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RESEARCH ARTICLE

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Strategic evaluation of the sustainability of the Spanish primary sector within the framework of the circular economy

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Abstract

Food security depends on the implementation of sustainable development in agri-food. It is essential to determine the sustainability of the main production systems in order to establish specific measures for each territory, by virtue of correcting their negative externalities and improving the commitment of stakeholders. Therefore, this article assessed the economic, social, environmental and global sustainability of the Spanish primary sector based on a synthetic indicator proposed in previous research. The results suggest the existence of a moderate degree of sustainability of the food production system in Spain (0.5019), with the regions of Aragón (0.5482), Castile and Leon (0.5473), Extremadura (0.5438) and Andalucía (0.5399) standing out. An inverse relationship between the economic and the environmental subcomponents of sustainability was obtained. The cluster analysis revealed the need to apply a customized territorial policy in order to meet sustainability goals due to the diversity of agricultural subsectors identified in them.

KEYWORDS
agriculture, circular economy, stockbreeding, sustainability indicators, sustainable development

1 | INTRODUCTION

Food production is an activity that provides employment and wealth. In the European Union, the wealth generated by agriculture and livestock (i.e., primary production) farming amounted to 1.8% of the Gross Value Added (GVA) and generated 4.4% of jobs in 2021. Spain generated 13.4% of the GVA produced by the primary production sector of the 27 member states in the European Union with only France and Italy producing more. In the same year, the GVA attributable to these activities reached 3.0% in Spain, and employment generated by the primary sector was 3.6%. Rural locations depend more on the wealth and employment generated by the primary sector (Maudos & Salamanca, 2022a, 2022b). Thus, in addition to safeguarding the sovereignty and food security of States, agriculture and stockbreeding help to sustain territorial balance, improve infrastructure, and combat depopulation in rural areas. The latter is due to the fact that rural areas generate both direct and indirect job opportunities through the auxiliary industry that satisfies the demand for products and services from the food production system. It is a fact that some types of primary production systems demand significant technology (i.e., digital tools, high-frequency irrigation systems, biofertilizers, bio-phytosanitary products, etc.) (Camacho-Ferre, 2004; Egea et al., 2017; Honoré et al., 2019; Martos-Pedrero et al., 2022; Valera-Martínez et al., 2017).

Since the mid-20th century, the intensification of food production has supported the increase in the world's population and its recent needs. In particular, the Green Revolution allowed for the expansion of the planet's carrying capacity, satisfying the demand for fiber and food required by an exponentially growing population. For example, wheat productivity rose 220.7% between 1961 and 2021. To achieve this, agricultural systems were transformed into models highly dependent on inputs (fertilizers, phytosanitary products, antimicrobials, energy, etc.) which genetically modify the plant species at the base of the food pyramid (FAO, 2017, 2019a, 2019b; FAOSTAT, 2022). The adverse effects have caused an increase in the consumption of natural resources, losses of genetic diversity, loss and degradation of soil, contamination of soil with animal health products, loss of air quality and groundwater, and the degradation of the ozone layer or visual pollution of natural spaces (Gómez-Tenorio et al., 2021; Martínez-Francés et al., 2009; Oehlmann et al., 2009; Pedraza et al., 2015; Zapata Sierra et al., 2022). Negative social externalities have also been observed, such as increasing disputes between inhabitants over land concession rights or the export of agri-food products from underdeveloped and food-dependent countries to markets of high economic interest, such as Europe (Ayompe et al., 2021). Therefore, it is necessary to identify the specific issues that affect the sustainability of each food production system to establish appropriate management measures and limit negative externalities. For this reason, it is crucial to make the information needed to make a decision available, which is not always the case (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023).

1.1 | Sustainability commitments

The signing of the 2030 Agenda by the UN Member States in 2015 meant the continuation of the sustainability commitments initiated at the end of the 1990s when the term sustainable development was defined. The 2030 Agenda includes 17 Sustainable Development Goals (SDGs) and 169 targets. These goals aim to improve the three subcomponents of territorial sustainability: social, economic, and environmental. The sustainability of agricultural and livestock production is also a priority, mainly from SDG-2, which aims to end hunger, and SDG-12, which addresses responsible production and consumption (ONU, 2015). Environmental impacts have led States to become more environmentally conscious, intending to mitigate the effects of climate change. In this sense, far-reaching changes are being made in structural policies to address this new reality (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Cifuentes-Faura, 2022; Davies et al., 2021). However, some current trends are calling for a greater change committed to degrowth, given the almost non-negotiable condition of the continued economic expansion of activities. Continued growth has been described as a utopian goal due to the biophysical limits of ecosystems (Keyber & Lenzen, 2021; Plaza-Úbeda et al., 2020; Rizos et al., 2017). Therefore, food production systems must adapt to current needs. This situation requires the implementation of strategic measures that allow sustainable development. To this end, it is necessary to have territorial information on the economic, social, and environmental sustainability of the production system to support the implementation of those strategies with objective data. Previous research has indicated that it is necessary to expand the information in the field of study and adapt it to the needs of each production system (Castillo-Díaz et al., 2022; Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Cirone et al., 2023; Streimikis & Baležentis, 2020).

