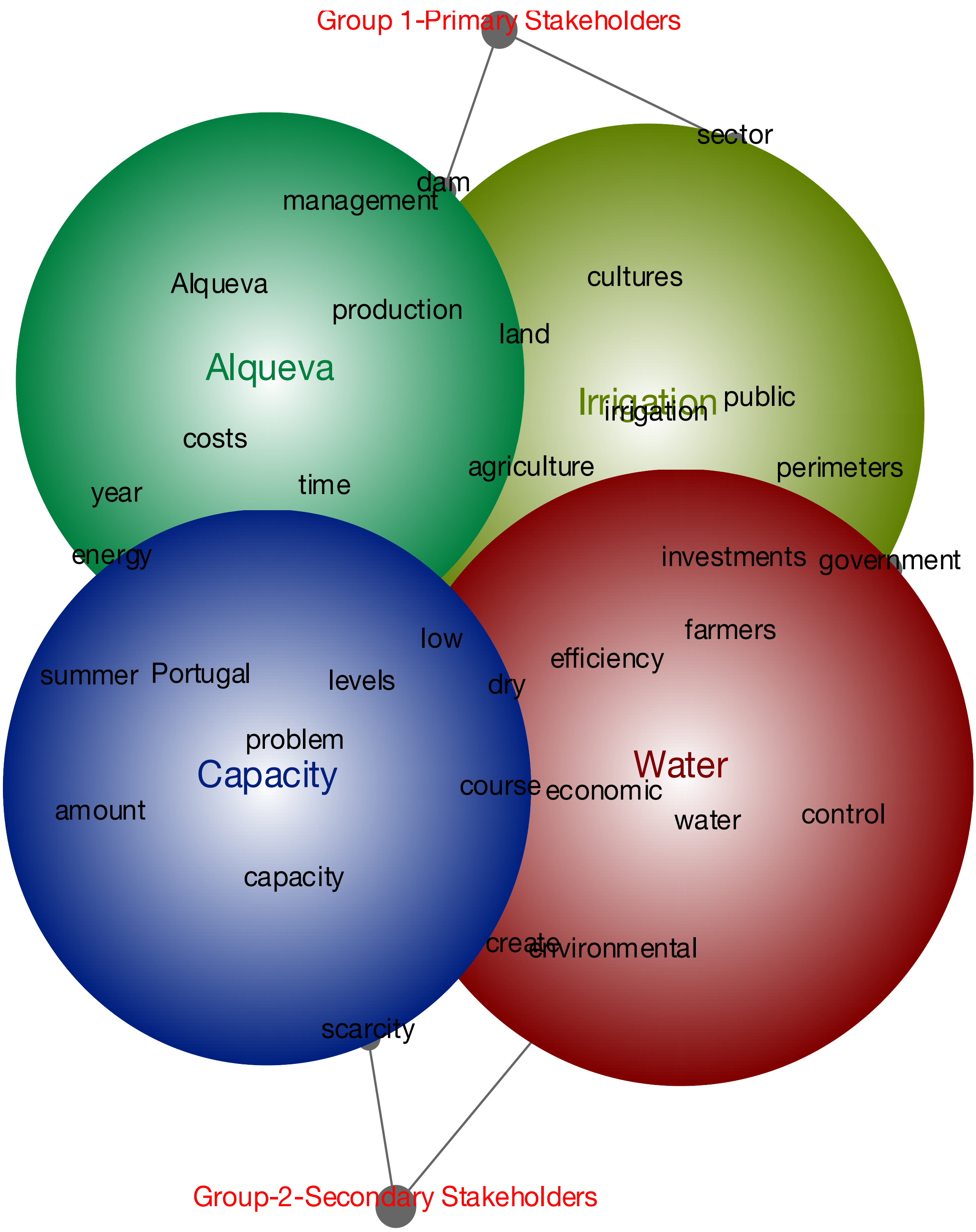


Fig. 2 - Concept Map – Interviews analysis separating primary and secondary stakeholders

In this second data analysis, Leximancer detected 10 concepts with relevancies ranging from 14% to 38%, as shown in Table 5.

