Hydroagriculture project - A Portuguese case study

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Abstract. Water plays an essential role in the social fabric and comfort of society, as it plays an important role in our survival and subsistence, in its accessibility, in economic activities, and in the particular case of this study, in the manufacture of agricultural products and activities. In a developing society, and with the number of the human population increasing, consumerism takes place, resulting in an increasing need to use space, resources and food. Agriculture is an ancient activity that serves as the basis for ensuring the subsistence and resilience of the population, producing crops and different types of food, from vegetables, fruits, legumes, seeds, etc... and they all have one thing in common: The existence of water. If there are fields suitable for agriculture, but there is no water, they become unusable. Water improvement and supply projects can drastically change this situation, thus stimulating agricultural production. The analysis of this case study, the largest hydroagriculture project in Europe nowadays, aims to highlight the importance of carrying out hydro-agriculture projects and the impact they can have on society, demonstrating that this project considerably increases the production of the rice harvest in Portugal through the artificial irrigation of land that previously could not be used for this purpose.

Keywords: Project design, Sustainability, Water scarcity, Climate change, resources

1 Introduction

After periods of evolution, Humankind established permanent settlements about 10.000 years ago. We went from a migrating population to a new way of living that allowed us to expand faster than ever before. Sedentary agricultural life made it possible to build infrastructures where it would be possible to obtain resources, creating an important relationship between humans and water. From this time onwards, the importance of obtaining clean and fresh water became evident, where water contaminated with pathogenic agents put lives at risk, with no notions of medicine like the one we practice today. Looking at history, it is recognized that the first settlement classified as urban was Jericho, between 8000-7000 BC, located near water sources. Later, in Egypt, there are traces of wells, and in Mesopotamia, stone rainwater channels, from 3000 BC. This evidence is multiplied by the civilizations that emerged, having one thing in common between them: proximity to water courses. Another intrinsic aspect in the use of water was the healthiness of the water, which was essential for carrying out agriculture, as well as sanitation. Wells and places used as toilets demonstrated the importance of maintaining good hygienic conditions in order to avoid the spread of diseases and environmental risks, as well as epidemics [1].

Growing population changed consumption patterns in the global demand for food and agricultural raw materials. This resulted in an expansion of harvest areas and intensification of land use, emerging techniques between land use and rest, and the need to modify land irrigation for agriculture. Large aqueducts, as shown in figure 1, allow the supply of water to society, transported over long distances to population centers. Later, as shown in Figure 1, the concept that would shape society and the way of obtaining water emerged: pumps. Even though they were quite rustic and inefficient versions compared to today, it was a very advanced technology in ancient times and whose impact was undeniable.

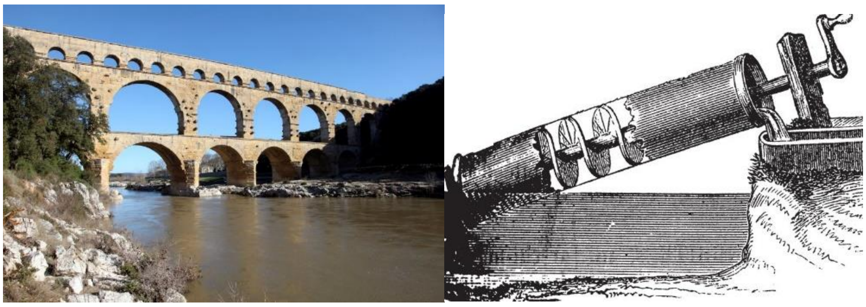

Figure 1: Roman aqueduct of Pont du Gard, which crosses the Gard river, France (Photo: Robert Harding Picture Library) and Archimedes screw working principle.

Irrigation now allows crops to be grown throughout the dry period of the year, thus enabling intensification of land use and multiple cropping systems[2]. Nowadays, technology has evolved, material manufacturing processes are of very good quality, and the need to obtain large quantities of water for agricultural purposes remains in order to respond to society's needs.