On an international scale, the European Union has positioned itself as one of the most proactive territories in expanding the triple aspect of sustainability in its growth model (Cifuentes-Faura, 2022). Given the new agreements reached in the 2030 Agenda, the European Union has proposed a progressive and ambitious change from its linear production model to one based on the circular economy, with a time horizon up to 2050. Although there is a partial revision of the policy every decade, the first objectives for 2030 have already been identified (European Commission, 2019; 2020b). In terms of food production, the aim is a 50% reduction in the use of pesticides and their subsequent risk, a 20% reduction in the use of fertilizers, mainly phosphorus and nitrogen, a 25% reduction in the use of antimicrobials, and an increase in the European organic surface area up to 25%. The EU also seeks to preserve the biodiversity of ecosystems because of their close relationship with global Gross Domestic Product (GDP). Fifty percent of global GPD depends directly on nature (European Commission, 2020a, 2020c). These objectives have also been transferred to the current reformulation of the Common Agricultural Policy (CAP) of the European Union. This reformulation of the CAP is more committed to environmental sustainability in response to the demands of European society itself (European Commission, 2020; European Council, 2021). Expanding knowledge on agri-food sustainability would help to improve the design of agri-food policies (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023).

Despite the common objectives of the European Union Member States regarding the circular economy, there are some that stand out in terms of the implementation of these policies. Spain is among the eight Member States best positioned to adapt its activities to the framework of the circular economy (Mazur-Wierzbicka, 2021). This is because there is a stronger tradition of applying regulations based on the principles of the circular economy in agriculture (i.e., management of phytosanitary-product containers). Additionally, Spain has adapted its policies to European demands and has published a bioeconomy strategy, the Circular Economy Law, and other regulations that aim to boost the expansion of sustainability. Some revolutionary measures have been identified, such as a tax on single-use plastic to reduce dependence on this input (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Jefatura del Estado, 2022).

1.2 | The need to identify sustainable activities

The political dynamics described above create the need to quantify the economic, social, and environmental sustainability of economic activities to establish management strategies with which to implement sustainable development (De Carvalho et al., 2022; Núñez-Cacho et al., 2017; Prados-Peña, Gálvez-Sánchez, García-López, et al., 2022). Agriculture and livestock farming stand out as basic activities for the states due to their relationship with food sovereignty and security

(Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Maesano et al., 2021; Suresh et al., 2022).

Previous research has indicated that the sustainability of the agri-food value chain can be measured through a composite indicator formed from a set of indicators (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Suresh et al., 2022). Using this type of indicator simplifies a complex reality and also facilitates decision-making (OECD & European Commission, 2008). However, some of this research is purely theoretical and consists of selecting indicators with no practical application (De Carvalho et al., 2022). Practical information on this subject is not abundant and research may focus on determining the sustainability of agrifood production at the country level as opposed to not delving into how the parameter fluctuates in its regions since there are different food production models within the same state (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023). In addition, fluctuations in sustainability indicators may originate in the regulatory heterogeneity between regions of the same country, as they do in Spain (Román-Sánchez & Belmonte-Ureña, 2013). Therefore, it is vital to determine the sustainability of agri-food production in each territory by considering its characteristics.

Adequately estimating the sustainability of the agri-food system of each territory will be especially useful for the administration and private entities, allowing them to correctly plan the direction and speed in which they should develop the measures aimed at improving the regional sustainability of agricultural and livestock production. Through this classification, corrective measures can be developed to strengthen specific points or to facilitate decision-making in the granting of public or private funding (e.g., CAP aid, agricultural loans, etc.) (Azahara & González, 2021; Bao et al., 2022; Hahn et al., 2009; Omerkhil et al., 2020; Suresh et al., 2022). This research aimed to determine the economic, social, environmental, and global sustainability of Spanish primary production at the autonomous community level while addressing the needs of each territory.

First, the methodology used to construct a composite indicator to determine the economic, social, environmental, and global sustainability of food production in Spain is presented. Second, the different results obtained after statistical analysis of the data collected are shown. This is followed by a discussion of the results. Finally, the main conclusions, the limitations detected, and the possible lines of future research are highlighted.

