Chapter 14

Sustainability of Rice Production at Baixo Mondego, Portugal:
Drivers, Risks, and System Improvements

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ABSTRACT

This chapter aims to analyze the rice production system at the Baixo Mondego Valley to understand the main concerns. Field research and field trials were carried out to analyze rice production, marketing systems, and different irrigation alternatives. An analysis on the worries was made, and a correlational attempt was done. The results show a production system oriented by agri-environmental policies. The problems related with rice irrigation are water scarcity, environmental impacts on water quality, agro-ecosystems, and methane emissions. To reduce water demand, the alternate wetting and drying flooding method, and the improvement of the precise land levelling were studied on the scope of MEDWATERICE Project. About 12-14% of water saving was observed, with impact on production lower than 3.5%, allowing period of 11-19 days of dry soil, expecting positive implications for greenhouse gas emissions. Innovation in the irrigation system may help to reduce some of the farmers' concerns and help to better adapt this crop to the new needs of agriculture in terms of environmental competitiveness.

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INTRODUCTION

Agricultural Risks

The agricultural business always involves risks associated with the nature of its production, since it is prone to climatic and biotic factors (climate, soil, and pests). In addition to issues related to agricultural production, the agricultural enterprise also must address market issues, such as price volatility, labor issues, seasonality, and changes in agri-food policies. According to literature, research on risk, risk perception and risk management strategies are increasingly analyzed. Climate change, globalization of markets and different consumer perceptions of food safety have raised concerns about risk.

Duong *et al*. (2019) carried out a systematic review of the literature and concluded that the amount of research on risk perception in agriculture and risk management has increased substantially since 1985. The author states that market risk is considered as the most significant followed by biosecurity, which highlights the gaps between the risks mentioned by farmers and the research on socioeconomic factors that explain the perception of worries. However, there are papers discussing both risks and adaptation strategies (Crane *et al.*, 2013; Ahsan & Roth, 2010; Harwood *et al*., 1999).

Girdžiūtė (2012) and Komarek *et al*. (2020) examine the risks in agriculture and identify that research work focuses on one risk, particularly on production risk, and that there are a limited number of studies exploring the various sources of risk, also showing the importance of risk assessment methods and the importance of studying the interrelationship and interaction between risks. The results of this work show that different types of risk are relevant at different levels and that it is necessary to interconnect risks to understand risk relevance to farmers who must struggle with many risk causes, from natural risks to economic ones (price volatility or flow production).

Market issues are the most important areas of concern followed by biosecurity which is defined by Waage & Mumford (2008) as:

means the protection of countries against alien pests (insects, vertebrates, etc.) and diseases. (p. 863).

There are other risks, such as climate risk, financial risk, governing restraints, and new technologies. Crane et al., (2013) defines risk as the chance of damage or a negative outcome linked to an action and uncertainty falls within these definitions. Harwood *et al*. (1999) reveals that risk affects an individual's welfare and is linked with loss. Risk perception influences farmers behavior and future business decisions such as the continuation in the market. Risk perception and behavior are linked with the resilience of the agricultural sector itself. According to Keil *et al*. (2000) loss level is the most important factor in shaping risk perception, and there is a significant relationship between risk perception and decision making. Sjöberg (1998) says that cultural biases are not major factors in risk perception and the variability within the public in a country is probably due to factors such as trust, beliefs, and human concepts.

Risk perception encompasses the mental processing of information and the skill mechanisms that people use to deal with uncertain events. In addition to definition issues and risk perception, one of the issues in literature is risk categorization. Literature presents different risk categories according to the sector and within agriculture. Categorization varies according to the subject matter focused by the researcher.

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Crane *et al*., (2013) and Harwood *et al*., (1999) identified production, marketing, economics, human resources, and the respective legal framework as the main five risk sources. According to Hardaker *et al*. (1997) business risks are those affecting farm business performance such as production, market, institutional and personal risks, and financial risks, connected to the company's financing. The OECD (2009) uses a holistic approach that identifies three risk layers requiring different responses, and this categorization is linked with risk management. The first layer concerns the normal variation in production, process, and weather; it does not require policy reply, and can be managed by farmers as business strategy. The second layer is marketable risk which can be handled through market tools. The third layer, considered as of low probability but reaching catastrophic levels, leads to high and irreversible losses affecting many or all farmers. Under these circumstances, resilience is beyond farmers or markets, and government intervention may be required. In the first layer, risk probability is high, and losses are low, the second layer covers low frequency risk and medium losses; finally, the third layer includes very low frequency, causing very high losses and requiring risk mitigation and risk transfer (Tedesco, 2017).

RICE PRODUCTION

Rice is the world's most important food crop as it is a staple food for more than half of the world's population and the world demand for rice will increase by approximately 24% over the next 20 years (Nguyen & Ferrero, 2012). Rice is cultivated over about 1.3 Mha in Mediterranean countries (FAOSTAT, 2016). Although in the Mediterranean region it is concentrated in specific areas, rice production has great socio-economic and environmental importance. Since it is a fundamental staple food for some countries due to its high quality, and to its role in preserving biodiversity (many important rice areas are in river deltas, estuaries, coastal wetlands or are part of protected ecosystems such as the EU Natura-2000 network). The most important rice-producing countries in the Mediterranean region are Italy and Spain in Europe (72% of the EU production; 345,000 ha), and Egypt and Turkey among the non-EU countries (practically all the production; 789,000 ha).

Traditionally, rice is grown in paddies flooded from pre-sowing to pre-harvest, thus requiring much more irrigation water than non-ponded crops (Cesari *et al*., 2016). This practice is highly water demanding, in comparison with most methods applied in irrigation of other crops, due to significant deep percolation, and the need for surface drainage of water from the basin. The main problems related with continuous flooding refer to water scarcity, environmental impacts on water quality and agroecosystems, and soil methane emissions into the atmosphere (Katoh *et al*., 2004). Rice paddies are one of the most important sources of atmospheric methane (CH4), producing about 5-20% of the total emission from anthropogenic sources (USEPA, 2006) and approximately 30% of global agriculture CH4 emissions. Moreover, many important rice growing areas in the Mediterranean region are in environments where soil salinity is an important constraining production factor.

