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Sustainability of European agricultural holdings

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ABSTRACT

European agricultural activity has an important contribution to European and global food security and also in the preservation of countryside and livelihood. The main goal of this paper is to analyze the agricultural sustainability of the twenty-eight Member States of the European Union in order to promote sustainable agriculture, food security and rural development in the European region. Information and data used are obtained from the European Commission database. The methodology includes the min–max approach and multivariate techniques, namely, Cluster and Factorial Analysis. The findings show the existence of three different clusters of farms in European countries, namely, Central European countries, New Eastern Member States, and the Mediterranean countries. The results also conclude that European agriculture and their respective farms have moderate sustainability where the subsidies from Common Agricultural Policy have a positive impact on. Moreover, agricultural activity in the European Central countries presents the highest value in economic contribution, whereas the Mediterranean countries present more contribution in environmental terms. The highest contribution in terms of creating rural jobs is found in Eastern countries. The main conclusion highlights the need to better adjust agricultural policies among the European Member States in order to better promote the sustainability of agriculture in Europe.

1. Introduction

European agricultural activity contributes about 1.6% to the European GDP, represents 4,5% of the total jobs in Europe and 1.2% and 1.4%, respectively, in the total exports and imports in European countries (World Bank, 2018). The agricultural sector has a significant contribution to food security in the twenty-eight European Member States (EMS) of the European Union (EU) and also in social, environmental and institutional terms. This sector not only contributes to the food security but also, has a positive multiplier effect in agroindustry's exports and imports, preservation and maintenance of the countryside and promotion of development in other direct and indirect activities, such as agritourism, agribusiness and associated industries (Olorunfemi et al., 2020). The activity also has positive impacts in the social cohesion and the maintenance of the rural regions and the production and promotion of public goods (Dos-Santos and Diz, 2019; Dos-Santos et al., 2019).

Agricultural systems are traditionally recognized as one of the elements that can foster the interrelationships of economic, social and environmental objectives. Therefore, these systems are recognized as sustainable systems (Sayed et al., 2020). Sustainability is traditionally defined by the literature with the dimensions, economic, social and environmental (Salvioni et al., 2014; Miličić et al., 2017; Dos-Santos and Diz, 2019).

At the social level, European agricultural land covers 1,845,340 (km2) (FADN, 2019). Arable land represents about 25.3% of the total European surface area. About 25% of the total population of the Member States in the European Union live in rural areas (World Bank, 2018). About 4.5% of them are directly employed by the agricultural sector, including 3.5% of female employment. But agricultural activity has, at the same time, other social impacts, namely, the maintenance of habitats and quality of life (Dos-Santos et al., 2019; European Commission, 2017).

At the environmental level, the contribution of agriculture to the preservation of habitats and biodiversity cannot be overlooked. The maintenance of the landscape and the of rural areas are possible by the existence of agricultural activity, which creates

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externalities, such the preservation of tangible and intangible rural heritage, with competitive advantages for rural development, tourism activities in rural areas, as well as, other value-added activities, such the attractiveness of young people and entrepreneurs who settle or return to the rural areas (Dos-Santos and Diz, 2019).

From a sustainability perspective, the existence of multifunctional agriculture that responds to the needs of society by providing non-market goods and services justifies government intervention in a market economy through agricultural and sectoral policies (Dos-Santos, 2016; Dos-Santos, 2018). In the European Member States of the European Union, the agricultural policy that directly supports and contribute with funds to the agriculture among the EMS, comes from the Common Agricultural Policy (CAP), through its 1st and 2nd Pillars. In the first Pillar, the Single Farm Payments (CAP 2007–2014) have been replaced in the 2014–2020 CAP by a Multifunctional seven-component payment system: (1) a 'basic payment' per hectare, harmonized according to economic or administrative criteria, whether national or regional, and subject to a convergence process; (2) an' ecological and environmental component', as additional support to offset the costs of providing environmental public goods not remunerated by the market; (3) an additional payment to young farmers; (4) a 'redistributive payment' to strengthen support for the first hectares of a farm; (5) additional income in areas with natural handicaps; (6) undifferentiated production aid for certain areas or types of agriculture, for economic and/or social reasons; (7) a simplified and voluntary scheme for small farmers with payments up to 1250 euros. The first three elements are mandatory for EMS, and the last four are optional (European Parliament, 2015a; European Parliament 2015b).