2 | MATERIALS AND METHODS

2.1 | Main indicators of the Spanish primary sector

This article studied the sustainability of primary production (i.e., agriculture and livestock) in the Autonomous Communities of the Kingdom of Spain. This sector is comprised of 914,871 farms. In 2021, exports of the agri-food sector amounted to €60,118 million, while imports reached €41,170 million with a trade balance of €18,948 million. The consumption of fertilizers, phytosanitary, and veterinary services was 1,570,347 t, 76,024 t, and 651.4 million euros, respectively. Table 1 identifies the main indicators of agricultural production in Spain (INE, 2022; MAPA, 2022a; Maudos & Salamanca, 2022a, 2022b).

2.2 | Source of information

The first stage of this research consisted of a selection of indicators to quantify the economic, social, and environmental aspects of the sustainability of primary production in the Autonomous Communities of Spain. For this purpose, the selection methodology proposed by previous research that has determined the sustainability of the agri-food sector in the 27 member states of the European Union was used (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023).

2.2.1 | Bibliographic review

We carried out a systematic bibliographic review of the scientific literature since this methodology allows us to focus on the problem under study. We aimed to identify a battery of indicators that would make it

TABLE 1 Main context indicators of agricultural production in the Kingdom of Spain.

Main indicators			
Indicator	**Value**	**Indicator**	**Value**
Number of farms	914,871[a]	Agriculture and livestock employment	3.6%[b]
Exports	60,118 mill. €[b]	Fertilizer consumption	1,570,347 t[b]
Imports	41,170 mill. €[b]	Pesticide consumption	76,024 t[a]
Trade balance	18,948 mill. €[b]	Consumption of veterinary services	651,4 mill. €[a]
Agriculture and livestock GDP	3.0%[b]	Agriculture and livestock GHG	51,079.9 t de CO_{2e}[b]

Source: Own elaboration based on other authors (INE, 2022; MAPA, 2022a; Maudos & Salamanca, 2022a, 2022b).
[a]2020.
[b]2021.

possible to quantify numerically the sustainability of primary production in Spain. For this purpose, a systematic review of the "chain of references" or "snowball" type was used, which consists of reviewing the bibliographic references of an initial sample of publications (Batlles-delaFuente et al., 2022; Kitchenham, 2004; Tranfield et al., 2003). The database used was Scopus because it is considered one of the most complete repositories of scientific information in terms of articles, reviews, book chapters, and books (Elsevier, 2023; FECYT, 2022). The search strategy focused on the keywords agriculture, livestock, primary production, agrifood sector, indicators, sustainability, economic sustainability, social sustainability, environmental sustainability, quantification, and their synonyms. The main publications related to our topic of study were identified based on the keywords. In the second stage, reports and/or regulations of governments and international institutions of relevance to the topic addressed were reviewed. The literature review was conducted between January and July 2023. Table S1 presents the list of publications reviewed.

2.2.2 | Selection of indicators

Second, the selection of indicators was carried out. The selection of indicators for this study is based on the well-established relationship between the environmental, social, and economic dimensions of sustainability and agricultural activities within the context of the circular economy (Silvestri et al., 2022). These indicators have been chosen by considering relevant and recent research and review articles that connect the sustainability of the agri-food sector with the circular economy or the aforementioned dimensions (Abbate et al., 2023; Correia et al., 2020; Orou et al., 2023; Ruiz-Almeida & Rivera-Ferre, 2019; Scandurra et al., 2023; Silvestri et al., 2022). Special attention was paid to the relationship with the circular economy, given the importance of this production and consumption model for the European Union (European Commission, 2020b). Table S1 provides additional sources consulted during the selection process.

The methodology for indicator selection has taken into account the most widely used and relevant indicators in this field, as determined by the current state of the art (Gallo et al., 2023). These selected indicators are not only widely utilized but also strongly aligned with the objectives of this article (Falkenberg et al., 2023; Silvestri et al., 2022). Emphasis has been placed on Life Cycle Assessments (LCA) indicators due to their significance in evaluating and improving the agri-food industry in terms of social and environmental impacts (Esposito et al., 2020). Additionally, indicators used in Life Cycle Sustainability Assessment (LCSA) models have been included to ensure a holistic approach that covers social, environmental, and economic dimensions in this research (Arcese et al., 2023). In addition, this study has taken into consideration recent challenges and identified gaps in the research field, as highlighted by previous studies. These findings have been duly incorporated into the analysis. Moreover, the initial set of indicators was subject to evaluation by professionals from the agri-food sector as well as a diverse group of researchers.