2 Sustainability in the agriculture sector

Nowadays, sustainability has reached relevance in society in which objectives accumulate, serving as a path towards a world that is less consuming of resources, more efficient and with less impact on the environment. The amount of water available depends on cycles, with each cycle taking its own time to complete, sometimes resulting in difficulty in having enough water for all ideal activities and consumption. It is noted that the water cycle, although constant, does not mean that the water replenished in each area is constant, and its deposition in oceans or glaciers may vary, lasting for many years. Therefore, in areas where precipitation is scarce or with prolonged periods without precipitation, water becomes scarce and can almost be considered a non-renewable element. Another aspect is related to fresh and drinkable water, consumable and within the quality parameters for human consumption, as its existence in its natural state is much smaller and may become scarce to stimulate all demand [3]. This work brings an original analysis contribution, which makes an allusion to the Sustainable Development Goals (SDGs), which are considered to have a positive effect on the following SDGs:

- SDG 2 – Zero Hunger – Increase the quantity and quality of crop production, diversifying the products available for consumption and making them available to society. It should be noted that this point can positively or negatively influence market prices, governed by the law of demand[4];
- SDG 3 – Good health and well-being – Entities such as UNESCO argue that every child has the right to health, food and adequate nutrition[5]. There is a direct relationship between food and health, so it is a fact: We are what we eat[6];
- SDG 8 – Decent Work and Economic Growth – Consulting statistics, Portugal in 1989 had around 1 560 990 people working in agriculture. In 2019, there were 648 252 people working in this area, which represents 2.4 times fewer workers. Although this factor can be justified by the modernization of infrastructures and technologies, Portugal is going through a period of lack of labor. It is urgent to stimulate and recruit labor and conditions so that the agriculture sector has the conditions to grow and be sustainable[7].
- SDG 9 – Industry, innovation, and infrastructure – Portugal covers an area of 89 089 km² of which 81% is rural. Also in these statistics, it is possible to verify that 47% is agricultural land while forests cover 39%. Another curiosity lays on that 33 % of the total populations lives in rural areas [8]. In the Portuguese context, the modernization and competitiveness of farms will be done through support, investment support will continue to encourage young people to set up new modern and competitive farm enterprises;
- SDG 11 – Sustainable cities and communities – The Portuguese Common Agricultural Plan (PCA) strategy requires Portuguese agriculture and its methodologies to become more sustainable. In this sense, large funds are allocated to farmers for actions that reduce the carbon footprint, organic fertilization, organic farming and integrated production. In order to contribute to European goals, 19% of the agricultural surface will be cultivated organically by 2030. With regard to climate change, actions will be carried out such as improving the quality of pastures and protecting against fires. Water management, in terms of quantity and quality, plays an important role. The support granted focuses on the renewal of old infrastructure and equipment used in collective irrigation systems and on agricultural farms, which will increase the agricultural area that receives support to improve the efficiency of water use to 4.5%. encourage the implementation of renewable energy, projects with this aspect will receive priority [9] .
- SDG 12 – Responsible consumption and production – The UN (2020) defines sustainable consumption and production as:” *the use of services and related products, which respond to basic needs and bring to a better quality of life while minimizing the*

use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generation". Crop production must respond to demand and demand, in order to avoid food waste, non-utilization of crops, or in the opposite sense, the lack of products on the market which, consequently, reflects the increase in prices and financial difficulties in the monthly budget of families.

• SGD 17 – Partnership for the goals – Creating partnerships between stakeholders results in the stimulation of obtaining results, design, fabrication, deployment of new products and technologies in order to comply with indicators outlined by the European Union.

3 Agriculture in the Portuguese national panorama

Portuguese agriculture is characterized by its diversity, since there are several factors in the country, the main one being location, which is subject to different climatic, topographic and pedological conditions. Agricultural products include wine, cereals, fruit and vegetables, olive oil, pork and poultry. In Figure 2 is shown the percentage of national agricultural production.