At the same time, great efforts have been made in the Second Pillar to achieve a more effective environmental function of the CAP with agri-environmental measures and multiple programs, based instead on a contractual and voluntary approach. The objective of "greening" direct payments is not new in the CAP (Dos-Santos et al., 2019). Since Agenda 2000, much effort has been made to justify direct support and the CAP, in general, as a policy capable of improving the environment and the synergistic link between agricultural activities and economic, social and environmental concerns (Dos-Santos, 2018; European Commission, 1996;). According to Dos-Santos and Henriques (2019 and Vitunskiene and Dabkiene, (2016), European agricultural companies are highly subsidized.

Therefore, this paper making a threefold contribution to the literature:

1) Despite the importance of that sector and the respective need of your sustainability, according to our better knowledge, are reduced in the literature the references at agricultural sustainability at multi-country level approach, besides the considerable number of references to local and regional sustainability, mainly in the environmental subject. Therefore, this paper aims to cover this gap in the literature in order to give new insights to the stakeholders of the sector, researchers and public decision-makers.
2) On the other hand, the references about sustainability at country level, report only the economic or social or environmental dimensions in the majority of the cases and few references, including all the dimensions of sustainability. This paper here also tries to cover this gap in the literature.
3) European farms are highly subsidized (Vitunskiene and Dabkiene, 2016; Dos-Santos, 2013; Dos-Santos, 2019; Silva et al., 2015), but the political and institutional dimension of sustainability never was analyzed. Therefore, the institutional dimension should be included in the global sustainability of European farms in order to design better, more adjusted policies on the future among the European Union.

1.1. Literature review

Sustainable development has become one of the most widely used conceptual frameworks for analyzing the agricultural and food sectors in a comprehensive and holistic way (Vitunskiene and Dabkiene, 2016). Agricultural sustainability is also a new concept at the plurinational level and raises several questions about the discussions of decision-makers, including agricultural entrepreneurs, economists, managers and policymakers (Gómez-Limón, and Sanchez-Fernandez, 2010; Vitunskiene and Dabkiene, 2016).

The focus of international organizations on agricultural sustainability has led to the emergence of studies in this area at the regional and national levels. Gómez-Limón and Sanchez-Fernandez, (2010) analyzed agricultural sustainability using composite indicators in Spain. Vitunskiene and Dabkiene (2016) assessed the sustainability of Lithuanian agricultural farms. Also, in the Middle East, namely, in Saudi Arabia and the United Emirates increasing the sustainable production by innovative techniques of production, namely, aquaponics, hydroponics and other sustainable techniques is a goal to promote food security concerning agricultural production and consumption according to Fiaz et al., (2018).

Literature about environmental sustainability has undergone a considerable increase due to the multitude of themes covered and the attention given by society to this dimension of sustainability. By the opposite, economic indicators target a relatively small number of themes referred mainly the quantitative information about the efficiency of use of resources. About the social indicators typically cover two main themes: sustainability relating to the farming community and sustainability relating to society as a whole. (Galdeano Gómez et al., 2016).

Other literature makes an important contribution to the agricultural sustainability of farms in various countries at the country level. Sayed et al., (2020) analysed the environmental sustainability and water productivity on conservation tillage of irrigated maize in red-brown terrace soil of Bangladesh. Koondhar et al., (2018) analyse and compare the economic efficiency of wheat productivity in different cropping systems of Sindh province, Pakistan, in order to promote economic sustainability. Ghozlane et al., (2010) analysed the impact of the National Fund for Agricultural Regulation and Development in assessing sustainability in the Tizi-Ouzou region of Algeria. By multivariate methods, the results show four groups of farms: small farms; medium-sized farms; medium farms; mid-sized farms in that region. These authors concluded that the funds granted to livestock farmers through has increased their milk production (55%), their land area (6%) and their income (456%).