After the literature review, the source of data to be used in the research was identified. The final availability of official information determined the type of indicator and its units. The time horizon of this research covered the years 2016–2021. Thus, a fundamental criterion was that the indicators should belong to official databases, guaranteeing precision in their collection, processing, and standardization. Therefore, the Territorial Indicators by Autonomous Communities offered by the Ministry of Agriculture, Fisheries and Food of the Government of Spain were used. These reports include Physical Environment Indicators, Agri-food and Fisheries Structural Indicators, and Investments and Transfers. The indicators were completed with information from other official sources, such as the National Institute of Statistics and the MAPA Statistical Yearbook. The e-mail addresses of the corresponding administrations and agencies were contacted to correct any missing data in the databases. During the initial phase, the indicators needed to fulfill the subsequent criteria: quantifiable, comprehensible, dependable, accessible, sustainable-oriented, official data, and of long-term nature (OECD & European Commission, 2008; Opon & Henry, 2019).

Finally, the selection of indicators was checked to ensure that they met the criteria of the Pressure-State-Response (PSR) model to validate the selected indicators because it is the most internationally accepted method to select sustainability indicators. This method has been recommended by institutions such as the Organization for Economic Cooperation and Development (OECD) and the United Nations Commission on Sustainable Development (CSD). (SDC) (Claudia et al., 2016; Lai et al., 2022; Martínez, 2009; Wang & Wang, 2021). This model is based on the principle of causality, which establishes that human activity exerts pressure on ecosystems, leading to changes that affect their quality. The model can also identify disturbances affecting ecosystems based on a cause-effect relationship between human actions and their effects on environmental quality. This allows us to classify the indicators into those that reflect the pressure of human activities, those that indicate the environmental situation, and those that reflect society's reactions to negative externalities (Martínez, 2009; Suresh et al., 2022; Woodhouse et al., 2000).

Finally, an impact on ecosystems (i.e., positive or negative) was assigned to each index (Table 2). This sign was given based on the literature consulted.

2.3 | Standardization of values

The second stage of this study consisted of applying a standardization procedure to the source indicators to obtain a synthetic indicator to compare the values of each indicator and the autonomous community. The review carried out in the previous stage made it possible to identify a standardized procedure recommended by institutions such as the UN, OECD, the European Commission and previous research (Bao et al., 2022; Hahn et al., 2009; Martínez, 2009; Nasrnia & Ashktorab, 2021; OECD & European Commission, 2008; Omerkhil et al., 2020; Pandey & Jha, 2012; Suresh et al., 2022). The normalization protocol uses the maximum and minimum values of the set of indicators, using Equation (1) for indicators that have a positive effect

TABLE 2 Indicators selected to evaluate the sustainability of Spanish primary production.

Aspect	Indicator	Unit	Impact on sustainability
Economic	Regional GDP weight of primary production	%	+
	Value of vegetable production	%	+
	Value of animal production	%	+
	Productivity	Euros/employee	+
	Fuel CPI	%	−
	Amount per mortgage on rural properties	Euros/mortgage	+
	Occupancy rate of rural tourism rooms	%	+
	Exports	Euros	+
	Rate of increase in exports	%	+
	Imports	Euros	−
	Trade balance	Euros	+
Social	Employed in the primary sector	%	+
	Food CPI	%	−
	Autonomous concession I Pillar CAP	%	+
	Regional concession II CAP Pillar	%	+
	Beneficiaries CAP small farmers	%	+
	Beneficiaries basic payment CAP	%	+
	Beneficiaries for practices favorable to the climate and the environment CAP	%	+
	Beneficiaries young farmers CAP	%	+
	Beneficiaries small farmers CAP	%	+
	CAP basic payment amount	Euros/beneficiary	+
	Amount for practices beneficial to the climate and environment CAP	Euros/beneficiary	+
	Amount for young farmers CAP	Euros/beneficiary	+
	Amount for small farmers CAP	Euros/beneficiary	+
Environmental	Cropland area	%	+
	Meadows and pastures	%	+
	Forestry area	%	+
	Nitrogen fertilizer consumption	kg/ha	−
	Phosphate fertilizer consumption	kg/ha	−
	Consumption of potassium fertilizers	kg/ha	−
	Consumption of phytosanitary products	%	−
	Consumption of veterinary services	%	−
	Energy consumption	%	−
	Protected crop area	ha	−
	Mulching area	ha	−
	Tunnel area	ha	−
	Irrigated crop area	%	−
	Farmers recycling packaging	%	+
	Recycled packaging	Container/area	+
	Census of white-coat pigs	Number of animals	−
	Cattle census	Number of animals	−
	Organic crop area	ha	+
	Organic livestock farms	Number	+

Abbreviations: CPI, Consumer Price Index; +, expresses a positive impact on the sustainability of primary production; −, expresses a negative impact on the sustainability of primary production.

on the sustainability aspect evaluated and Equation (2) for those that have a negative effect, namely:

$$Index_{sd} = {}^{S_d - S_{min}}\!/\!_{S_{max} - S_{min}}, \tag{1}$$

$$Index_{sd} = {}^{S_{max} - S_{sd}}\!/\!_{S_{max} - S_{min}}, \tag{2}$$

$$0 \le \mathrm{Index}_{sd} \le 1,$$

where, S_d is the value of each indicator, S_{max} y S_{min} is the maximum and minimum value for each selected indicator during the 2016–2021 period.