Table 5 - Leximancer's identification of Concepts and Themes according to Stakeholder segmentation

Concepts	Relevance (%)
Irrigation	38%
Agriculture	33%
Alqueva	25%
Farmers	24%
Costs	18%
Public	17%
Time	16%
Capacity	16%
Production	14%
Government	14%

5. Discussion

After Leximancer's concept map generation a link between the identified themes and concepts was established with the information gathered from the interviews, also known as *use cases*. More specifically, the *use cases* were created by relating the topics around the themes shown by the map, allowing us to create a storyline built around the emerging attributes from the software.

5.1 Global Analysis – Water, Capacity and Agriculture

> **Use case:** Water will only be useful for Portuguese agriculture as long as we have the capacity to store it.

Variables such as *weather conditions* aren't controlled by man, but it doesn't mean we can't do something to mitigate its impact. Alentejo has always been a region scarce in water and it's getting slightly worse, as it was confirmed by most of our interviewees.

Meteorological stations have registered a higher number of extreme events per year such as high temperature days or precipitation condensed in a small number of days. Additionally, the yearly rain heterogeneity is an important factor to take into account before establishing an agricultural investment in Portugal, especially in Alentejo.

As ε and β say, a decrease in the total amount of rain is not alarming per say, since we have still a surplus in water, "It's the annual irregularity in its distribution that makes this decrease alarming". Historical records show us that on average it rains 880 mm/year in Portugal. Although this, most regions in Alentejo struggle to get half of those quantities while other regions in the north can easily get 1200 mm/year (PEA, 2021).

Heterogeneity in rain across the territory presents a main challenge for agriculture, especially since it's in Alentejo where scarcity is higher while being the region with the highest agricultural intensity. This fact increases the necessity to artificially supply water to crops.

The proper way to cope with precipitation heterogeneity is to increase water storage capacity. As ε says, our weather demands for irrigated crops as the best potential growth period matches the dry season. To be able to incorporate mass scope irrigation systems, water needs to be storage when abundant to be used when needed. α reminds us that a reservoir built for a certain crop needs to have the capacity to respond for 2 to 3 dry years to significantly decrease the risks of water shortage. In this sense, β detects an incapacity of Alentejo's storage to satisfy the needs for 3 full years of drought. In fact, Portugal is only able to store 15 to 20% of the water that reaches the country either by rain or by superficial runoff from Spanish rivers, "*This is justified by the small storage capacity that we have*" confirms π. Because of the small storage capacity, Portugal hasn't been able to fully utilize the water that reaches the country, allowing it to flow back to the sea without being used, "*our storage capacity must be increased*" ε says.

5.2 Global Analysis – Farmers, Government and Agriculture

Use case: *"No Measurement is a Third World Reality"*

The main flaw detected by our interviewees was the incapacity for Portuguese agencies to measure the water that it's being used. As farmers α, β and μ say, not only we store only a small percentage of the water that reaches our country, but we are also inefficient and inaccurate when measuring the one we use.

A Gulbenkian study concluded that 71% of Portuguese farmers don't use flowmeters to determine the water used in their activities (Dias and Correia, 2020). μ believes this to be a third world country reality, *"How can we improve efficiency and innovate if we can't even know who is using what?"*. Professor ε also points that the water used in most perimeters is controlled by farmers and private companies, and they can declare whatever values they wish, it's an incentive to dishonesty.

From Reguengos, viticulture manager γ tells us that "*If we can't measure what we do, we'll never be able to improve*" and when his company started to control the flow of water in every pump-station they were able to detect leaks on their channels that were wasting 50% of their water allowing them to fix it right away.