Also, Wrzaszcz and Zegar, (2014) presented proposals for measuring the economic sustainability of agricultural holdings in Poland based on Agricultural Census data. These authors used the indicators of economic sustainability: land productivity, labour profitability, farms market activity and sources of households' income and maintenance. The analysis concerns individual agricultural holdings with at least 1 ha of agricultural land, and it is also carried out in the area groups. The results further show that economic and environmental objectives are complementary at the farm level, but it is not infinite. Based on a comparison of market and farmers' holdings to all analysed farms, these authors concluded that the economically sustainable units more often conduct pro-environment agricultural activities.

Ali et al., (2017) analysing the impacts of climate change on adaptation practices and impacts on food security and poverty in

Pakistan, by sustainability indicators in social, environmental and economic terms.

Vitunskiene & Dabkiene, (2016) refer to all the previous works developed in European countries. The majority of them have a country level or a regional level. The referred studies use FADN database, but some of them focus on social or environmental or economic sustainability but not at the aggregation level of the sustainability of farms.

Marchand et al., (2014) and Vitunskiene & Dabkiene, (2016) also suggested two working definitions of the sustainability assessment tools at the farm level, i.e., the Full Sustainability Assessment (FSA) and the Rapid Sustainability Assessment (RSA). The FSA tools use detailed farm data and/or expert information, require trained advisers and/or expert visits to gather data, and are rather long and expensive in duration. That means this procedure is more adjusted at a farm level but not on a comparative study at a multi-country level. According to these authors, "the RSA tools are more directed toward learning and can act as a trigger for the farmers to become interested in farm sustainability". Furthermore, such an assessment can raise the farmers' awareness and reveal particular problems or barriers in the development of farm sustainability (Marchand et al., (2014) and Vitunskiene & Dabkiene, (2016), but can not be used on a simple way for comparing farms at a multi-country level.

2. Material and methods

Information and data come from the Farm Accounting Information Network (FADN, 2019) the European database from European Commission (2019). The analysed information and data are reported to the year 2017, the last one available. We use the year of 2017 because the "new" CAP Policy Framework 2014–2015 from Multiannual Financial Framework from European Union for the European Member States was disseminated and adjusted for all the EMS in the final of 2015. So, we use the year of 2017, because we believe that in 2017 was the better year possible to analyse the "new" CAP implementation policies, namely, agricultural investment and other agricultural measures from the I and II Pillar of the CAP. On the other hand, 2017 was the last year available without missing information and data on FADN (2019).

The sustainability indexes are obtained according to Dos-Santos et al., (2019) and Vitunskiene & Dabkiene, (2016), but adjusted and namely, includes:

1. Literature review: initial set of indicators depending on sustainability dimension based on actualized references when the majority were from SCOPUS and Web of Science, (mainly, but others come from FLINT Project (2015) and OECD (2008).
2. Composition of a set of indicators from social, environmental economics and institutional sustainability, identifying their variables and the source of information (FADN, 2019) and Authors results (2019).
3. 3 Data shortage evaluation and identification of variables for *proxy* indicators from FADN (2019).
4. FADN database analysis: identification of potential years without missing variables to calculate the selected indicators from the FADN database. Correlation analysis among variables with the *Pearson* test and their comparative analysis with the *Kendall* and *Spearman test*, in order to avoid correlation among variables.
5. Identification of the possible indicators and the missing data (ex: to construct environmental indicators).
6. Construction of indicators and correlation analysis by the *Kendall* test of the selected indicators for the exclusion of the strongly correlated ones.
7. Composition of the final set of indicators depending on the sustainability dimension (or global sustainability) and its validation.