After standardizing the selected indicators, the value of the economic, social, and environmental subcomponents was calculated based on the average value of the set of indicators in each subgroup. Global sustainability was calculated by assigning a similar weight to each subcomponent of sustainability because of the European Union's goal of building an economic system capable of generating wealth and employment decoupled from the consumption of natural resources (European Commission, 2019). Different authors have recommended calculating global sustainability from the average of economic, social, and environmental sustainability (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Ćulibrk et al., 2021; Nasrnia & Ashktorab, 2021; Suresh et al., 2022). The process of aggregation simplifies the interpretation of outcomes, enabling the synthesis of intricate or multidimensional matters into a comprehensive perspective that facilitates a holistic examination of the system. Such representation not only promotes effective communication but also enables us to assess the system's efficiency. Hence, this type of representation was employed for these reasons (Nardo et al., 2005; OECD & European Commission, 2008). Figure 1 shows the pros and cons of using this composite indicator.

The following mathematical formula was employed:

$$\mathrm{IS} = \frac{\sum_{i=1}^{n} \mathrm{Index}_{sd}}{n}, \tag{3}$$

$$0 \le \mathrm{IS} \le 1,$$

where, IS is the global sustainability index of the primary production of each autonomous community in Spain, Index_{sd} is the economic, social, and environmental sustainability index of the primary production of each autonomous community in Spain, and n is the number of subcomponents.

2.4 | Statistical treatment

A statistical treatment was applied to identify behaviors from the results.

First, an analysis of variance was performed on the social, economic, environmental, and global sustainability index, using the one-way ANOVA test and establishing the independent variable as the territory. The assumptions of normality and homoscedasticity were previously checked. The post hoc test of least significant differences (LSD test) was performed at a confidence level of 95% to establish subgroups. This analysis is recommended by previous research to identify the existence of statistically significant differences between factors of the same variable (García-Raya et al., 2019; Marín-Guirao et al., 2019).

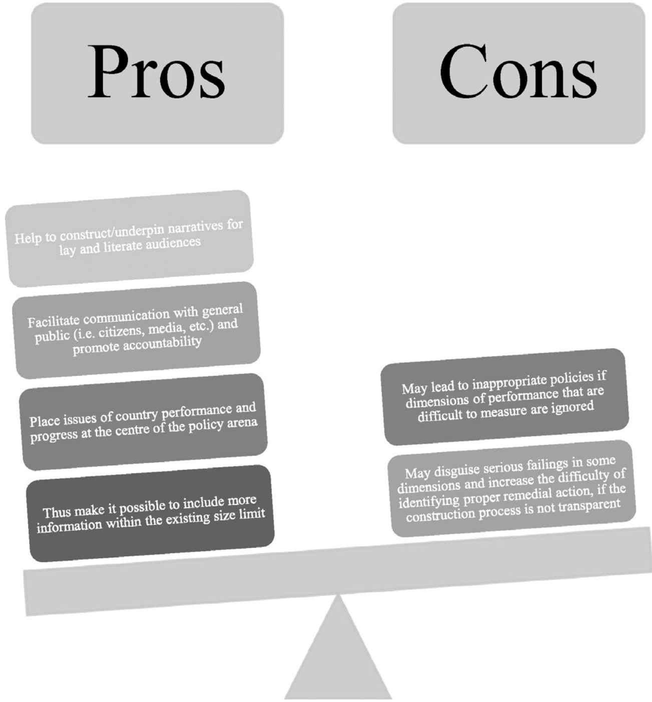


FIGURE 1 Advantages and disadvantages of using a composite indicator. Source: Own elaboration based on OECD and European Commission (2008).

Secondly, a hierarchical cluster analysis was performed using Ward's method to identify the similarity between the sustainability of the different autonomous communities in Spain (Saraçli et al., 2013). Through this approach, which has been used in a multitude of investigations, patterns and trends can be identified in a set of data and variables (Liu et al., 2022; Pasin & Gonenc, 2023). This is achieved by minimizing the distance between observations and maximizing the distance between clusters (Basel & Prabhakara, 2022). The number of clusters was determined using the binomial coefficient offered by the three subcomponents of sustainability, according to previous research (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023). To compare the results obtained with each other, the ANOVA test and the LSD test indicated above were performed.