Alqueva, on the other hand, has a rigorous method to quantify water expenditures. Having flowmeters in every corner of the distribution network allows EDIA to control the water used by each farmer as well as detect any leaks on their tubes. EDIA is the agency in charge of managing Alqueva, the biggest artificial lake in Europe. It was finished in 2002 and in 2009 was able to start supplying water for agriculture. Connecting 25 big dams, Alqueva was a progressive work until today's time with a total of 150 000 ha of land supplied plus 50 000 ha of precarious watering, confirms μ.

5.3 Global Analysis – Water and energy

Use case: Total water price is calculated by a adding the resource price and the energy price needed to extract and supply it to crops.

Water as a resource has such a low price that it becomes irrelevant in most agricultural activities. As for energy, it symbolizes a big slice of the overall yearly costs. Farmer α confirms:

> "*For example, between July and August of 2022, energy to pump water from and underground water hole for 20 ha of corn costed around 20 000€. Leading to 1000€/ha just on water. Comparing to a price of 3,25 cents per* m^3 *in Alqueva, if we use 8000* m^3 *of water per hectare (average amount of water for this culture in this region) we only pay 260 €/ha. So, the highest cost is energy, and EDIA hasn't input on the water price the increasing price of energy*"

Open-sky channels charge water as a resource as they have low costs of energy. Farmers can either save energy costs with flooding irrigation or invest in pumps for other irrigation systems such as dropwise and sprinkling where efficiency is higher. Water prices are relatively low and there are few incentives for farmers to invest in more efficient systems.

Perimeters such as Alqueva's, supply water per gravity at a price of 4 cents/m^3 and pressurized water for 8 cents/m^3. They're all underground tubes with distribution efficiencies near to 100%. Although this, Alqueva is an excellence exception particularly in the south of Portugal where water is scarce like nowhere else in the country.

In the event of being outside of an irrigation perimeter, most farmers choose to extract water from underground holes. In these cases, energy costs are fully covered by the farmer while paying a small price for the water as resource. Professor ε points several problems with this system as he says that the current control agency is incapable to accurately measure the overall water extracted by private companies from these holes, "*the flow of water pumped is controlled by the farmers, so they can declare any amount they wish and sometimes it doesn't match the real amount extracted*" (Appendix 1). Other types of frauds include unlicensed holes or unauthorized water extractions.

Most interviewees agreed that water prices from public perimeters are lower than from private underground holes and this incentivizes the over exploitation of the resource while promoting unresponsible behaviors. On the other hand, in Alqueva, water prices are adjusted with its value, leading to a more conscious use.

The second problem with low water prices is the inevitable degradation of public infrastructures. Public perimeters aren't designed to be profitable but instead to promote local economy and agriculture. Although this, as π refers, if water supply remains almost free for everyone, there will be no money to invest in maintenance of infrastructures putting the whole efficiency of the investment in jeopardy.

As said previously, many farmers are charged per hectare of land without a scrutinous evaluation of the amount of water utilized.

5.4 Primary Stakeholder Analysis – Irrigation and Alqueva

Use case: "*With Alqueva, everything changed in terms of cultures and players. Higher foreigner investments in perennial cultures and somehow a greater numbness of local economies*" - interviewee β (Appendix 2)

As β says, the reality of an Alentejo with water for irrigation is quite new and it now represents 60% of the irrigated land in the country with an approximated area of 300 000 ha

The annual heterogeneity in precipitation makes it crucial to increase water storage, as stated by DEGADR (n.d.). In this context, irrigation emerges as a key component to guarantee agricultural viability. For that reason, public investments were made from the 1960's until now to try creating a stronger agricultural sector. Now days, Portugal has an international scale agriculture, compared to much smaller scale practiced 20 or 30 years ago (Appendix 2) and the major reason is water availability for irrigation. Francisco Palma reminds us (Appendix 1) "*not so long ago, we had no water in Beja for agriculture. Alqueva only arrived 7 years ago*".