All the tasks referred before are not static and unidirectional and includes a holistic analysis with reversible steps among the points 1 to 7.

Two sustainability Indexes have been developed: The Index of Relative Sustainability (IRS) and the Index of Global Sustainability (IGS). The IRS includes environmental, economic and social indicators at the farm level among all the farms in EMS. IGS includes beyond the previous indicators referred, also, the institutional indicators to reflect the measures, policies and programs from Common Agricultural Policy (CAP) from the European Union for all the EMS. The construction of the indicators and respective Index were based on Silva e Marote (2013) and Silva et al., (2015). On the other hand, the IRS was based on SMART methodology (Lockie et al., 2005); Vitunskiene and Dabkiene (2016), and Dos-Santos et al., (2019) and Dos-Santos and Diz (2019). The IGS was based on Dos-Santos (2018), Dos-Santos et al. (2019).

The main advantage of sustainability indexes is the development of an analytical tool to assess relative and global sustainability of farms using the FADN data (Vitunskiene & Dabkiene, 2016) on a country or multi-country level and allow comparing the performance among groups of farms in order to give insights to public decision-makers to better adjust agricultural policies among countries or groups of countries (Dos-Santos et al., 2019).

However, this procedure presents also some limitations. The major limitation is the lack of information and data from the FADN database for the construction of the different indexes of sustainability, mainly at environmental index. FADN database is not adjusted to obtain all the required information mainly at an environmental level. On the other hand, the conjugation of FADN with another database in environmental parameters could be one solution but challenging to operationalize and conciliate with FADN due to the different aggregation level of measures and units.

Also, the indexes of sustainability present a considerable level of aggregation. Some European countries, namely, Portugal or German, among others, presents different farms structure between North and South regions (Salvioni et al., 2014). That means the Northern region is dominated for small and a great number of farms (majority family farms) and the Southern region with the biggest farms. That could present a difficult task to define agricultural policies among the EMS. The FADN database also presents the country divided into regions, but the aggregation in clusters of farms could compromise this technique because the results can appear in different regions from different countries in the same cluster.

Due the reduced number of degrees of freedom (because the countries are only 28), we analysed the correlation among variables with the *Pearson* test, and their comparative analysis was performed with the *Kendall and Spearman* test, in order to avoid correlation among variables.

FADN database (2019) has limitations due to the limited number of variables available for the 28 EMS, on the one hand, and, by the other, due to the high level of aggregation of data and information of the database.

Table 1 presents the economic indicators of European farms. The results of the correlation analysis show that variables E_1 and E_5 were correlated as a result greater than 0.8 by the *Kendall test*. However, according to Dos-Santos, (2018) and Ahmed et al., (2019) the correlation between labour productivity frequently occurs. Due to the relative importance, both of these variables have been considered for analysis.

Table 2 presents the social indicators of agricultural activities at the farm level. Although there are also here other relevant indica-

Table 1
Economic indicators from farms in EU countries.

Variable	Indicator
Ec_1	Labour productivity - Farm gross added value/Annual work unit
Ec_2	Capital Productivity - Cash flow/ Capital
Ec_3	Land productivity - Farm gross added value/ Utilized agricultural area
Ec_4	Solvency - Total assets/Total liabilities
Ec_5	Family Farm Income - Farm income/ Family annual work unit
Ec_6	Investment capacity – Investment/ Utilized agricultural area (UAA)
Ec_7	Other incomes - Income outside of agriculture/ Total income

Source: Results from authors, 2019 based on Dos-Santos and Diz (2019).

Table 2
Social indicators from farms in EU countries.

Variable	Indicator
S_1	Family Farm work - Number of hours worked by family members/ Total annual work hours
S_2	Farm Jobs creation - Total annual hours worked/AWU
S_3	Innovation and cycle agricultural life - Net Investment/UAA
S_4	Family farm income /Total Income
S_5	Job creation- Total AWU/total UAA

Source: Results from authors, 2019 based on Dos-Santos and Diz (2019).