Although the common use of laser land leveling has allowed a significant reduction of water use, there are still common water management problems to deal with, to face climate global changes and the raising of social emergent consensus. The issue of rice irrigation water saving is challenging and intensively studied, demonstrating several irrigation management systems, such as zero-grade fields, alternate wetting and drying, multiple-inlet, furrow, pivot irrigation and drip irrigation (Datta *et al*., 2017; Vories, 2017).

Mediterranean rice agroecosystems are nowadays facing numerous problems, such as the need to match irrigation demand with the availability of the resource, environmental protection, the need to ensure an adequate income for rice producers, the impossibility of introducing the crop in farmlands characterized by limited water availability despite the increase of rice consumption in the Mediterranean basin, and the lack of specific studies conducted in Mediterranean countries addressing environmental and socio-economic peculiarities of these areas. Due to these problems, the introduction of water management practices alternative to continuous flooding is imperative to enhance water use efficiency and safeguard environmental quality in Mediterranean rice agroecosystems.

Rice Crop in Portugal

Rice was introduced by the Arabs in southern Iberian Peninsula in the eighth century. Thus, rice growing was a key factor in the economic development of originally very underprivileged areas and for the emergence of social and cultural traditions contributing to the reputation of these regions still today. In 2020, rice accounted for about 830 thousand hectares in the 27 countries of the European Union (EU) with an average annual production of 3.4 million tons (Agri-Food Data Portal, 2021), and in 2019/2020 market year the EU import 1.4 million tons of rice (EU, 2021). Today, rice cultivation plays an essential role in maintaining the ecological balance and biological wealth of the ecosystems mentioned above.

The rice value chain begins with the production of paddy rice, which can be dried either on the farm, on the cooperative (farmers' associations) or by the industry. In both cooperative and industrial facilities, dry paddy rice is subject to husking, bleaching, polishing, and packaging. Imported rice may be imported as paddy rice for the rice industry or already packed for final consumption.

Rice plays a role of great social and economic importance in Portugal. We must bear in mind that rice cultivation occupies areas that could not or could hardly be allocated to other productions, thus playing an important role in the conservation of these specific ecosystems. Due to cultural issues rice is of utmost important in the Portuguese diet.

The rice producer is entitled to the Basic Payment Scheme (BPS) of the Common Agricultural Policy (CAP) whose payments are allocated to land rights. Rice production also benefits from voluntary coupled support (VCS). VCS is applied voluntarily by Member States to support certain sectors or types of agriculture facing difficulties and that are economically, socially, or environmentally significant. This support has two goals: to ensure a stable supply to the local processing industry, enabling it to maintain a certain level of production and to avoid disruptive situations in the sector leading to the abandonment of the activity. In Portugal the VCS grant for rice is 194€/hectares (ha) *per* year. The support given to integrated rice production amounts to around 376 €/hectare (ha) for areas under 30 ha and 75 € for areas over 120 ha (Table 1). In the *Baixo Mondego* Valley (case study), a significant part of rice production done is an integrated production system. In some cases, farmers can apply to *Greening* measures, but the set of supports may not exceed 600 €/hectare.

Table 1. Support amounts per hectare per year

Hectares	30 ha	> 30 and ≤ 60 ha	> 60 and ≤ 120 ha	> 120 ha
Grant (Euros)	376	301	188	75

Source: (https://www.ifap.pt/, accessed in 20/10/2020)

Portuguese rice growers are involved in the Integrated Production System for sustainable production, in compliance with agri-environmental CAP measures. To accomplish this measure, farmers are required to use 120 kilograms of selected and certified rice per hectare of cultivated area. Depending on seed availability of *Carolino* rice in international and domestic markets, the Government may alter the quantity of seed to be used.

Table 2 shows the evolution occurred between 2004 and 2018 (triannual average). It is worth noting that Portuguese exports increased more than imports, which led to an improvement in the trade balance. The national representativeness of *Beira Litoral* rice (Mondego representing the main area of production) decreased both in terms of relative area and production, despite the increase of rice production. In 2004/2006, the *Beira Litoral* region accounted for about 27% of the surface area (6,617 ha) and 23% of production (31,723 tons). In 2016/2018, these numbers fell to 22% (6,359 ha) in surface area and to 19% in production (32,186 tons). Rice productivity in Portugal has slightly increased from 5.7 tons/ha in 2004/2006 to 5.8 tons/ha in 2016/2018. In *Beira Litoral*, the productivity was lower but the increase in the analyzed period was higher than the national average; it rose from 4.7 in 2004/2006 to 5.1 tons/ha in 2016/2018 (INE, several years).

Table 2. Variables of rice production and portuguese milled and semi milled rice market

Average	**Rice Surface**	**Rice Prod.**	**Yield**	**Market of milled and semi-milled rice**					
	1,000 Ha	1,000 Tons	Tons/ha	Prod.	Imp.	Exp.	Human Consumption	Consumption *per capita*	Degree self-sufficiency
				1,000 tons				kg *per capita*	%
2004- 2006	24	139	5.7	157	21	5	166	15.8	92
2010-2012	31	180	5.9	164	14	8	169	16.0	96
2016-2018	29	170	5.8	173	26	45	156	15.2	109
Annual Average Growth Rate	2%	2%	0%	1%	2%	20%	-1%	0%	1%
Growth Rate	20%	22%	2%	10%	20%	800%	-6%	-4%	19%

Note: Annual Average Growth Rate and Growth Rate between 2004/06-2016/18).
Source: (INE, several years)

Objectives

The aim of this paper is to provide empirical analyses of how farmers grow rice in the *Baixo*-Mondego Valley in Portugal, how they prioritize their concerns, how they relate their concerns with risk perception, and how these concerns interact with rice production systems and sociodemographic characteristics. The focus was not to directly address the idea of risk, but rather on worries or concerns. In OECD (2019), the word "worries" was used instead of "risk" and "concerns" words was also applied in Sjoberg's work (Sjöberg, 1998) to avoid manipulating the dialog.

