SUSTAINABILITY OF RICE PRODUCTION SYSTEMS: AGRO-ECONOMIC ANALYSIS OF *BAIXO MONDEGO* AND *LIS* IRRIGATION DISTRICTS, PORTUGAL

Fátima OLIVEIRA[1,2*], Pedro REIS[3], Sérgio OLIVEIRA[1], António JORDÃO[4], António RUSSO[5], Henrique DAMÁSIO[6], Rui EUGÉNIO[6], José PAIXÃO[5], Filipe MELO[1,2], Manuel NUNES[1], Margarida TEIXEIRA[4], Kiril BAHCEVANDZIEV[1,2], José M. GONÇALVES[1]

[1]Polytechnic of Coimbra, Coimbra, Agriculture School, Coimbra, Portugal
[2]CERNAS – Research Centre for Natural Resources, Environment and Society, Coimbra, Portugal
[3]National Institute of Agrarian and Veterinary Research, Oeiras, Portugal
[4] Regional Directorate of Agriculture and Fisheries of Center Region, Coimbra, Portugal
[5] Lower Mondego Water Users Association, Montemor-o-Velho, Portugal
[6] Lis Valley Water Users Association, Leiria, Portugal
*Corresponding author:foliveira@esac.pt

Abstract

Rice crop has an important economic and social value in Portugal, being cultivated under continuous flooding irrigation. Despite the technological advances achieved in the last decades in Portugal, such as the common use of laser precise land leveling, the problems of water management are yet frequent. To cope with the global changes and the raising social pressure to reduce water consumption and the environmental negative impacts, there is an emergent consensus to improve water saving methods and technologies, for water use efficiency and the safeguard environmental quality. A research project into solving this problem is underway. It deals with the evaluation of water saving solutions, and the assessment of agro-economic sustainability. The case studies here reported refer to Lower Mondego Valley and *Lis* Valley Irrigation District, located on Center of Portugal. These perimeters have a Mediterranean Temperate climate, with critical issues such as water scarcity, soil salinization risks, and economic sustainability. The applied methodologies consider: I) Monitoring of the water irrigation use of on-farm systems, both the traditional practices and the newly water saving techniques; II) Evaluation the effect of water saving technologies on cropping system operation; III) Development of performance indicators, to allow the comparison with other regions. The evaluation of the sustainability of rice production will use several data sources with *stakeholders* support, including data collection in field parcels, irrigation district records of crop performance, farmers' questionnaires and interviews, social acceptability, and environmental issues. This communication will present the preliminary results of referred research project, particularly farmers' socioeconomic data.

Keywords: *Rice sustainability, Rice continuous flooding, Rice water saving, Lower Mondego Valley, Lis Valley.*

Introduction

Rice is the most cultivated and the most consumed cereal in the world. Rice crops, together with Wheat and Corn, occupy more than half of the world's agricultural land and, even though rice is neither a staple food nor an important crop in Europe, it has important socio-cultural significance and environmental importance in several European Mediterranean countries. The total area of rice cultivation in the 27 member countries of the European Union (EU) is about 472 thousand hectares, the average annual rice production is about 3.1 million tons and the annual average import of rice is 1,1 million tons. In 2015, the rice-growing cultivated area of Italy and Spain together comprised around 75 % of the total area, *i.e.* around 360 thousand

hectares. (Kraehmer et al., 2017). Greece and Portugal account for around 12% of Europe's rice production (Pinto, 2015). The world's demand for milled rice can be expected to rise from 439 million tons in 2010 to 496 million tons in 2020 (World Atlas, 2019). The annual *per capita* consumption of milled rice ranges from 3.5 to 5.5 kg in non-growing countries of northern Europe to 6-18 kg in southern Europe. Portugal has the highest European *per capita* consumption of rice, which is 17 kg *per* year. This figure, no more than one tenth of the Asian average, far exceeds consumption in other European countries, including Italy (Ricepedia, 2019). To improve rice cultivation and water management, with the aim of improving their competitiveness and environmental sustainability, some Mediterranean countries have joined together in a Prima Program research project, named MEDWATERICE. It deals with the quantification of water use efficiency and environmental, economical, and social sustainability of innovative water saving irrigation options, compared to the traditional flooding irrigation practice. Alternative irrigation techniques to be tested will be selected taking considering the specific characteristics of rice production, on the basis of available data and *stakeholders'* (SHPs) knowledge. A multi-scale – multi-disciplinary and multi-actor – approach is used in the project, which goes beyond the state-of-the-art in five dimensions.