Table 3
Environmental indicators from farms in EU countries.

Variable	Indicator
E_1	Fertilizer input - fertilizer used/UAA
E_2	Energy use – Cost of electricity, equipment, heating, transport fuel and oil/ Farm gross value added
E_3	Meadows and pastures – Total of meadows and pastures/UAA
E_4	Livestock density - Total livestock units/UAA
E_5	Environmental measures - Total *set-aside* agricultural area/UAA (%)

Source: Results from authors, 2019 based on Dos-Santos and Diz (2019).

Table 4
Institutional indicators from farms in EU countries.

Variable	Indicator (%)
I_1	Total farm dependence on subsidies- Total subsidies/Net farm income
I_2	Dependence on crop subsidies - Crop subsidies/ Net farm income
I_3	Dependence on livestock subsidies - Livestock subsidies/ Net farm income
I_4	Dependence on milk subsidies - Milk subsidies/ Net farm income
I_5	Dependence on environmental subsidies - Subsidies for environmental measures/ Farm net income

Source: Results from authors, 2019 based on Dos-Santos and Diz (2019).

tors (Dos-Santos and Diz, 2018 and Vitunskiene and Dabkiene, 2016), such as age, education, way of a succession of farm activity, they have not been considered due to the lack of availability at FADN/other databases for the 28 EMS.

In the social indicators' variables, S_1 and S_5 are correlated. Despite this, we have kept both in the analysis, because family work and paid work to have crucial importance to the social sustainability farm level (Dos-Santos and Diz, 2019; Miličić et al., 2017).

The environmental indicators of agricultural European farms (Table 3) were based on the literature, although the restricted data from FADN.

The institutional indicators of agricultural activity (Table 4) are based on the results of Dos-Santos et al., (2019). As referred before they are only used to calculate the IGS Index. The IRS Index uses the indicators presented previously.

Descriptive statistics of sustainability indicators are presented in Annex 1.

Before the construction of the IRS and IGS, weights were assigned to the presented indicators (Table 5) by Factorial Analysis (FA) to estimates the weights of the selected indicators in order to construct the sub-indices. The result of the *Kaiser-Meyer-Olkin* obtained was 0.80 that confirm the adjustment of the data to the sample. The *Varimax* method was used for factor rotation according to Hairs et al., (1998). Results were performed by SPSS Version 22.

The results of FA have allowed performing composite indicators, according to Ahmed et al. (2019), i.e., the clusters with higher loading factors. After the indicators were grouped by assigning to each one of them a weight similar to the value of explained variance. (Table 5).

The min–max approach was used to standardize the indicators because they are expressed in different units (Tables 6 to 9) in order to perform a common basis. According to Milligan, and Cooper. (1988) standardization of variables would seem to be necessary in those cases where the dissimilarity measure, such as *Euclidean distance*, is sensitive to differences in the magnitudes or scales of the input variables, as occurs in this study. The purpose, according to Milligan, and Cooper. (1988) is to equalize the size or magnitude and the variability of the input variables. These authors present different forms of standardizations. Among these presents the standardization of variables using the min–max when involve using the range of the variable as the divisor, as occurs in our study **(Annex 2)** Table 10.

The sub-indices can be expressed in equation (3) with the restriction (4) proposed by Krajnc and Glavič (2005) and Dos-Santos et al., (2019) (**Annex 3**).

Where $SI_{sub,ij}$ is the sustainability of the sub-index for indicator group *i* (economic *i* = 1; social *i* = 2; and environmental *i* = 3; P*ij* is the weight of indicator *j* for sustainability indicator group *i*. The equation (6) was used to combine the sustainability sub-indexes for farms (Krajnc and Glavič, 2005), **(Annex 4).**

Table 5
Estimated weights of economic, environmental, social and institutional indicators by factorial analysis.