Medwaterice project (prima-section 2-2018; www.medwaterice.org) is studying these problems aiming to explore the sustainability of innovative rice irrigation methods and technologies in the mediterranean basin, to reduce rice water use and environmental impacts, and to extend rice cultivation outside traditional paddy areas to meet growing demand. Studies are carried out at the farm scale, including the *baixo* mondego valley, to support the selection of the most appropriate irrigation management options to be tested and demonstrated. In turn, data collected at the farm scale is upscaled at the irrigation district level to support management and policy making decisions.

METHODOLOGY

Baixo-Mondego Valley Scheme

Field work was performed at the *Baixo* Mondego Valley (Lower Mondego Valley), located in the Beira Litoral region, covering an area of about 12,000 hectares down river. Water used for irrigation comes from a weir on the Mondego river located in Coimbra city. The concrete embankment along the river is a multipurpose canal and the left bank is served by a pipeline installed along the irrigation fields. In the main valley, the predominant crops are maize and rice, occupying more than 90% of the area. In the tributary valleys, these are also the leading crops, but rice keeps the top position.

In the Baixo Mondego Valley, rice cultivation started in the second half of the 18th century and was done by the Coimbra friars in swamp areas. Rice was a marginal crop until the 19th century but during the 19th and 20th centuries was supported by the state, which allowed higher producer prices while consumption was bound to urban areas. However, the culture was negatively seen at different times, because of the effects land flooding, required by cultivation, had on the populations, notably the emergence of diseases such as malaria. With the help of technology and soil drainage, the negative effects have diminished, and rice cultivation has become an important income source for local populations. Moreover, rice became part of the gastronomic culture and rice fields modelled part of the Mondego heritage.

Rice Farmers Survey

A survey was conducted to grasp the full range of farming enterprises typology. This methodology provided indicators to address the actual farm conditions and represents current agronomic managing practices as noted by Dantsis *et al.* (2010). The survey was conducted in person, face to face, at the farms site. The questionnaire was divided into four groups of questions designed to provide information about:

1. the farmers' socioeconomic profile,
2. agricultural cultural practices and its production inputs,
3. production costs optimization,
4. production mode according to its environmental sustainability, mainly related with the application of fertilizers and phytopharmaceuticals.

The questions presented were closed single or multiple-choice questions with a maximum of two possible choices.

To assess the degree of fulfillment in relation to certification instruments, policy support and marketing channels, an analysis of the degree of satisfaction was done. The five points of the Likert scale were used (Vagias, 2006) to perform the satisfaction analysis. According to Hardaker *et al*. (1997) the source of risk may be production, human or personal, financial, and business risks. Chartier *et al*. (2019) conduct risk analysis *per* type of risk classified as: price output, yield and income risks, environmental and climate risk, animal, and plant health and the financial, institutional, legal and policy risks. In the current analysis, the categorization of Crane *et al*. (2013) which considers marketing risk (price and market channel) the production risk (production costs and yield risks) and legal and financial risks was used.

The Chartier *et al*. (2019) categorization, namely environmental risks perceptions were also considered.

Nonparametric correlations the Spearman coefficient (rho) were applied, using the SPSS 25 software. For the Regression analysis the SPSS 25 and STATA15 software were used.

The 34 validated surveys were carried out in June 2019 at the central region of the *Baixo-Mondego* Valley. The 34 questionnaires represent 20% of rice farmers at this location (table 3). The interviewed farmers were chosen by opportunity due to the difficulty to have personal contacts within their available time. To determine the sample size, Taro Yamane formula (Yamane, 1973) was applied:

$n = \mathrm{N}/[1+\mathrm{N}(e^2)]$ (1)

where, n: sample size; N: population size; and *e:* acceptable error.

Alternate Wetting and Drying Flooding Irrigation

Alternate wetting and drying (AWD) consists of intermittent flooding, through a sequence of irrigation cycles with flooding for a certain period, followed by an interruption of supply, until the soil dries up, creating conditions of non-saturation in the surface layer (Tuong & Bouman, 2003). In this way, the volume of water used to irrigation is reduced, compared to continuous flooding (CF), as well as the reduction of greenhouse gas emissions (Runkle *et al.*, 2019) and lower arsenic accumulation in the grain (Linquist *et al*., 2019), due to soil aeration conditions during non-saturation periods. AWD has been successfully used in several countries, such as India (Jalindar *et al*., 2019), the Philippines (Lampayan *et al*., 2015), and the Mi-South of USA (Reba & Massey, 2020).

The experimental farm scale plots were in Montemor-o-Velho (Bico da Barca) and Quinta do Canal, with the work carried out in 2020, on the scope of MEDWATERICE Project. In each location, two parts were considered, to evaluate the practices of CF and AWD. The measurements and evaluations carried out in these plots allowed daily data according to the following procedure: irrigation and drainage flows, by spillways or volumetric counters; stored surface water through water pipes, equipped with automatic level sensors; evaporation from free water, based on a class A evaporimeter can; reference evapotranspiration, by the Penman-Monteith method, based on data from a local meteorological station; cultural evapotranspiration (ETc) through the cultural coefficients 1.25, in flooded soil, and 1.0 to 1.10, in dry soil; deep percolation determined by the method of hydrological balance in the site, applying the previous data. Conventional cultivation techniques were used in soil preparation fertilization, and health control operations. Ariete was the selected crop variety and to assess productivity, samples of the crop were collected at representative points

The AWD essay applied the following procedure based on Bouman *et al*. (2007) and Gonçalves *et al.* (2021), with the adjustments to local agronomic practices:

1. Initial flooding allowing wet sowing, like the traditional practice (follows an initial drying event to favor the emergence),
2. Shallow ponding during the vegetative phase, considering the drying periods required for herbicide application, usually twice, with particular attention during the flowering period because it is very sensitive to water stress,
3. AWD technique during all stages after flowering, until last irrigation; the target was a flood water depth not higher than 5-7 cm; the irrigation schedule considered was an interval between 10 to 14 days of irrigation events; ensuring that the water level should not fall to 15 cm below the soil surface, measured in a water tube,
4. The last irrigation should be about 20 days before the harvest.