Water availability in Alentejo suffered a big transformation with the construction of Alqueva. Irrigation incentivized agribusiness companies to settle in rural regions such as Alentejo by making them competitive and profitable. Professor ε estimates that on average, irrigated crops in Alentejo produce 5 more times than they would if they weren't watered. The potential gap is quite large, and it becomes more attractive when there is water available. In the same way, David Slattery (DESCO Arizona, LLC) interviewed by Areias (2020) says that agriculture is a profit-driven industry. In Portugal you still may find subsistence agriculture (own consumption of what is produced), but its proportions are derisory. Furthermore, agriculture's future is on sustainable intensification (Appendix 2; Areias 2020).

Before Alqueva, the major problem with water availability was the irregularity felt by farmers. The storage capacity was able to respond for only 1 or 2 dry years, states α. In this scenario, most agricultural choices were made of annual crops such as cereals, as they were investments with low loss, in case water runs out. Farmers use to plant and harvest this types of cultures in the same year avoiding eventual water shortages. "*If we had no water in beginning of the season, we could always plant cereals on dry-land and expect to take some money out of the culture on that year*" α says. Therefore, dry land farming was a common practice in Alentejo, especially in places that had no access to water. To be able to choose perennial intensified cultures for long-term investments, farmers would need guaranteed water for many years.

In a way to increase productivities and study agricultural intensification, some farmers started to build their own dams. They could extract water from bigger public dams or from local water streams, "*the problem with private dams is the time and cost to build them. It's essential to understand that it's only worth building a dam if it can hold enough water for 2 or 3 dry years*" α says. The company to whom γ works, was one of them. They are a wine and olive oil company in *Reguengos* supplied by a local stream of water. Around 30 years ago, they built a reservoir to help satisfy the water needs of their vineyards and industrial winery. Their special strategy of inducing water stress on the plant allows their grapes to develop more concentrated flavors and smell while saving great amounts of water. "*Our yearly water consumptions are relatively low, meaning that the reservoir has always been able to cope with our needs*". Although this, something changed in 2016, when the reservoir went dry, "*Good thing we had Alqueva to save us*" emphasizes γ.

5.5 Secondary Stakeholder Analysis – Capacity and Water

Use case: *"It's dangerous to blindly seek environmental neutral policies without looking at social and economic benefits from increasing water storage capacity"* - Professor ε

Irrigation in Alentejo started around the 1950's when some dams were built in the main riverbeds. This was the beginning of public perimeters for agricultural irrigation. Later in the 70's, another batch of projects were approved, and dams were built. More recently in 2002, we have the end construction of Alqueva.

Throughout time the distribution channels utilized evolved. The first projects built had a distribution network with mainly open-sky channels powered by gravity. Dams were built in the riverbeds and then supply water to fields at lower elevations. Alqueva's perimeter, on the other hand, was built with a network composed by underground tubes with pressurized water. "*We have zero losses on our tubes, no leaks nor cracks. We control the flow and quantity of water in every step of the process. We are what I believe everyone else should be, rigorous*" μ says. The main differences between these two types of distribution channels are age, control capacity and efficiency.

Professor ε tells us that older public perimeters lack regular maintenance. With time, these open-sky channels made from concrete and cement start to develop cracks and fissures leading to major wastes in water. At the same time, direct exposure to sunlight leads to losses in evaporation to the atmosphere. Most interviewees agreed with this and confirmed that these channels waste up to 50% of water due to infiltrations and direct evaporation.

As for control, α reminds us that the flow powered by gravity makes it difficult to control the amounts of water used per each farmer: "*Farmers pay per hectare of land and not for the water they use, this is an incentive to over-use and irresponsible farming*". It's hard to measure the water flowing through an open-sky channel.

Lastly, efficiency with these types of old perimeters is quite low, not just because of cracks and over-use but because in the end of the main channels there are no recycling systems and water flows back to riverbeds being lost forever. δ confirms this in his public irrigation perimeter, "*It's known that St. Barbara's dam is very inefficient, (...) in the end of the line, the water flows to the ocean, there is no mechanism to recycle*".

Farmers and agents of the sector are fully aware of the weather conditions in our country. Knowing that precipitation is condensed in a few months of the year is also understanding the importance of storing water for the rest of the year. From our interviews, we were able to identify two reasons for which increasing water storage has been difficult.