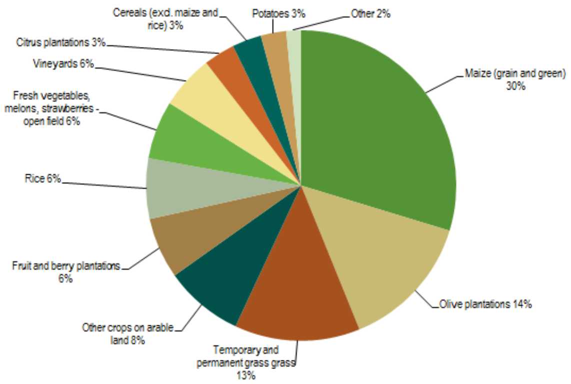

Figure 2: National agricultural production in Portugal.

However, Portuguese production is not at the top of European countries, with France, Germany, Poland and Spain together produce more than half of the cereals in the EU-27[4]. Although agriculture represents an important activity in the countries, in Portugal only contributes to less than 3% of the country's economy (Total Gross Value Added - GVA). As mentioned previously, quantity, quality and productivity influence the market value of the agricultural product, which is why national indicators vary annually. This results in a certain uncertainty for producers who are regularly faced with costs inherent to production, as shown in Figure 3 [9].

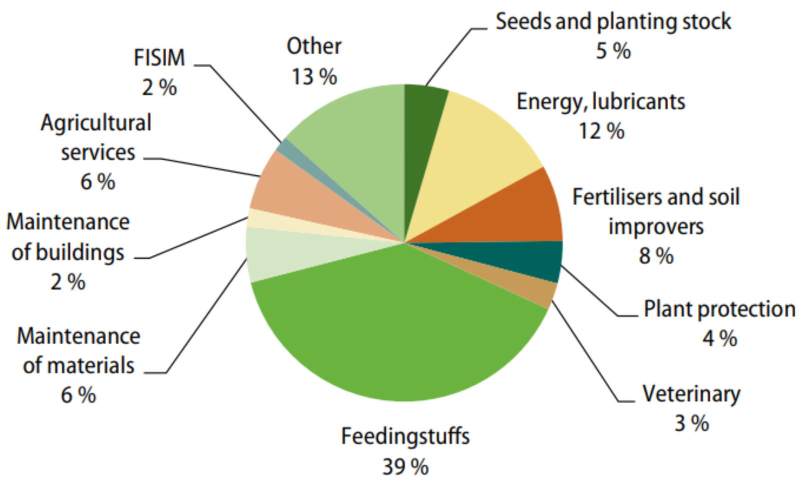

Figure 3: Percentages of average costs associated with agricultural activities [9].

By consulting statistical data and factors associated with agricultural activity, it is possible to understand the influence of extreme and anomalous phenomena in agriculture. For example, the meteorological drought of 2022 resulted in a severe and extreme drought in critical months of the year. In the same year, the winter cereal campaign was the worst on record, matching the worst cereal harvests with the most severe droughts. Rice production was 155.6 thousand tons, which corresponds to a decrease of 11.6% compared to the previous campaign[10].

Portugal is the fourth rice producer in the EU after Italy, Spain and Greece, with the agricultural area dedicated to rice cultivation equivalent to 28 000 hectares, with a production of 5.6 tons per hectare [11]. The need to resort to projects and developments that enhance crop production and increase the probability of them being successful becomes evident, thus mitigating the effects associated with extreme phenomena, thus avoiding social and economic effects that have a significant impact on society.

4 Previous benefits hydroagriculture project

In order to analyze the present case study, it is essential to review the literature in order to compare it with other projects already carried out. It should be noted that there are very few large-scale projects for the capture and supply of freshwater for agricultural purposes, which is why it is difficult to carry out a literature review for similar projects. In the same area and river basin, there were actions that focused on how to improve the agricultural conditions that have served to increase the crop productivity in improved areas. This same study explains that there were particular social circumstances that led to the reduction in anthropogenic nitrogen sources, which has been accompanied by a decline in the nitrogen that is exported at the river basin [12]. This study also mentions that during the past few decades, the Low Mondego basin underwent major modification, namely, new irrigation and drainage system, mechanized and intensified cropping by increasing the cultivated areas through land consolidation programs and access conditions. Mondego River Valley was designed to be implemented on 12 200 ha of land with very high agricultural potential. The priority was to modernize small farms. However, only some blocks were developed in a very slow and inefficient process, ending up with only an area of 6706 ha being improved. This resulted in an abandonment of agricultural developments. The study also characterized the harvests in the Baixo Mondego area, according to Table 1.