OUTCOMES

Characterization of the Lower Mondego Farmer Sample

Due to the high number of very small agricultural properties and the heterogeneity of properties in terms of cultivated area and the importance of properties with medium or large size as decision makers in the rice chain and in production systems, the cultivated area was adopted as a basis of the sample size. If we apply as the population size the number of hectares of rice cultivated area, and for an acceptable error of 5%, the sample size will be 328 hectares. ´

The sample size is displayed in table 3. The surveyed farm holders own 764 hectares (representing about 42% of the rice-cultivated area in the lower Mondego valley), that is, the sample is larger than the minimum required. The decision to use all the data obtained in the research fieldwork allows a better image of the production systems and avoids data loss. Four categories were considered according to the production area (Table 3).

Table 3. Sample categories and number of producer's holders according to production areas

Hectares	Farmers Survey		Rice Farmer		Representative sample
	Number	%	Number	%	%
≤6.30	5	14.7	103	59.2	4.9
≥6.31 and ≤ 22.60	16	47.1	52	9.2	30.8
≥22,61 and ≤ 38.80	5	23.5	8	4.6	62.5
≥38.81	5	14.7	11	6.3	45.5
Total	34	100	174	100	19.5

Source: Oliveira et al. (2019:1215)

The study conducted with rice farmers shows that 82.4% of respondents are full-time farmers, 2.9% are part-time farmers and 14.7% are agricultural pensioners. About 32.4% of respondents: are between the ages of 20 and 40; 26.6% are older than 60 years old. Approximately 62% of the interviewees have nine years of schooling and 26.5% of the respondents have university-level education. When compared to national results, these figures are higher in terms of both the farmers' age and educational level. The average literacy level in Portugal shows that 46.3% of farmers have elementary education and only 8.0% attended university on a nonagricultural sector and 1.3% attends university on the agricultural sector. In terms of age group, about 52.5% of Portuguese farmers are over 65 years (INE, 2021).

All farmers apply integrated production systems. A weak correlation was identified (significant at 5% and 1% level of significance), between the importance of agricultural activity in the farmer's professional life (full-time; part-time, retirees) and farmer's level of education and age, respectively. In the case of young rice producers, agriculture is their main activity compared to the other age groups. At the same time, young producers hold higher education degrees. No correlation between the farmer's characteristics and the size of the farm they manage was found. The farmers' education level is positively related with the turnover generation level (Table 4).

Table 4. Socioeconomic correlation between economic variables (Spearman coefficient)

Variables	Education Level	Age Class	Size famer Category (ha)
Farmer relevance activity	-.364*	.517**	-.013
Sig. Level	*.034*	*.002*	*.942*
Education Level	-	-.748**	.088
Sig. Level	-	*.000*	*.622*
Age Class	-.748**	-	.027
Sig. Level	*.000*	-	*.880*
Size famer Category (ha)	.088	.027	-
Sig. Level	*.622*	*.880*	-

Note: * significance level of 5% (p=0.05); ** significance level of 1% (p=0.01)

The *Carolino* rice variety, *Ariete*, (Oryza sativa L. subspecies Japonica), represents approximately 77% of the rice cultivated area (considering the area analyzed in this work). About 56% of the farmers produce one only rice variety, 19% grow two varieties and 6% produce more than two rice varieties. Variety diversification can reduce the production risk. Around 91%, produce *Carolino Ariete*, followed by *Euro* and *Opale* varieties.

Fixed Assets and Costs

In agriculture, fixed assets refer to farmers' technical equipment. The fixed assets to total assets ratio are the main factor distinguishing farms. Farmers' competitiveness depends on the use of technical capacity. Property, plants, and equipment are the physical and technical basis of production capacity. An analysis of a farmer's ability to invest in equipment and his dependence on equipment from others can explain and help understanding the farmer´s notion or perception of risk in relation to long-term production or investment. All respondents own their tractors (88% respondents have three or four tractors) which are used with different types of equipment needed for rice cultivation. In general, most farmers own their equipment (Table 5).

Table 5. Owner of fixed assets

	Plowing and harrowing		Levelling land Machine		Rice Seed Sowing Machine		Pulverizer		Rice Harvester Machine	
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Owner	34	100	30	88.2	31	91.2	32	94.1	28	82.4
Rent	0	0	4	11.8	3	8.8	2	5.9	6	17.6

Only two farmers rent rice dryers and only one owns peeling and bleaching equipment. Land ownership may be important for risk perception. Not knowing if land may be accessed in the future may be a concern, because some lands are rent. All respondents are landowners, but about 47% also use leased land. When controlling weeds, plagues and diseases farmers are subject to integrated production rules regarding the quantity and quality of herbicides and pesticides applied. All farmers claim to apply herbicide one to four times. Regarding other pesticide uses (insecticides and fungicides), the number of applications is less frequent: 5.9% do not apply, 50% apply once and 44% apply twice.

Production costs are the most important variable on farm profitability, and they can affect risk perception. Production risk involves both the quantity and the quality of the output, as noted by Chartier *et al*. (2017).

The relationship between farm income and underlying factors such as yields, and prices is not as straightforward as one might think. (p. 28).

Income variability depends on the correlation between price and income risks, the farm's cost structure (fixed and variable costs) and specially the variable costs that constitute the activity's crop account and bring up to date the farmer´s efficiency and even their ability to support themselves and the risk awareness brought to family life by their activity. Duong *et al*. (2019) include in production risks: climate problems, biosecurity, technology change and yields; and Komarek *et al.* (2020) refer that literature focus on production risks is understandable.

Production risks arise from natural processes and are connected to climate variability and to pests and diseases outbreaks. Other yield limiting factors, also acting as production risks, (e.g., excessive heavy metals in the soil or soil salinity) are very important factors in rice crop. It is important to know the cost system of rice production since it depends a lot on climate variability and other factors such as weed and pest emergence.