Economic		Social		Environmental		Institutional	
Variable	Weight	Variable	Weight	Variable	Weight	Variable	Weight
Ec_1	0,17	S_1	0,14	E_1	0,14	I_1	0,21
Ec_2	0,12	S_2	0,14	E_2	0,22	I_2	0,17
Ec_3	0,18	S_3	0,32	E_3	0,20	I_3	0,25
Ec_4	0,12	S_4	0,22	E_4	0,22	I_4	0,21
Ec_5	0,15	S_5	0,17	E_5	0,23	I_5	0,16
Ec_6	0,12	–	–	–	–	–	–
Ec_7	0,15	–	–	–	–	–	–
Total	1	–	1		1		1

Source: Results of the authors, 2019.

Table 6
Clusters of countries according to the levels of farms 'sustainability.

Clusters	Country
(1) New Eastern Member States	Austria; Bulgaria; Croatia; Cyprus; Czech Republic; Estonia; Hungary; Ireland; Lithuania; Sweden; Slovakia and Slovenia.
(2) Mediterranean countries	Greece; Italy; Poland; Spain; Romania and Malta; Portugal.
(3) Central European countries	Belgium; Denmark; France; Germany; Luxembourg; Latvia; Netherlands; Finland; United Kingdom.

Source: Results of the authors, 2019.

Table 7
Results of economic indicators of agricultural holdings by the cluster of countries.

Variable	Cluster of Countries		
	Eastern	Mediterranean	Central European
Ec_1	0,53	0,14	0,11
Ec_2	0,30	0,34	0,61
Ec_3	0,32	0,09	0,35
Ec_4	0,01	0,04	0,41
Ec_5	0,56	0,14	0,15
Ec_6	0,49	0,25	0,03
Ec_7	0,24	0,09	0,32

Source: Results of the authors, 2019.

Table 8
Results of social indicators of agricultural holdings by the cluster of countries.

Variable	Cluster		
	Eastern	Mediterranean	Central European
S_1	0,61	0,67	0,87
S_2	0,09	0,06	0,52
S_3	0,71	0,42	0,18
S_4	0,56	0,14	0,15
S_5	0,04	0,09	0,30

Source: Results of the authors, 2019.

Table 9
Results of environmental indicators of agricultural holdings by the cluster of countries.

Variable	Group of countries with		
	Eastern	Mediterranean	Central European
E_1	0,46	0,23	0,42
E_2	0,30	0,54	0,19
E_3	0,07	0,23	0,21
E_4	0,58	0,15	0,07
E_5	0,09	0,15	0,07

Source: Results of the authors, 2019.

Table 10
Results of institutional indicators of agricultural holdings by the cluster of countries.

Variable	Cluster		
	Eastern	Mediterranean	Central European
I_1	0,17	0,15	0,42
I_2	0,04	0,17	0,21
I_3	0,06	0,21	0,05
I_4	0,08	0,13	0,04
I_5	0,02	0,18	0,02

Source: Results of the authors, 2019.

The attributed weights were based on the triple bottom line approach to sustainability. The weight assigned to each of the three dimensions of sustainability on IRS and in the four dimensions on IGS sustainability was equal, respectively, in the three and four dimensions of sustainability, presented in equations (7) and (8) **(Annex 5).**

After calculating the IRS and IGS, Cluster Analysis was used in order to aggregate the farms into homogeneous clusters.

Cluster Analysis is a multivariate technique widely used to form homogeneous groups (Gómez-Limón and Sanchez-Fernandez, 2010), i.e., with high internal homogeneity and high external heterogeneity (Dos-Santos (2018). The hierarchical classification was done, and the *Ward method* was used as an aggregation criterion, and the *Euclidean distance* was used as a proximity measure. The choice of the number of clusters was based on the partitioning method were defined as appropriate as these seem to be most representative, according to Bidogeza et al., (2009).