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Table 1. Areas dedicated to different crops in Low Mondego.

Crops	Crop Areas (ha)									
	1986–1989	1990–1992	1993–1995	1996–1999	2000–2002	2003–2005	2006–2009	2010–2012	2013–2015	2016–2018
Maize	12,152	11,726	10,295	11,434	9945	8293	8658	8070	8470	7953
Rice	7258	5832	7030	5822	5622	5744	5890	6112	5817	5876
Vineyards	6397	6341	5787	4490	3972	3707	2542	2230	2248	2249
Olive trees	3992	3896	3696	4437	4144	3587	3270	3053	3051	3048
Oat	2374	1579	955	1564	1266	943	752	569	536	612
Potatoes	2172	2038	1646	1142	804	633	443	295	289	294
Wheat	956	853	772	598	470	311	620	444	369	417
All forage crops	16,281	15,321	11,557	10,362	9683	9602	6513	5684	5631	5719
All fruit trees	903	892	849	557	465	392	235	191	192	193
Other cultures	2297	2088	2012	1037	735	708	880	809	788	822

5 Case study

5.1 Brief building description

Represented in Figure 4, the Baixo Mondego Hydroagricultural Development benefits a total area of around 15 000 ha, is located in the Baixo Mondego valley and runs along the Mondego River, in Portugal, for a length of approximately 40 km, including the banks of the main tributaries of the Mondego. The water supply to the various irrigation blocks in Vale do Pranto is made from the Pranto Right Aductor and the Marnoto Distributor, which establish the connection between the primary infrastructure - the Mondego General Conductor Canal - and the sprinklers, allowing the benefit of an area of around 909 ha. The agricultural system is entirely dominated by rice cultivation, which is intended to be maintained in the area under study after the land consolidation project. Irrigation in rice cultivation is carried out using the submergence method, through the process of flower beds or flooding.

The Right of Pranto Pipeline will benefit Campo da Amieira, Campo do Conde, Campo do Seminário and Campo do Porto Ferro. Campo do Velho e Marnoto and Campo da Telhada, Paul do Quinto and Calçada will benefit from the Distributor of Marnoto, originating in the Aductor located in the first third of Campo do Conde. In the vicinity of Campo do Seminário, where the Pranto Right Aductor ends, the Quinta do Semirário Hydraulic Circuit will be built so that it is possible to benefit from areas downstream (Seminário Field and Porto Ferro Field). Campo do Conde has an area of around 346 ha and is limited to the north and west by the Pranto river, to the east by the road EM 621 to the Vinha da Rainha area and from here along a path to Quinta do Seminário. The cofferdam to be built on the Pranto river, immediately downstream of Comportas da Maria da Mata, will allow the continuation of water supply to the cultivated fields, during the period foreseen for the execution of the work. The Casenho dam will be located on the Seiça stream next to the bridge on the municipal road, and will allow the diversion of around 200 l/s to benefit the Calçada and Ribeira da Telhada fields. Next to the Casal da Rola bridge (EN 342), the Casal da Rola dam will benefit the Porto de Ferro Field, deriving approximately 150 l/s from the Pranto river.