Third, Pearson's correlation coefficient (r) between economic, social, and environmental sustainability was determined to identify direct or inverse relationships between the three subcomponents of sustainability. This procedure has been used in a multitude of previous studies to determine the relationship between the variables (Schober & Schwarte, 2018).

The one-way ANOVA test, LSD test, and Pearson's coefficient (r) were obtained with the statistical package STATGRAPHIC

CENTURION XVIII (Manugistic Incorporate, Rockville, Maryland) for Windows, while the cluster analysis was carried out with the SPPS v.28 package for Windows (IBM, Armonk, NY, USA).

Figure 2 shows a flow chart identifying the stages followed in the methodology of this work.

3 | RESULTS

3.1 | Composite indicator

3.1.1 | Economic, social, and environmental sustainability

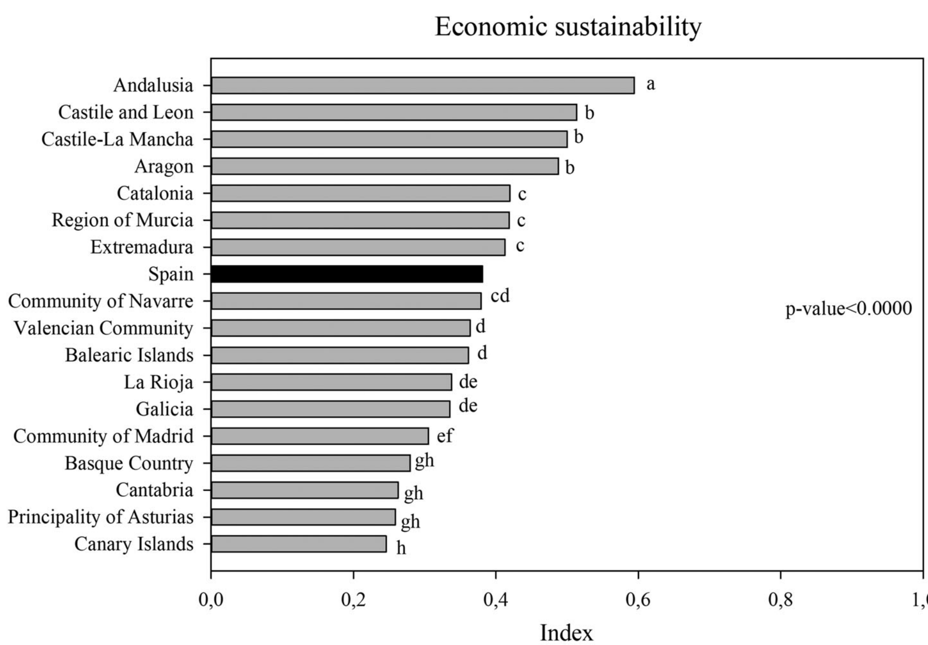
Graphs 1–3 show the synthetic indicator of the economic, social, and environmental aspects of the sustainability of primary production in the 17 autonomous communities of Spain during the period 2016–2021. Statistically significant differences (one-way ANOVA; p-value <0.05) are appreciated between the different territories evaluated within each subcomponent of sustainability.

In terms of economic sustainability, Andalusia (0.5945) shows the highest values of the composite indicator in the period analyzed as it is significantly higher than the rest of the autonomous regions. Behind this region, the autonomous communities of Castile and Leon (0.5134), Castile-La Mancha (0.4999), Aragon (0.4875), Catalonia (0.4194), Region of Murcia (0.4188) and Foral Community of Navarre (0.3793) stand out. On the other hand, the territory that showed the lowest value of economic sustainability was the Canary Islands (0.2459), although this sustainability is similar to the figures offered by the Principality of Asturias (0.2585), Cantabria (0.2625), and the Basque Country (0.2795).