The first ground-breaking objective is methodological: the introduction of participatory action research as innovation strategy in the Mediterranean rice sector. MEDWATERICE will use participatory action research to test non-conventional irrigation-efficient methods tailored to local conditions. Secondly, the project will develop a comprehensive multidisciplinary indicators-based tool to assess the overall sustainability of rice systems at the on-farm and district scales. Production with sustainable methods have the added advantage of being people and planet-friendly and of having greater chance of success and higher prices in the market. Thirdly, MEDWATERICE will build a novel framework for computing effective water efficiency and productivity by up-scaling farm efficiency data to irrigation district scale, in order to prevent fake or rebound effects of water saving measurements. Given that constraints on rice irrigation improvements are often connected to the difficulty to monitor and control irrigation inflows and outflows, the fourth action of the project will use state-of-the-art hydraulics and sensors to monitor and support water saving management practices.

Additionally, this will be a contribution to the implementation of the EU Water Framework Directive whose requirements for all water uses measurements is clearly unfulfilled in the rice sector. Finally, the set of water-saving techniques, proven in the field and ready to be adopted, which the project will produce, is unique in the Mediterranean basin; firstly because of the innovative nature of some of the techniques and secondly because of the methodology and approach to transnational research that will give them unprecedented strength and robustness. To the best of our knowledge, none of these five dimensions have been explored exclusively in Mediterranean rice agroecosystems in order to improve irrigation efficiency and overall sustainability. The development of water management practices as an alternative to continuous flooding is imperative to enhance water use efficiency and safeguard environmental quality in Mediterranean rice agroecosystems. (Masseroni *et al.*, 2017). The agroeconomics study considers the development of a set of indicators, which in turn will allow the comparison of water saving technologies, to assess the evaluation of rice production sustainability. Data collected through farmer's surveys and interviews is analysed and processed. This project meets the recent innovation system PROAKIS (Labarthe, et al, 2014) which stipulates that innovation is set up by stakeholders, including farmers, researchers, advisers, and companies operating in the agricultural and agri-food sector.

Materials and methods

Description of case studies: Lis: Valley Irrigation District and Lower Mondego Valley

The Lis Valley Irrigation District (LVID) is a state initiative, with a total area of about 2000 ha, it is an agricultural perimeter of the Centre of Portugal, located in the municipalities of Leiria and Marinha Grande, whose irrigation and drainage system dates from to 1957. The main problems of water management in collective irrigation and drainage networks, as well as the field level, are due to the scarcity and poor water quality in the summer, flood risk and poor drainage, and incipient source of hydraulic and hydrological information to support the Lis Valley Water Users Association (ARBVL) planning and operating the network so that optimization of water productivity is achieved, and farmers' income is improved. Under the rural development program, modernization works are planned to transform water distribution networks (in sub-perimeter I, downstream), which will stimulate agricultural development. The dominant LVID soils are modern alluvial soils of high agricultural quality, some subject to poor drainage. The works present defence objectives of the fields through slope collectors, valley drainage and irrigation carried out with the application of several reservoirs from the Lis River and its tributaries (Fig. 1). The Perimeter is structured in seven hydraulic blocks designed according to the logic of the drainage network. The irrigation network comprises 17 dams and 15 pumping stations (PS), collecting water from the Lis, tributaries and drainage ditches, running by water through a gravity network with channel water conduction. The length of the primary irrigation network is 44,5 km; the secondary irrigation network consists of 180 km of small lined or earthen channels. In terms of water distribution, the most important problems are water shortage and poor water quality in the dry summer period, and the absence of automation mechanisms to control water levels in the network channels, leading to malfunctions and high labour load.