Respondents were asked about rice production and processing costs in the last three years. Taxes, interest, amortization of fixed assets and certification costs were not included. It is important to note that water costs include a fixed component (conservation fees) and a variable component of water use, that is, exploitation fees (0.00262 €/m^3; one hectare uses about 16,390 m^3 of water).

Table 6 shows that five variables represent 70.4% of rice production costs. To understand the relationship between costs and the production costs for the rice activity a regression analysis was performed.

The method of Ordinary Least Squares (OLS*)* was applied. The presence of multicollinearity, heteroscedasticity, and residual autocorrelation tests (Durbin-Watson) was searched for. The heteroscedasticity test was performed by analyzing regression residues in SPSS25 and later confirmed by regression performed by STATA15. According to table 6, we can safely conclude that there is no collinearity and the absence of multicollinearity since the *Tolerance* (Tol.) is greater than 0.1 and the *Variance Inflation Factor* (VIF) is less than 10.

Table 6. OLS regression and weight of costs components in costs rice production

OLS Regression (exogenous variable: Costs for Rice production; Euros/hectare). Endogenous Variables. Costs in Euros/hectare; The variables Surface are in hectares and Production are in tonnes						Costs (Euros/ha)			
Explanatory Variables	**Beta**	***t*-test**	***p*-value**	**Tol.**	**VIF**	**Costs**	**Average**	**Std Desv**	**Weight**
Intercept	6857	1.22	.24			Total	1731.3	299,7	100%
Costs Labor	.23	1.65	.11	.18	5.60	Labor	287.0	116.1	16.6%
Costs Herbicides	.23	2.59	.02	.43	2.32	Herbicides	305.9	54.8	17.7%
Costs Fungicide/ insecticide	.12	1.39	.18	.46	2.16	Fungicides/ insecticides	111.4	52.7	6.4%
Costs Seeds	.20	2.49	.02	.50	1.98	Seeds	191.1	24.3	11.0%
Costs Machine & fuel	.20	2.13	.05	.39	2.56	Machines & fuel	225.0	43.1	13.0%
Costs Fertilizers	19	2.21	.04	.46	2.16	Fertilizers	209.9	55.8	12.1%
Costs Land Rent	.59	7.84	.00	.58	1.71	Rent	188.4	193.0	10.9%
Costs Insurance	.01	0.07	.95	.44	2.29	Insurance	2.7	1.2	0.2%
Costs Water/ Irrigation	-.10	-1.20	.24	.48	2.09	Water/ Irrigation	88.1	0.3	5.1%
Costs Dryer Rice	.19	2.25	.04	.45	2.25	Rice dryer	117.6	46.5	6.8%
Costs Peeler/ Bleaching	.34	2.85	.01	.24	4.15	Peeler/ Bleaching	4.4	25.5	0.3%
Surface	-.43	-3.32	.00	.20	5.07				
Production	. 45	4.22	.00	.30	3.39				
Adj R^2 = .889	F(13, 20) = 21.50					Breusch-Pagan chi2(1) = .00			
Durbin-Watson = 1.890	Prob > F = .00					Prob > chi2 =.98			

The production and area variables introduced and improved the value of the Durbin-Watson statistic (DW). According to DW test, we can reject the *autocorrelation* in residuals. The model is fit and explains the independent variable (Table 6).

Production is negatively correlated with costs, that is, the higher the production, the lower the costs and the larger the cultivated area the higher the costs. The rental cost variable is significant and has the highest partial regression coefficient (the increase of one unit in the rent costs implies an increase of 0.59 units in the total production costs).

Labor costs represent 16.6% of the total cost, although, according to regression, this variable does not help explaining production costs. It is interesting to note that the weight of each component of total costs is not directly related to the weight of this component in explaining the costs of producing rice. It is important to emphasize that despite the questions about total costs of rice production and the costs per cost component in rice production have been carried out in different parts of the questionnaire, there were no significant differences between the total costs calculated by component and the total production costs indicated by the interviewees. This means that farmers have a good perception of both the costs *per* cost component and the rice activity cost as a whole.

We checked whether there is a correlation between cost components and education level, age group and activity relevance to farmers. To measure the degree of association between variables we can apply for different criterions. For Cohen (1988), rho coefficient between between 0.10 and 0.29 represent a small relationship; between 0.30 and 0.49 are moderate; values between 0.50 and 1.0 signified a large association. However, other authors such as Pestana & Gageiro (2014) point to a slightly different classification. For Pestana & Gageiro (2014), values of $|rho|<0.20$ represent a very weak association; $0.2 \leq |rho| < 0.4$ weak; $0.4\leq |rho|<0.7$ moderate; $0.7\leq |rho|<0.9$ higher and values of $|rho| \geq 0.9$ very high association. According to Pestana & Gagueiro (2014) differences between the scales.is due to the domain of science in which this classification is applied. For this work, we will apply the classification of Jacob Cohen (1988).There is a large negative relationship, significant at the 0.05 level between herbicide costs and farmer relevance to activity (Spearman's coefficient: rho = -0.525; p-value = 0.001).

Channel Marketing

Market risk is considered in literature as the most significant risk and is related to the market process, price volatility and the marketing channel efficiency. Hardaker *et al*. (1997) refers that output prices matter but so do inputs prices, and Harwood *et al*. (1999) gives greater importance to price aspects, output price, inputs prices, the vertical integration and market contracts as well.

Market risks are related to the possibility of market loss or revenue loss due to a lower price than expected. Lower sales and lower prices caused by the increasing numbers of competing producers or by consumers' preference changes are common sources of market risk. Market risks can also arise from the loss of market access due to the loss of one element of the value chain, either the cooperative or the industry capable of turning rice into a finished product. To analyze market behavior, respondents were asked about the channel to market used to sell their rice, the reason for their choice and their degree of satisfaction.

With respect to processing capacity, only one interviewee is able to transform and sell under his own brand. All other respondents depend on either the cooperative or the industry for processing paddy rice. Considering the channels to market, one of the farmers sells 80% of his yield for retail, a unique case only possible because he has his own brand. The remaining 20% are sold to industry. About 20 of the rice farmers (59% of the respondents) sell all their harvest straight to manufacturing and 11 (32%) of the interviewees sell their entire crop to the Cooperative of *Montemor-o-Velho*. There are currently three cooperatives in Portugal's Center Region capable of processing paddy rice. Only three producers use two channels to market simultaneously. The degree of satisfaction is higher for the industry then to the cooperative and it has been noticed that they are satisfied (average value: 2,93) with the channel to market used (Table 7).