The first reason holds to its environmental impact: *"It's dangerous to blindly seek environmental neutral policies without looking at social and economic benefits,"* Professor ε reports.

Today's society is much more aware of the environmental impact of human activities. As ε says, there is always an environmental impact from building dams and reservoirs. The driver, nonetheless, must be the tradeoff between environmental impact and the economic and productive benefits. If the impact can be softened or even mitigated with innovation and new technologies, then investments in increasing water capacity must be encouraged. γ also highlights the importance of guaranteeing a certain ecological flow from rivers but never percentages like 80% or higher, that's what we have now "*part of that water could be utilized or transferred to regions where water scarcity is high*".

On the other hand, for farmers such as α and δ, increasing storage capacity isn't a priority. In fact, this farmers exercise their activities in such a dry regions that even their small reservoirs and dams aren't full. Aspects such as maintenance, recycling systems and water transfers become evident as primary techniques to face drought.

6. Conclusions

6.1 Main Conclucions

This dissertation gives us a valuable perspective on the impact water scarcity is having on the agricultural sector in Alentejo. Furthermore, it gives us insights on how our stakeholders are dealing with a challenging and evolving environment. Finally, it sheds light on the role the Portuguese government should assume in developing effective water policies to address agricultural water demands. Keeping focus on the three research questions, this study has contributed to a better understanding of the origins of water scarcity in the south part of Portugal, while delivering good potential solutions to reduce its impact.

On RQ #1 – How is water scarcity impacting the agricultural sector in Alentejo? – The results of the present dissertation shed light on the severe impact water shortage is provoking on the Portuguese agricultural sector in Alentejo. This region has historically been known by water scarcity which has been affected by the increasing demand of global scale agriculture while increasing irregularity in precipitation and a higher frequency of extreme events such as long droughts and rainy periods condensed in fewer months. The necessity of an artificial supply of water to crops underscores the need for increased water storage capacity. Lastly, the study also reveals issues with inefficient water measurement and usage, as well as the detrimental effects of low water prices on resource exploitation and infrastructure maintenance.

On RQ #2 – How will farmers deal with water scarcity in the short-term future? – the study reveals that both farmers and other stakeholders are employing different strategies to face with the water dilemma they have in their hands. Building private dams and reservoirs has been a common practice to secure water resources for their activities. However, this approach is limited by the cost required for construction as it is only beneficial if it holds enough water for 2 to 3 full years of drought. On the other hand, the availability brought by Alqueva, the largest artificial lake in Europe, has been instrumental allowing farmers to leverage their agricultural options with an abundant reservoir of water while permitting them to intensify their productions. The study also emphasizes the importance of measuring water usage accurately, as demonstrated by one of the interviewees who detected and rectified water leaks through improved water flow control allowing him to save up to 50% of water in his irrigation system (γ). It is evident that in the short term, improving measurement accuracy, implementing efficient irrigation systems, and relying on public irrigation perimeters like Alqueva are key strategies for farmers to address future water shortages

On RQ #3 – In the long run, how can the Portuguese Government have a crucial role in developing effective water governance to cope with agricultural water demands? – In the long run, effective water governance is essential to cope with Portuguese agricultural needs. This study underlines the increasing necessity to improve Portugal's water storage capacity and improve maintenance of public irrigation perimeters. For that the Portuguese government must be a key partner when promoting sustainable water management practices, mainly including accurate measurement of water usage, promoting efficient irrigation systems, and adjusting water prices to reflect its value. Furthermore, the government's role in developing water governance policies that consider ecological flows, water transfers, and the specific needs of regions facing water scarcity is essential for long-term balance and sustainability.

6.2 Theoretical Implications

This research aligns with major environmental and governance theories by addressing the issue of water scarcity and its impact on the agricultural sector in Alentejo. It highlights the principles of sustainable development goals following the recent scientific and social trends on ecological balance while allowing the agricultural sector to be an attractive sector for investments.