The Baixo Mondego Irrigation Scheme (Lower Mondego Valley) has an area around 12,000 hectares and is located along the Mondego River valley, from Coimbra to Figueira da Foz. It is 5 km long and 4 km wide. Only 6,538 hectares of the potential irrigated lands are equipped: the secondary Ega and Arunca valleys and Pranto and Cernache streams, on the left bank, as well as river Foja and ribeira de Ançã, on the right bank, still lack infrastructures. The water source is a dam located in Coimbra, out of which a multi-purpose canal was built (for the irrigation of the right bank). The left bank is served by a water main installed along the left stripe irrigation fields. The irrigation scheme is divided into 18 irrigation blocks and, except for São Martinho and São João block, covering 696 hectares near Coimbra, irrigation infrastructures were designed and built for gravity irrigation. The predominant crops are maize and rice, with an area of more than 90%. In the areas of the secondary valleys, these are also the dominant crops, but with greater emphasis on rice. The total number of irrigation plots is around 16,600 and the number of farmers around 2,000.

At this stage an inquiry was made, attempting to cover the different typologies of agricultural enterprise This approach allow obtained indicators that are “based on real farm conditions and represent the current agricultural management practices” and and capture significant information on impacts on agricultural systems and simplify complex concepts such as sustainability (Dantsis *et al*. 2010)

The survey was conducted in person and at the site of the farms. The survey presented four sets of questions that allow (i) socio-economic characterization of the farmer; ii) characterization of production factors use; iii) optimization of production costs and lastly the characterization of production according to its environmental sustainability, especially in relation fertilizers and pesticides use. The questions were closed, single choice or multiple choice in as many as two possible choices. It attempted to evaluate the degree of satisfaction with the options taken in relation to certification mechanisms and commercialization channels. The concern with agrienvironmental issues was also evaluated. Some results are present in this paper.

Results and discussion

The survey was carried out in June 2019 in the *Mondego* Valley with a total of 34 surveys (20% of rice farmers in the Mondego Valley). These farmers hold 767 hectares (42% of the total rice area in the Mondego Valley). SPSS 25 software was used to analyse the data. The correlation between the coefficient of Pearson (r) and Spearman's coefficient (ró) was used to measure the strength of the association between the variables. According to the production area three farmer/producer classes may be considered. (Table 1)

Table 1 – Categorization of sample and farmers population in relation to production areas

Hectares	Farmers Survey		Rice Farmer		representative sample
	Number	%	Number	%	%
≤6,30	5	14.7	103	14.7	4.9
≥6.31 and ≤ 22,60	16	47.1	52	47.1	30,8
≥22,61 –and ≤ 38,80	5	23.5	8	23.5	62.5
≥38.81	5	14.7	11	14.7	45.5
Total	34	100	174	100	19.5

The study carried out with rice producers, has showed 82.4% of the interviewees are full-time farmers, 2.9% are part-time farmers and 14.7% are retirees from farming or other economic activities. Around 32.4% of the respondents are between 20 and 40 years old and 26,6% are over 60 years old; 62% had access up to the ninth year of schooling, while 26,5% have a higher education degree All farmers apply integrated production methods. When compared to national results, these values are better in terms of both farmers' age and at educational level. National average show 71.4% of the farmers hold basic education and only 5.8% possess higher education; in terms of age at national level, 54.6% are ≥65 years old (INE, 2017). There was a weak correlation which is significant at 5% or 1% of level of significance between the relevance of the agricultural activity and farmers educational level and age. For younger farmers, agriculture becomes more important as a main activity; they have a higher education level, but there is no correlation between the characteristics of the farmer and the size of the farm. Access to land is an important issue for generational turnover (Table 2).

Table 2 – Socioeconomic correlation between economic variables

	Education Level		Age Class		Size famer (há)	
	Spearman (rô)	Pearson (r)	Spearman (rô)	Pearson (r)	Spearman (rô)	Pearson (r)
Farmer relevance activity	-,364*	-,350*	,517**	,569**	-0,013	0,036
Sig. Level	*0,034*	*0,043*	*0,002*	*0,000*	*0,942*	*0,840*
Education Level			-,748**	-,720**	0,088	0,067
Sig. Level			*0,000*	*0,000*	0,622	0,705
Age Class	-0,748	-0,720			0,027	0,076
Sig. Level	*0,000*	*0,000*			*0,880*	*0,669*
Size famer (ha)	0,088	0,067	0,027	0,076		
Sig. Level	*0,622*	*0,705*	*0,880*	*0,669*		