Table 7. Degree channel to market satisfaction

Point	Level of satisfaction	Industry		Cooperative Montemor-o-Velho		Retail with Brand		Total	
		Nº	%	Nº	%	Nº	%	Nº	%
1	Not at all satisfied	1	4.3	0	0	0	0	1	2.7
2	Slightly satisfied	4	17.4	6	46.2	0	0	10	27.0
3	Satisfied	10	43.5	5	38.5	0	0	15	40.5
4	Very satisfied	8	34.8	2	15.4	1	100	10	27.0
5	Extremely satisfied	0	0	0	0	0	0	0	0
	Total	23	67.6	13	38.2	1	100	36	100
	Average Degree *Std. Deviation*	3.09 .85		2.69 .75		4.00		2.93 .80	

These results match the results found by Székely & Pálinkás (2009) who state that selling agricultural products through contracts with industry or cooperatives is less risky due to contractual factors. Selling products individually is probably the most profitable way to market them, especially when there is greater competition, and the farmer has no bargaining power.

Out of the 34 farmers interviewed, 32 respondents (representing 94%) of the sample answered the question concerning the reason to choose the channel to market in which each respondent could choose two options. Since respondents could choose two options, a set of 55 responses was obtained (Table 8). About 38% respondents (out 32 respondents) choose the channel to market because of "Flow ease production" and 34% because they have no processing capacity (out of 32 respondents). Regarding quality certification standards applied by the farmer, all respondents answered to the question and they only have the certification of integrated production. Although "*Arroz Carolino do Baixo Mondego*" has been certified since 2015 as a product with "Protected Geographical Indication, (PGI) none of the interviewed producers claimed to PGI certification

Table 8. Reason to choose the channel marketing and standard certification

	Reason to choose the channel marketing (% in total of answers)							
Reason	**Best price**	**Easy flow production**	**No processing capacity**	**Price stability**	**Guaranteed Production flow**	**Fastest payment**	**Support production**	**Total**
Nº answers	7	12	11	8	9	6	2	55
% in total	12.7	21.8	20.0	14.5	16.4	10.9	3.6	100
	Reason to choose the standard quality certification (% in total of answers)							
Reason	**Best price**	**Easy flow production**	**Because other did**	**Price stability**	**Guaranteed Production flow**	**Option to choose the channel**		**Total**
Nº	12	20	0	8	15	2		57
% in total	21.1	35.1	0	14.0	26.3	3.5		100

All respondents answered the question on the reason for choosing the certification system and about 59% respondents (% in total respondents) chose this type of certification due to the “ease production flow”, and 44% due to the “guarantee production flow”, that imply that ease and ensuring flow production are key factors for choosing the channel to market and influenced the quality certification system (Table 8).

Main Concerns

The producer’s concern analysis provides an important explanation for the degree of risk perception. A list of “concerns” was presented and farmers were asked to respond to their degree of concern for each question on a Likert scale from one to five points (Table 9). There were 33 answers to all items, except for the question “Flow production” (32 responses). Respondents indicated seven most important worries (values above the average: 3.31). The most important concern was the issue of weeds, followed by seed costs which is easily understandable.

Because farmers produce in an integrated production approach, the application and the type of herbicides used by farmers must comply with the regulation and they must apply certified seeds, as mentioned above. These two variables are significant in the regression (Table 6) accounting for the highest estimated regression coefficients. Five out of the seven concerns are about the costs of paddy rice produced; market and environmental concerns, mainly climate change, complete the list of issues.

Table 9. Degree of concerns by worries

Degree	1 -No worry		2 - Little worry		3 - Worry		4- Pretty worried		5 - Very worried		Average	*Std, Desv* Value
Answers	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%		
Weeds issues	0	0.0	0	0.0	0	0.0	4	12.1	29	87.9	4.88	*0.33*
Seed cost	0	0.0	1	0.0	2	6.1	9	27.3	22	66.7	4.61	*0.61*
Climate issues	0	0.0	0	0.0	3	9.1	11	33.3	19	57.6	4.48	*0.67*
Plagues and Diseases issues	1	3.0	0	0.0	2	6.1	11	33.3	19	57.6	4.42	*0.87*
Rice price producer	0	0.0	3	9.1	4	12.1	9	27.3	17	51.5	4.21	*0.99*
Fertilization issues	0	0.0	5	15.6	13	40.6	10	31.3	4	12.5	3.41	*0.91*
Machine and fuel costs	0	0.0	5	15.2	17	51.5	7	21.2	4	12.1	3.30	*0.88*
Rice dryer issues	1	3.0	10	30.3	14	42.4	6	18.2	2	6.1	2.94	*0.93*
Labor availability	4	12.1	13	39.4	7	21.2	3	9.1	6	18.2	2.82	*1.31*
Labor cost	2	6.1	19	57.6	5	15.2	4	12.1	3	9.1	2.61	*1.09*
Machine availability issue	10	30.3	13	39.4	2	6.1	6	18.2	2	6.1	2.30	*1.26*
Seed quality issues	0	0.0	1	3.0	3	9.1	10	30.3	19	57.6	2.30	*0.79*
Water issues	14	42.4	5	15.2	12	36.4	2	6.1	0	0.0	2.06	*1.03*
Flow production issue	8	24.2	21	63.6	1	3.0	1	3.0	2	6.1	2.03	*0.98*
Soil salinity	23	69.7	3	9.1	0	0.0	4	12.1	3	9.1	1.82	*1.42*

If we apply for Cohen rank (Cohen, 1988), we found a moderate positive correlation (at 0.05 level of significant) between education level and water issues, (rho = 0.375), a moderate negative correlation (at 0.05 level of significant) between class age level and water issues (rho= -0.412). A moderate or medium negative correlation (at 0.05 level of significant) between class age level and soil salinity (rho= - 0,351). Several moderate correlations between production area and different worries were found (at 0.05 level of significant) such as: water issues (rho = 0.388); soil salinity (rho = 0.395); seed quality (rho = -0.414). We found (at 0.01 level of significant) a large negative correlation between rice price producer and production area (rho = -0.520). This finding is interesting to explore in future works because it goes against the economic theory of the supply model. Small farmers are more sensible to rice price.