The study promotes shared value by identifying opportunities for improvement and innovation in water management practices, which can benefit all stakeholders in most agricultural activities. Finally, this study contributes to increasing performance metrics by identifying key indicators that can measure the impact of agricultural choices when addressing water scarcity, facilitating evidence-based decision-making and evaluating the effectiveness of water governance strategies in enhancing agricultural productivity and environmental sustainability.

6.3 Limitations

Despite its valuable insights, this dissertation is circumscriptive to a very specific part of Portugal, bringing limitations to take conclusions from a broad national level. Additionally, although the depth of the interviews was satisfactory, the research primarily relied on narrowed data collection of 10 interviews, which may introduce potential biases or inaccuracies in relation a broader analysis. Although this, it provided an orientation and potential solutions to the broad challenge of water scarcity in the biggest agricultural region of our country.

6.4 Further Research

In light of the results and limitations of this dissertation, it was possible to detect several potential topics for further reasearch.

Firstly, expanding the scope of the study to a geographically wider group could benefit the results as it allows to understand the relationships between various levels of water needs in different agricultural regions of our country while making it possible for us to draw nationwide solutions such as water transfers that were only analyzed in a broad term in the present study.

Secondly, investigating the potential synergies between agricultural water governance and other sectors, such as energy or urban planning, could provide insights into integrated approaches that promote sustainable water management and support the agricultural sector. With global trends such as renewable energies being on the spotlight in nowadays communication channels, a well-structured water governance could enhance many sectors while promoting sustainable growth and increasing economic benefits.

Lastly, exploring the role of technological innovations, such as precision irrigation systems, water-saving irrigation strategies or new water storing and distribution technologies, in mitigating water scarcity impacts on agriculture would be valuable. Assessing the feasibility, cost-effectiveness, and scalability of these technologies in the context of the Alentejo region or other water-stressed agricultural areas would provide practical insights for policymakers and farmers.

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Appendices

Appendix 1 - Interview with College Professor *ε*

What are your connections with Agriculture?

I have 3 different activities. I am a college professor at Instituto Superior de Agronomia in fields related with strategy and management. Secondly, I’m partner at an agribusiness consulting firm whose main areas of expertise are investment projects, innovation, and strategic studies. Finally, more recently I’ve been managing my family agricultural business

How is water used in Agriculture?

Portugal has a Mediterranean weather, so our winter is rainy and cold, and our summer is hot and dry. For this reason, it becomes essential to store water during rainy season to use it for irrigation during the spring and summer where the growing potential is higher.

When people say that we use 80% of water in agriculture it’s because of our weather characteristics and not by chance nor because capitalistic greed.

Our water comes primarily from superficial runoff stored in dams and other part from subterranean holes. The last holds a problem this days since the information regarding the amounts of water that are extracted are not revealed and sometimes not even measured.

Who controls subterranean holes?

Farmers apply to a license given by the environmental agency (APA) and once the permit is given, they can dig the hole to extract groundwater. The problem here is that the flow of water pumped is controlled by the farmer, so they can declare any amount they wish and sometimes it doesn’t match the real amount pumped. Other types of frauds could come from people that install/dig groundwater holes without the permit. On top of this, APA doesn’t reveal the global quantities of water pumped from private groundwater holes, it’s very hard to estimate the national water necessities when we don’t even know how much we’re using.

How big is our water storage capacity?

Compared to other north European countries, our capacity is really high.

The first argument made by the majority of our farmers (in which I’m included) is that since our rain is concentrated in just a few months of the year, we still have large amounts of water lost to the ocean so, our storage capacity should be increased.

A second argument defends that our heterogeneity of water availability within the country could be solved by transferring water from the north to the south.

If water storage is such a deal breaker, why don't we make more public investments in dams?