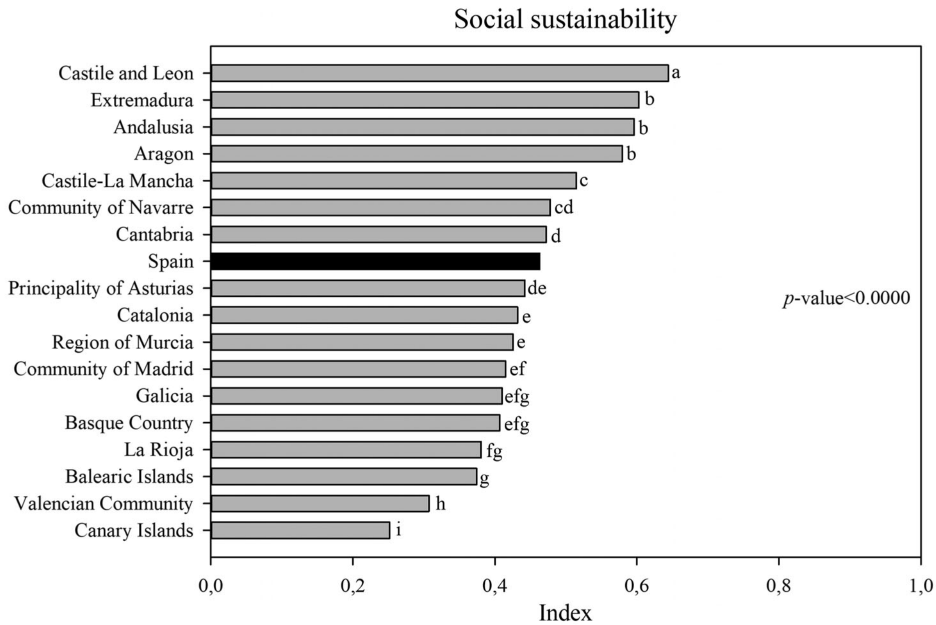
Furthermore, according to the proposed indicator, Castile and Leon (0.6443) was the Spanish autonomous community with the highest social sustainability. Behind this region and above the average value for Spain are Extremadura (0.6027), Andalusia (0.5963), Aragon (0.5794), Castile-La Mancha (0.5145), the Autonomous Community of Navarre (0.4779) and Cantabria (0.4719). It can be noticed that some of the communities located in the highest positions of the ranking coincide with the most important regional primary production. Thus, the correlation coefficient between the variables is moderate ($r = 0.6150$; p-value ≤ 0.05; Graph 4).

The environmental sustainability of primary production shows an inverse relationship with the economic ($r = -0.6643$; p-value ≤ 0.05) and social ($r = -0.3801$; p-value ≤ 0.05) subcomponent (Graphs 5 and 6). In this sense, territories such as the Community of Madrid (0.7125), the Basque Country (0.7073), La Rioja (0.6915), or the Principality of Asturias (0.6845) that were in lagging positions in the economic or social sustainability rankings get the top spot in terms of environmental sustainability. The regions of Andalusia (0.4600), Castile and Leon (0.5005), Catalonia (0.5521), the Region of Murcia (0.5525), Castile-La Mancha (0.5334), Aragon (0.5679), Extremadura

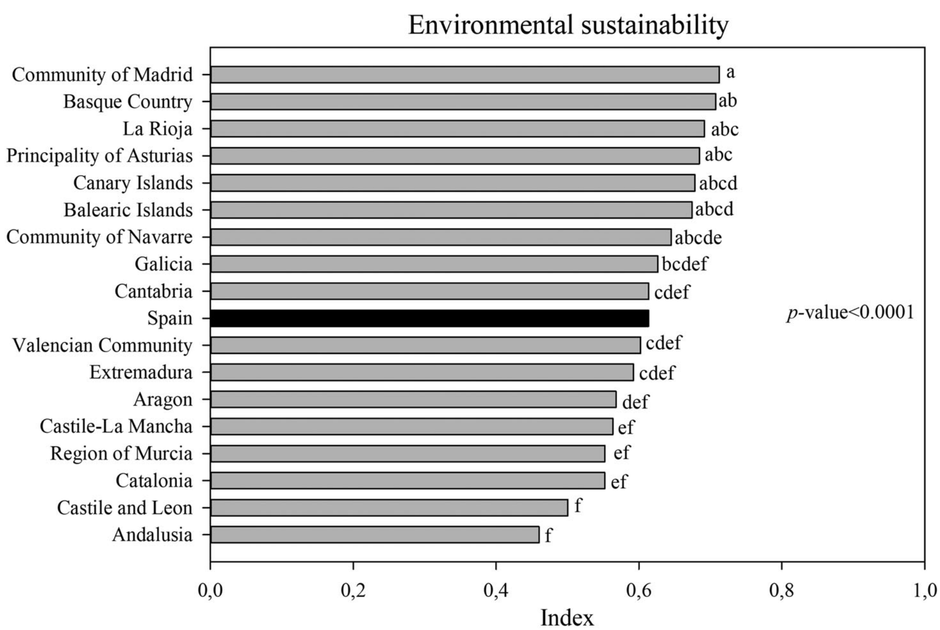
FIGURE 2 Stages followed in the construction of the composite indicator.



GRAPH 1 Economic sustainability of primary production in the autonomous communities of Spain. Different letters indicate significant differences between autonomous communities (one-way ANOVA; p-value ≤ 0.05; LSD test).