Flooding Irrigation Water Savings

The number of days with wetland and dry soil, with CF and AWD, in the three experimental sites, is shown in table 10. The differences result from the practice of AWD after flowering starts, since the irrigation management was similar in the vegetative stages and even beginning of flowering. The increase in time with dry soil due to AWD was 10, and 25 days, corresponding to a period with dry soil related to the cultural cycle of 47%, and 57%, for Quinta do Canal, Bico da Barca, respectively (Gonçalves *et al.* 2021; *Nunes et al.* 2021).

Table 10. Number of days with flooded and dry soil, in continuous and AWD flooding trials

Plot	Soil condition	Complete crop season period (days)		After vegetative stage (days)	
		CF	AWD	CF	AWD
Quinta do Canal	Flooded	88	78	40	29
	Dry soil	59	69	33	44
	Total	147	147	73	73
Bico da Barca	Flooded	83	58	40	21
	Dry soil	52	77	39	58
	Total	135	135	79	79

CF - Continuous (traditional) flooding; AWD - alternate wetting and drying flooding.

Water use values in the experimental plots, with CF and AWD, are shown in Table 11. The irrigation allocations with CF were 1588 mm at Quinta do Canal, and 1725 mm at Bico da Barca, with the relative savings of AWD water was 12.6%, and 11.8%, with reductions in cultural evapotranspiration of 1.6%, and 3.4%, and in deep percolation of 22.1%, and 15.0%, for Quinta do Canal, and Bico da Barca, respectively.

Table 11. Water use in continuous and AWD flooding trials

Plot	Water use (mm)	Complete crop season period		After vegetative stage	
		CF	AWD	CF	AWD
Quinta do Canal	Evapotranspiration	696.3	685.1	298.9	287.7
	Irrigation	1588	1388	651.5	425.1
	Precipitation	130.4	130.4	77.6	77.6
	Deep Percolation	538.5	419.7	261.4	152.6
	Surface Drainage	516.4	460.8	211.6	117.0
Bico da Barca	Evapotranspiration	588.0	568.1	282.0	263.4
	Irrigation	1725	1522	742.1	537.5
	Precipitation	99.6	99.6	87.8	87.8
	Deep Percolation [1]	1264	1075	651.4	494.2

[1]Includes a small fraction of surface drainage

Production values in the experimental plots, with CF and AWD, are shown in Table 12. Production was 9.58 t/ha at Quinta do Canal, and 8.10 t/ha at Bico da Barca, with production decreasing in AWD by 3.4% at Quinta do Canal and increased by 0.3% at Bico da Barca. In turn, water productivity increased in both locations, 10.6%, and 13.6%, in the same order, reaching the highest at Quinta do Canal with 0.667 kg/m^3, and 0.543 kg/m^3 at Bico da Barca.

Table 12. Yield and water productivity of continuous and AWD flooding trials. Local

Plot	Técnica	Y (t/ha)	WP (kg/m^3)	WG (g)	SY (t/ha)
Quinta do Canal	CF	9.582±1.230	0.603	28.9±1.42	5.49±0.70
	AWD	9.252±6.120	0.667	28.9±0.74	5.62±0.53
Bico da Barca	CF	8.101±0.987	0.470	31.0±1.68	4.45±0.39
	AWD	8.124±0.920	0.534	31.0±0.53	5.28±0.77

CF - Continuous (traditional) flooding; AWD - alternate wetting and drying flooding; Y- Rice grain yield at 14% humidity (t/ha); WP - Water Productivity=grain yield at 14% humidity/ (irrigation + precipitation) (m^3/ha); WG - Weight of 1000 grains at 14% humidity (g); [6]SY - Straw yield, dry matter (t/ha).

Regarding the AWD technique, the results seem to be in accordance with several published studies (Tuong & Bouman, 2003; Jalinda, 2019; Lampayan, 2015), showing that there is a relative potential for saving water. In table 12, we can see water savings, with an impact on production of less than 3.5%. AWD allowed a period of 11 to 25 days of dry soil, expecting positive implications for greenhouse gas emissions and the arsenic content of the rice grain. The improvement of precise land levelling is considered a priority to optimize the water level above soil surface, aiming water saving. On the other hand, the need to carry out frequent and planned irrigation events in the AWD period (after mid-July), makes inflow control devices more demanding, making place for its automation.

FUTURE RESEARCH DIRECTIONS

Business diversification is a strategy used by farmers as risk protection. Mishra & El-Osta (2002) suggests that diversification and farm size may be negatively correlated according to economic theory, but the study provides evidence that farms receiving government payments are more diversified than others. Diversification is the most widely used risk avoidance instrument and is based on risk spreading. The motivation for diversification is based on the principle that when one activity generates low revenue, other activities may be profitable.

The multiple activity agricultural enterprise significantly reduces the possibility for local natural disasters to have a simultaneous negative impact on all activities and allows diverse income source on and off the farm. From an environmental point of view, diversifying agricultural production on a farm or agricultural region is one of the main tactics adopted by farmers to restrain the long-term changes induce by environmental changes. However according to Lancaster &Torres (2019) the diversification of agricultural operations would result in more steady ecosystems over time, enabling quicker responses to climate and social changes.

About 50% of respondents said rice farming is their main source of income (≥ 50% of farm income) and for 24% it represents 100% of income. About 47% of respondents have two and 29% have at least three agricultural activities, including rice and 18% have a non-agricultural income (Table 13).