My PhD was about Alqueva back in 1997, before its conclusion. Even at the time there were a lot of negative opinions on the environmental impact it would create, and some people even doubted the economic and social benefits it would create. Today, 25 years later, we see how it has revolutionized the whole country. There is always an environmental impact, but it can be mitigated with innovation and new technologies. In general, it's all about balance. If there is a positive balance between impact and benefits, investments must be encouraged. It's dangerous to blindly seek environmental neutral policies without looking at social and economic benefits.

How can technology improve inefficiencies on water use?

It's possible to analyze beneficial improvements from technological innovations. Take distribution channels as an example. For Alqueva, underground and pressurized channels allow to have efficiencies near 100% on the distribution net. Those are high values when compared with older distribution channels that can lose up to 40-50% of water just on direct evaporation and leakage. From this fact, losses also happen within irrigation systems since they're not pressurized, and irrigation is done by gravity or flooding. It's crucial to rehabilitate those older public perimeters.

Is this water scarcity alarming?

What I've been seeing in terms of long-term scenarios is an increase of extreme phenomena such as high temperature periods or precipitation condensed in a small number of days and a decrease on the overall quantity of rain, experts say that from 2000 to 2050 the overall decrease in rain will be about 20%.

A decrease in the total rain is not alarming per say since we have still a surplus in water. It's the annual irregularity in the distribution of rain that makes this decrease alarming. Increasing storage capacity is important to mitigate irregularity.

How can we create a more resilient agricultural sector?

There should be a complementarity between public and private investment. Public investments should be aligned with the necessity of increase irrigation perimeters, especially because in Alentejo irrigated agriculture is on average five times more productive than on dry land, so there is a huge gap between the two productive and economic potentials.

If we look at what have been the private investments in agriculture, they're usually supported or helped with public incentives. The government has, somehow, been present in those investments. Generally, the average Portuguese investor has low economic means and what we have seen for the last 15-20 years, are the landowners shifting from local people to bigger companies or funds that want to host their companies on these irrigated lands for profitable investments.

Is there still land to where we can grow?

Yes, but it depends on our investment capacity to build solid irrigation perimeters to stablish profitable companies. If we want to grow, we need to invest in more water storage infrastructures or allow private companies do dig more groundwater holes.

For example, in one of my properties APA doesn't let me dig more holes for no specific reason. What would make sense would be to let me increase my water extraction under the condition that in dryer years the boundaries for the amount extracted is smaller. But since from the beginning they can't know who is extracting what, they're just legislating on the lack of capacity to control.

Do you see any positive sign from public institutions on long-term water management?

Well, European policies are done by unanimity and our policies are very much aligned with European rules. The problem that holds is that for the rest of Europe, water scarcity doesn't present an issue, therefore all our policy is ill adjusted with our reality. If we talk with any farmer from the northern part of Europe, they barely know what irrigation is. They're more focused on water quality then with quantity.

From our agricultural ministry, we see more signs of awareness to local farming then perhaps promoting higher dimension investments that after all are the ones that create jobs, social and economic income and territory cohesion. For example, if there wasn't Alqueva, all that region would be desert.

The new reform for common agriculture (PAC 2023) brings any news?

The PAC 2023 is very oriented to environmental issues and, then again, with limitation to profitable investments. Public incentives decrease with the size of the project. Medium and big companies will be negatively impacted in the incentives they receive, around 15 to 20%. At the same time, environmental demands will increase.

What role do farmer's associations have in the matter?

For what I've seen, claim power from local associations has been lost over the years, especially with the current absolute majority of our government.

Alternative sources of water are a priority?

I believe that first we should turn to optimizing the systems we have now, especially distribution systems in order to make them more efficient. Although this, there might be occasions where water transfers are a good solution but always keeping an eye to the environmental impact of each measure. To invalidate an investment over ideologic opinions with no fundament is what we have seen most times and it isn't a good practice.

Desalination is another polemic question because of its efficiency and the energetic impact. If we talk about desalination powered by fossil energy, it becomes clear that it's not a viable option. This argument is simply technologic, let's see how new technologies will evolve over the years.

If we were to have a transversal policy to the party in power, what were the priorities to legislate upon?