4. Results and discussion

Results of the cluster analysis of agricultural holdings in the 28 EMS confirm the existence of three different typologies of farms in the respective European countries based on economic, social, environmental and institutional indicators. Should be noted, that there are no significant differences in the cluster's construction, with and without the institutional component, because before this phase all highly correlated variables, had been eliminated in order to avoid multicollinearity issue.

The results show the existence of three groups that include, respectively:

(1) Group of farms mainly composed of the New Eastern Member States;

(2) Group of farms mainly composed of Mediterranean countries;

(3) Group of farms mainly composed of the Central European countries.

The results of the economic indicator groups (Table 7 and Table 11) and the value of the sub-economic Index confirm that the countries of Central Europe (Cluster 3) and the Eastern countries (Cluster 2) have highest values in the following indicators: labour and capital productivity, financial indicators, income and fixed capital investments. As a result, cluster (3) has highly efficient and competitive farms. On the contrary, farms in the Mediterranean countries have the lowest value in the economic sub-index, and, consequently in the IRS Index. The Eastern Countries are the last group of countries to have joined the EU, most of them since 2005.

Concerning the social indicators and sub-indices of agricultural activities among the groups, results confirm the importance of the social indicators for each of the three groups on this sub-indicator, mainly with the strong contribution of farms in Clusters I and III. Agricultural holdings in Central and Mediterranean Europe have important values on job creation on agricultural holdings, innovation, rural development and the conservation of tangible and intangible heritage. The results of the social indicators and the value of the sub-social index also confirm that the Central European countries (Cluster 3) have a high value in this sub-index, in line with previous research (Dos-Santos and Diz, 2019; Dos-Santos et al., 2019; Salvioni et al., 2014). This demonstrates the social importance of European agriculture, mainly in the Central,

Table 11
Global and relative farm sustainability index and respective sub-index by cluster.

Cluster	Sub-Index					
	Economic	Social	Environmental	Institutional	Index IGS	Index IRS
(1)	0,72	0,35	0,46	0,53	0,58	0,47
(2)	0,08	0,19	0,90	0,43	0,42	0,35
(3)	0,56	0,46	0,27	0,16	0,43	0,36

Source: Results of the authors, 2019.

Mediterranean and Eastern European countries. These results also confirm the significant contribution of family farms to maintaining rural development and sustainability.

About environmental indicators, results confirm that Mediterranean countries present the highest contribution in environmental terms among the European farms, due the low inputs use, (fertilizer's; energy etc.,) and the existence of more extensive livestock systems. These results confirm the need for Common Agricultural Policies (CAP) in the future define friendly policies to promote the environmental Mediterranean agricultural systems.

The results of the farm indicators and institutional sub-index from all the clusters confirm that farm dependence on subsidies is greater in Central European countries (full dependence of farms on subsidies, milk subsidies and environmental, financial support measures from the CAP).

Regarding the IRS, the results confirm that all EU farms have average sustainability levels. These results are according to previous studies (FAO, 2013; Vitunskiene and Dabkiene, 2016; Dos-Santos et al., 2019 and Dos-Santos e Diz 2019). The results strongly confirm that European agricultural policies from CAP, strongly improve the sustainability of farms and allow increasing levels of global sustainability.

5. Conclusion

The results confirm that European farms have, in general, intermediate levels of sustainability. The environmental sustainability is high in the Mediterranean farms, while Central Europe farms have high economic sustainability and the Eastern farms are the top contributor in social terms. Mediterranean and Central European farms also have the highest values and contribute to the maintenance of rural areas. In general, in all the European farms, family farms and small subsistence farms make a significant contribution to the job creation and the maintenance of the rural countryside. That suggests to the public decision-makers need to adjust the CAP policies among the different clusters of the European countries differently. The CAP subsidies contribute to increasing all the levels of sustainability among all the Member States. However, this contribution is the highest in Central and Northeast countries compared with the other agricultural systems in Europe. Once again, these conclusions could give insights to the public decision-makers in the order they better could adjust the agricultural policies in the future to promote sustainable food production and food security.