Table 13. Income source by agricultural activity and percentage of rice in agricultural income

Source of income	Frist		Second		Third		Rice income by % in total of farm income		
Activity	Nº	%	Nº	%	Nº	%	Class	Nº	%
Rice	17	50.0	13	38.2	4	11.8	< 25%	4	11.8
Beef	1	2.9	2	5.9	1	2.9	25 – 39%	4	11.8
Fruit			1	2.9	1	2.9	40- 49%	9	26.5
Maize	15	44.1	8	23.5			50- 79%	5	14.7
Horticultural					4	11.8	80- 99%	4	11.8
Others	1	2.9	2	5.9			100%	8	23.5

According to the responses, all farmers surveyed received support from agricultural policies, namely the Rural Development Program (RDP), over the past decade. However, no support demands were submitted to support policies for organic farming, for diversification and for commercialization and processing. Farmers were satisfied or more than satisfied with the progress of the measures on their farms, and all respondents stated that they want this production system in the near future, at least during the next couple of years (Table 14).

Table 14. Submission for RDP policy aid over the past decade and satisfaction grade

	Aids	Advice Service		Farms Modernization		Environmental		Integrated farming		Young Farmer		BPS include VCS rice	
	Application	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
		33	97.1	7	20.6	34	100	31	91.2	8	23.5	33	97,1
Point	**Level**	**Degree of Satisfaction**											
1	Not at all satisfied	0	0	0	0	0	0	0	0	0	0	0	0
2	Slightly satisfied	3	9.1	0	0	13	38.2	0	0	0	0	1	3.0
3	Satisfied	22	66.7	2	28.6	15	44.1	10	32.3	1	1	14	42.4
4	Very satisfied	7	21.2	5	71.4	6	17.6	15	48,4	6	6	14	42,4
5	Extremely satisfied	1	3.0	0	0	0	0	6	19,4	1	1	4	12,1
Average Degree *Std, Deviation*		3.0 *0.6*		3.7 *0.5*		3.8 *0.7*		3.9 *0.7*		4.0 *0.5*		3.6 *0.7*	

In this question, respondents could justify their answer by choosing at most two main motives to maintain the agricultural activity. The financial reasons and family income balance represented 24.3% of the responses, respectively, but 21.6% stated that agricultural activity would only continue due of the nonexistence of profitable alternatives.

Regarding rice crop, only one farmer replied he/she does not intend to keep producing rice due to the crop´s absence of economic sustainability. Approximately 89,2% of the farmers want to maintain rice production, and 45.5% said they preserve this activity since there are no suitable agronomic systems available for their land, given the current agronomic and technological systems' availability for farmers in the region. Around 24.2% of the sampled producers consider that knowledge about rice is an important reason to keep the crop. About of 21.2% of the farmers in this work believe that the economic viability justifies the option to continue cultivating rice

Rice farmers are reasonably satisfied with the functioning of this farming system. The fact that they use marginal lands that cannot be used for other cultural systems is an important factor and agri-environmental policies support their production decisions. The lack of development of own brands is highlighted, but this fact can be justified by the high level of satisfaction they have with industry, and also with supporting cooperatives. Crop diversification contributes to reduce the economic risk in the most complex agronomic systems particularly in places with high pest incidence.

Rice industry policies, together with the rice food chain, aim to promote rice, through the promotion of its quality attributes and through the European rice agri-environmental attributes This promotion of Portuguese rice involves encouraging the consumption of national rice in Portugal and increasing the consumption of rice in Northern Europe countries. The attribute of consuming European rice set to reduce the carbon footprint, and how rice is grown choosing areas of the EU's wetlands, which are home to migratory birds, stimulate environmental choices. On the other hand, if European rice gains a share in the domestic market, we will help to reduce imports of rice from third countries that do not pay customs duties entering the European Union.

The main issues related to water management in rice cultivation that determine future research are the following: 1) Water saving in irrigation, to reduce impacts on water resources and to better adapt to situations of water scarcity; in this sense, improving the practice of AWD is of great importance. 2)

Automation of irrigation supply to paddies, for better control of the water applied and the feasibility of AWD practice. 3) Reuse of drainage water, whenever water quality conditions allow it. 4) Improvement of agronomic practices to reduce the use of pesticides and facilitate weed control, namely by mechanical control or the use of crop rotation. 5) Reduction of methane emissions to the atmosphere because of flooded soil conditions; to this end, the practice of AWD in flooding irrigation, or more significant changes in irrigation techniques, such as drip irrigation, are envisaged as possible solutions, when soil and economic conditions allow it. 6) Improve water management at the irrigation district level, to ensure more reliable and consistent solutions that ensure spatial equity of water savings and farmers' income. 7) Optimize the positive role of paddy rice in preserving biodiversity of agroecosystems, making it possible to value the crop in terms of environmental services.

CONCLUSION

The work carried out an analysis of the rice production and marketing system in the Mondego valley. This system is supported by CAP measures of which farmers are aware, benefit and are satisfied with. The concern with production costs is clear, as well as the concern about rice price. Production risk is important and is related to the price obtained for rice. Market risk is spotted by the producer despite the reduction in volatility and price growth in the last five years.

The choice of channels to market has to do with rice flow output guarantees, but this is not a relevant concern. In terms of market risk, there is a difference between what farmers consider to be a price risk and safest choice. Farmers are aware of the problems and try to find risk mitigation strategies, diversifying the activity, choosing the channel, controlling production costs, and applying specific Portuguese policies as well as agri-environmental measures.

The issues of climate change and how these changes may affect production, such as rice that uses sensitive ecosystems, are important issues to consider in European governance policies and in agricultural policy discussions in Europe. Farmer's perception of risk involving important crops in terms of food sovereignty and the guarantee of national and European food self-sufficiency, namely cereals, are issues to consider when developing agricultural policies for an environmentally and economically sustainable development of agri-food production.

The need to deal with reduced availability of water for irrigation and the requirements to reduce negative environmental impacts, call for very effective actions in agronomic changes and in irrigation techniques for rice crops, to ensure economic income for farmers and rice production in quantity and quality, to satisfy consumption. These changes are generally complex, due to crop sensitivity and the soil system therefore, increased efforts are needed in research and experimentation, as well as in supporting farmers and other interested parties.

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