The first one is the environmental legislation who we see that it's already a priority and I think it's important not to forget. Secondly, we need a national water legislation that starts by measuring where the water is being used and design strategic plans. Lastly, I would say innovation. With innovation we can achieve many things in the future that we aren't able to even imagine today.

Appendix 2 - Interview with farmer and president at cereal producer's association, *β*

What new reality was brought by irrigation?

Portuguese agriculture has now an international scale, compared to much smaller scale practiced 20 or 30 years ago. So, to maintain competitiveness, irrigation becomes mandatory in most scenarios as source of cultural stability and production increase.

How has your activity change over the years?

I am very fond of cultural diversity with scale and professionalism. I always have a good percentage of animal grazing in agroforestry habitats and then a wide range of Mediterranean cultures. Most is irrigated such as corn, but I still have some on dryland, mostly cereals.

With Alqueva, everything changed in terms of cultures and players. Higher foreigner investments in perennial cultures and somehow a greater numbness of local economies.

Let's talk about Alqueva.

Alqueva has proven to be a winning public project and its management top of the line. Prices are tabled and will eventually increase, which I think it's a good way to promote good practices and efficiency increase.

With this project, good quality land was equipped with water and the gains for the sector and for the region were incalculable. We have overall 200 000 ha irrigated by Alqueva and around 100 000 ha more with other public perimeters in Alentejo, this is 60% of the total Portuguese irrigated land.

Of course, there are a lot of sterile lands as well as forests that cannot hold agriculture, but we still have plenty of land to use. The lack of water resources doesn't help it, though. Increase water reserves and storage is essential to change this.

Is there chance to build other big public perimeters?

At this moment, political willingness doesn't show that as a priority. We notice that some deals with urban environmentalists have shifted the attention from those necessities. Portuguese agriculture needs this types of projects and everyone that deals with water scarcity in the sector knows it, but there are many concessions to other interests from ill-informed lobbies.

Here in our region of Vigia's dam perimeter, we could triple our production area if we had more water. Vigia holds approximately 17 million m^3, and the yearly consumption is about 8 to 9 million m^3, so it holds for only 2 years if there is no rain. Since we still need to guarantee some public supply, it doesn't even hold for 2 full years. Historically we have one good year, the second one with some restrictions and the third one with major cutbacks. The solution foreseen is to increase the supply of water from Alqueva to Vigia dam.

What are the main challenges in the implementation of more efficient irrigation systems?

Investing in innovation and technology at all levels seems to be the number one priority. Many successful case studies have been sprouting in the private sector and it must constitute an aiming point for all farmers. There is a collective conscious of its necessity since this good management of the resource leads to major cost cuts in the overall economic balance, not directly due to water but because farmers that innovate in water management also are in the front foot of monitoring cultural needs and inputs' efficiencies.

What is your general opinion on alternative sources such as water transfers and desalination?

Portugal has a high surplus of water overall, but the heterogeneity of distribution is what most affects us. It's completely reasonable for me to build infrastructures that will allow the transfer of water from the northern part where the surplus is high to the south where agriculture is strongly predominant, but the lack of water is higher.

Of course, this doesn't substitute the fact that we need to promote more regional independency by increasing water reservoirs and storage capacity.

In terms of desalination, I'm 150 km away from the sea so I don't see it as a viable option for the future. Plus, the price we must pay in the investment and for energy is extremely high and very uncompetitive. It's not a priority for now.

What do we need in order to create a long-term plan for water management that align policies with national interests?

First of all, we need a strong agricultural ministry or someone that oversees the whole sector, creating a pact between all stakeholders for the nation best interest. We must come to terms, at least for a majority of the stakeholders. For this, we need people to be informed about the technical and political issues in water management.

To implement the strategy, we need knowledgeable people from within the sector to run operations.

Third in line is control, to manage we need to know how much has been used. Many public perimeters lack flowmeters to control the amounts of water used.

A current positive aspect from our government is that there has been a delegation of responsibilities in regional irrigation associations that were reasonably well managed.