Author' contribution

Dos-Santos, Maria design and performed all the paper alone, from de beginning to the end, namely, since database searches and analysis, all the methods, results, wrote an internal revision of the paper. Ahmad Nawaz wrote an internal revision of the paper, improved the text, proofread the paper and made language-related corrections.

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Appendix 1. Descriptive statistics of sustainable indicators.

Descriptive statistics	Sustainable indicators																								
		Economics							Social					Environmental					Institutional				
		Ec1	Ec2	Ec3	Ec4	Ec5	Ec6	Ec7	S1	S2	S3	S4	S5	E1	E2	E3	E4	E5	I1	I2	I3	I4	I5
	Max	90	0.6	1,8	0.5	0.8	1.9	0.4	95	5	141	0.5	0.5	180	4.6	30	41	30	55	25	55	10	8
	Min	1.1	0.05	0.2	290	0.01	0.2	0.01	34	0.01	8.1	0.02	0.01	50	2.4	1.1	2	15	35	0.5	0.4	0.2	2
	Mean	19.1	0.4	1.1	17	0.6	0.7	0.2	77	1,2	9.1	0.2	0.3	110	3.1	12.1	12.5	22	45	12.4	21	7	6
	SD	21.4	0.5	0.9	44	23	0.0	0.4	30	4.1	127	0.6	0.9	31	2.3	27	49	12	17	21	66	9	7

Appendix 2

$$\hat{O}_{\text{,}CL}(\theta_1, ..., \theta_G; l_1, \cdots .., l_n|y) = \prod_{i=1}^{n} f_{t_i}(y_i|\theta_{t_i}) \tag{1}$$

Where the l_i are labels indicating a unique classification of each observation, $l_i = k$ if y_i belongs to the k^{th} component. In the maximum likelihood (1), each component is weighted by the probability that an observation belongs to that component. The presence of the class labels in the classification likelihood introduces a combinatorial aspect that makes exact maximization impractical (Fraley, & Raftery, 2002).

Each indicator x_{qc}^{t} for a generic country c and time t is transformed in

$$I_{qc}^{t} = \frac{x_{qc}^{t} - min_c(x_q^t)}{max_c\left(x_q^t\right) - min_c(x_q^t)} \tag{2}$$

where $min_c(x_q^t)$ and $max_c(x_q^t)$ are the minimum and the maximum value of x_{qc}^{t} across all countries c at time t. In this way, the normalised indicators I_{qc} have value lying between 0 (laggard, $x_{qc}^{t} = min_c(x_q^t)$) and 1 (leader, $x_{qc}^{t} = max_c(x_q^t)$) (Milligan, & Cooper, 1988; OECD (2008).

Appendix 3

$$SI_{sub,ij} = \sum\nolimits_{i=0}^{n} P_{ij} * I_{ij} \tag{3}$$

With the restriction:

$$\sum\nolimits_{i=0}^{n} P_{ij} = 1 \tag{4}$$

Appendix 4

$$I_{index} = \sum\nolimits_{i=0}^{n} W_i * I_{sub,ij} \tag{5}$$

Onde W_i is the factor that represents the weight of the sub-index.

While equation (6) was used to combine the sustainability sub-indexes for IDGR farms.

$$IG_{index} = \sum\nolimits_{i=0}^{n} W_i * I_{sub,ij} \tag{6}$$

Appendix 5

$$ISR = 0,33 * I_{sub,1j} + 0,33 * I_{sub,2j} + 0,33 * I_{sub,3j} \tag{7}$$

$$IRGS = 0,25 * I_{sub,1j} + 0,25 * I_{sub,2j} + 0,25 * I_{sub,3j} + 0,25 * I_{sub,4j} \tag{8}$$

where:

$I_{sub,1j}$ = is the value of the economic *sub-index*
$I_{sub,2j}$ = is the value of the environmental *sub-index*
$I_{sub,3j}$ = is the value of the social *sub-index*
$I_{sub,4j}$ = is the value of the institutional *sub-index*

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