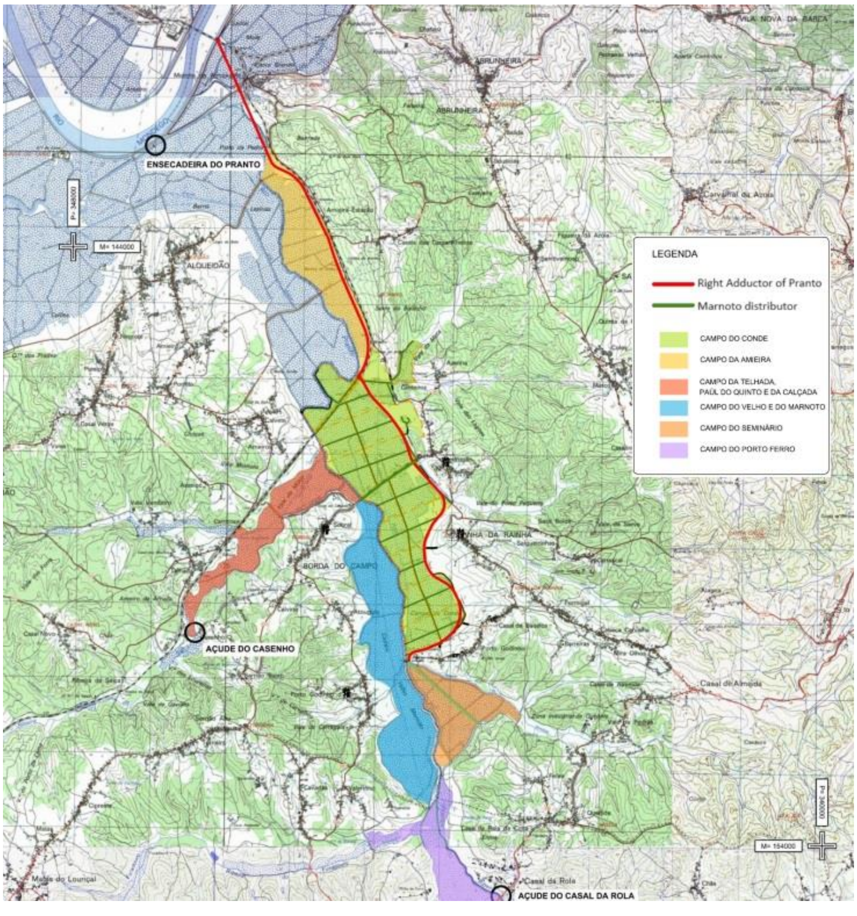

Figure 4: Project implementation.

The Pranto right pipeline begins at the T 25 water intake of the Mondego CCG, as shown in Figure 5, located near the Block of Almoxarife Mill.

5.2 Project development characterization

The characteristics of the project are presented in Table 2, namely purpose, methodology, capacity and sizing.

Table 2. Irrigation technology and sizing parameters.

Cultural occupation	Rice
Irrigation technologies	submersion or flooding
Filling the beds	April
Average filling volume	930 to 950 $m^3.ha^{-1}$
Unit flow (30 l/s module)	2 $l/s.ha^{-1}$
Flooding time, ta (15 ha block of beds)	5,5 days
Rotation between beds - flooding (bed with 4 ha)	1,5 days
Sizing flow of primary and secondary networks	2 $l/s.ha^{-1}$
Area effectively irrigated	95% of the area equipped

5.3 Characterization of benefited areas and efficiency

In order to characterize the project, the characteristics of each portion of the area surrounding the project are presented in the tables below, namely capacity and sizing aspects.

Table 3. Right Adductor of Pranto.

Benefited area	909 ha
Equipped area	851 ha
Irrigable area	808 ha
Maximum flow	1.62 m^3/s
Length	9 931 m
Material	Structured HDPE (SN4)
Diameters	1800 to 900 mm

Table 4. Distributor of Marnoto

Equipped area	286 ha
Irrigable area	271 ha
Maximum flow	0,54 m^3/s
Length	873 m
Material	Structured HDPE (SN4)
Diameters	1200 to 1000 mm

Table 5. Campo do Conde irrigation network

Benefited area	346 ha
Equipped area	301 ha
Irrigable area	286 ha
Batch numbers	255
Batch area	291,59 ha
Material	PEAD
Diameters	250 to 450 mm

Table 6. Quinta do Seminário hydraulic circuit

Benefited area	157 ha
Equipped area	148 ha
Irrigable area	140 ha
Batch numbers	25
Batch area	6,136 ha
Material	PEAD
Diameters	800 to 600 mm

The irrigation methodology used to irrigate the agricultural fields of Vale do Pranto has the particularity of not presenting water losses due to operation either at the supply/distribution level or at the plot level. All water that is not consumed (evapotranspiration from crops and direct evaporation from ditches) returns directly to the Pranto River through drainage ditches. In this way, the only loss of water in the system is limited to evaporation in the main ditches and the set of existing ditches inside irrigation blocks used simultaneously for irrigation and drainage.