* significance level of 5% (p=0,05); ** significance level of 1% (p=0,01

About 77% of the surveyed area is occupied by Carolino rice (Oryza L, subspecies Japónica), Ariete cultivar. Although the European Commission recognized the name "Arroz Carolino do Baixo Mondego" as a Protected Geographical Indication (PGI) in 2015, none of the respondents stated having the PGI certification. All respondents applied for agricultural support (within the Rural Development Program), over the past ten years. There were three measures respondents did not apply to. Applicants degree of satisfaction concerning the results of the

applications and their development is high and they feel satisfied or more than satisfied with the progress of the measures on their farms (Table 3)

Table 3 – Application for RDP measures over the past ten years and satisfaction degree

	Advice Service	Modernization	Greening	Organic farm	Integrated farm	Diversification	Marketing and processing	Young Farmer	Basic payment include rice grant
Application	33	7	34	0	31	0	0	8	33
% in total survey	97%	21%	100%	0%	91%	0%	0%	24%	97%
	Satisfaction degree in percentage for each application support (% in total of applications)								
Partly Satisfied	9,1								3,0
Satisfied	66,7	28,6	38,2		32,3			12,5	42,4
More than Satisfied	21,2	71,4	44,1		48,4			75,0	42,4
Very Satisfied	3,0		17,6		19,4			12,5	12,1

All respondents want to continue farming in the next two years. Respondents could choose at most two main reasons for continuing agricultural activity. Economic viability and family income complement represented 24.3% of the responses, respectively, but 21.6% answered that agricultural activity would continue because of the lack of economic alternatives. Concerning rice cultivation, only one respondent (2.7%) answered he does not intend to keep producing rice because of the lack of economic viability of the crop. About 89,2% want to continue producing rice, and 45.5% said they keep growing this crop because alternative uses for their land are not available. About 24.2% consider that knowledge of the crop characteristics was an important factor to continue growing rice and 21.2% consider that rice economic viability justifies the option to go on growing rice. Considering marketing channels used by farmers, only one farmer sells 80% of his products to retail, under his own brand name, and the remaining 20% are sold to industry. About 59% of the farmers sell their yield directly to industry, and about 29% sell their production to the Montemor-o-Velho Cooperative. Only three producers use two marketing channels simultaneously. Thirty-two respondents (94%) answered the question concerning the commercialization channel which allowed the choice of two options, having provided 55 responses. About 22% of the respondents have chosen a marketing channel due to "production flow ease", and 20% have done it because they have no processing capability. About 16% have chosen the option "guarantee production output", and 15% have chosen "price stability". The options "best price" and "fastest payment" have been chosen by 13% and 11% of the respondents, respectively. Only two interviewees (4%) have chosen the channel because of the support given to production. These preliminary results of the survey demonstrate that rice cultivation is done by farmers with both knowledge in the area and skills to use community and national support measures. More data have been obtained to allow the development of socio-economic and quantifiable indicators of the environmental sustainability of agriculture (Reytar *et a-l*, 2014). Studies are being conducted in different areas of the world to study alternatives to rice production systems with the aim of increasing productivity, net income and at the same time reduce environmental impacts (Sita and Ponnarasi, 2009**)**. The sixth task, fundamental to deal with knowledge transfer and innovation, is being carried out.

Conclusions

Among the numerous problems Mediterranean rice agroecosystems are currently facing, sustainability is of utmost importance and a great challenge. Due to drivers such as climate

change, population growth, increasing concern of civil society towards environmental impacts of human activities, there is pressure on the rice production sector to reduce water consumption and minimise environmental impacts (OECD, 1993). At the same time, rice is a strategic production for food security, a nutritional alternative to wheat, and an important economic exchange-earning agricultural product. Therefore, there is great pressure to increase rice production within the Mediterranean basin, but these pressures have not changed much the state of rice production yet; continuous flooding is still predominant. So far, results have shown a dynamic sector in need of options to deal with new challenges, such as consumer perception of water use in agriculture and profitability increase generated by inputs efficiency boosting. The interest of this project is observable in the support farmers and Water Users Association have provided to the development of the work, which is a key indicator of the need for applied research to the business sector in which it operates.

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