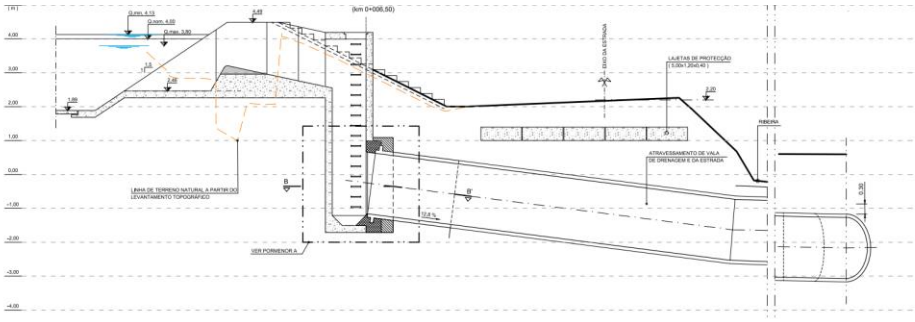

Figure 5: Detail of water intake for irrigation.

The Campo do Conde block is served by the Vala Real main ditches (about 3.8 km long) and Vala da Galegoa (about 2.1 km long) and by the internal network of ditches that total an area of around 60 ha. With the set of infrastructures for the primary and secondary network where water is transported in closed pipes, there are no losses due to evaporation, meaning the volume to be derived for irrigation will always be lower than the volume currently required. Taking as a reference the average monthly evaporation values (mm) from the Barra do Mondego Climatological Station, the average volume of water that is lost by evaporation from the surface of ditches serving the Campo do Conde block during the irrigation campaign, between April and the end of September was estimated at 0.7 hm^3, which represents around 10% of the volume of water derived from the Pranto river for irrigation of the Campo do Conde and Seminário blocks. These interventions will, therefore, achieve global efficiency in the transport and distribution network of the order from 95% to 100%, translating into an efficiency gain of between 5 and 10%. The Baixo Mondego Hydroagricultural Development benefits a total area of around 15 000 ha, so compared to the production that occurred in year 2018, according to table 1, there is a benefit of around 2.5 times more of the area dedicated to current rice production. The size and impact of this project is clear: It benefits around 53% of the total existing area in the Portuguese context dedicated to rice production, resulting in a production of 840 000 tons of rice annually.
For the purpose of measuring global impact, and for mere academic reasoning, in 2005, UN agency distributed 1 000 tons of rice to 50 000 people in five provinces of Cambodia, struggling to cope with food shortages caused by a searing drought. In the same proportion, the production of the Baixo Mondego Hydroagricultural development would be sufficient for 42 million individuals.

6 Conclusions

Water plays an essential role in the social fabric of society, being a factor that influenced the rise of civilizations, as well as their fall. Technologies play a fundamental role in the use of water, from providing the population with water to drink it to irrigating fields for agricultural purposes to respond to a growing population with needs.

Regarding the case study project, although the entire Baixo Mondego could be considered an irrigated area, before the works were carried out, irrigation took place in very poor and difficult conditions throughout the entire valley. This work, still in the construction phase, aims to regularize rivers, defend against floods, controlled drainage and irrigation in appropriate conditions. Parcelling has also been implemented in some areas of Baixo Mondego. With the implementation of this project, the largest currently at European level, it was possible to considerably increase the production of the rice harvest in Portugal, which increases competition at national level in the production capacity of this cereal, as well as its export to international markets. The potential of increasing this production was also demonstrated, as the increase in the number of doses of rice will serve to feed the population and their needs.

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