GRAPH 2 Social sustainability of primary production in the autonomous communities of Spain. Different letters indicate significant differences between autonomous communities (one-way ANOVA; p-value ≤ 0.05; LSD test).



GRAPH 3 Environmental sustainability of primary production in the autonomous communities of Spain. Different letters indicate significant differences between autonomous communities (one-way ANOVA; p-value ≤ 0.05; LSD test).

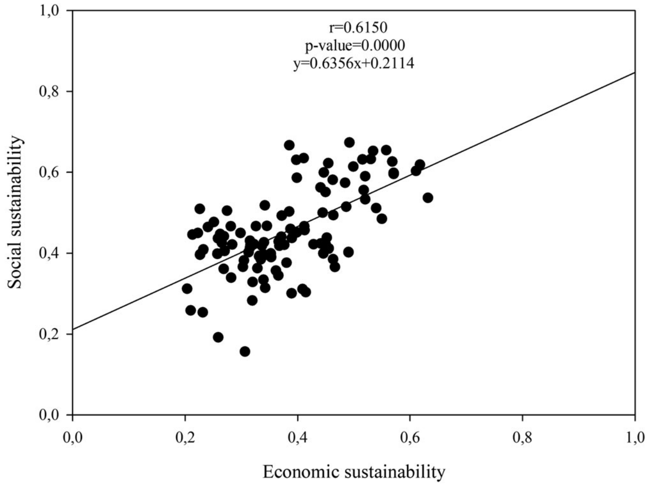
(0.5925), the Valencian Community (0.6023), Cantabria (0.6136), and Galicia (0.6266) show the lowest environmental sustainability, being statistically similar to each other. Despite this, there are diverse agricultural and livestock production systems in these territories, which articulate and balance the rural vertebration.

3.1.2 | Global sustainability

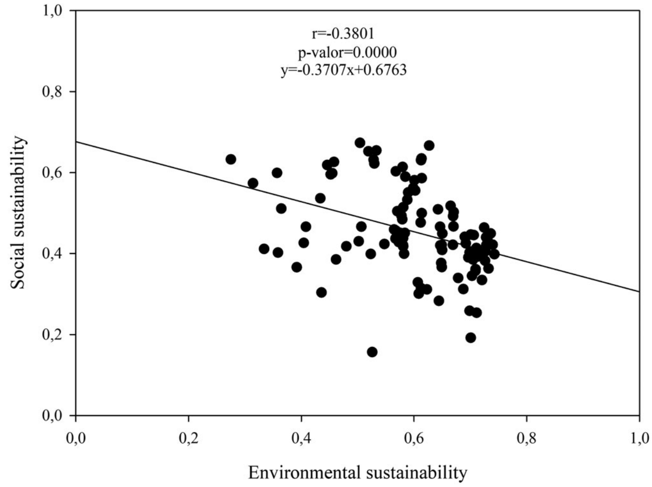
Graph 7 shows the overall sustainability of Spain's primary production between 2016 and 2021. This graph shows statistically significant differences between different groups of autonomous communities. However, there is a statistical similarity between the first 11 autonomous territories. Aragon (0.5482), Castile and Leon (0.5473), Extremadura (0.5438), Andalusia (0.5399), Castile-La Mancha (0.5305), and the Foral Community of Navarre (0.5305) showed an overall sustainability higher than the average for Spain. The Valencian Community (0.4451) obtained the lowest overall sustainability of primary production for the period 2016–2021, although it was statistically similar to the 10 autonomous communities that surpass the average value of this community.

3.2 | Cluster analysis

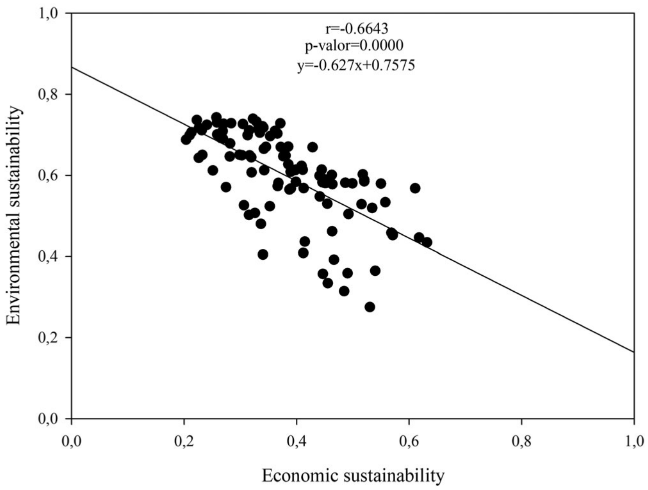
Table 3 contains the cluster analysis carried out to determine the aggregate similarity of the economic, social, and environmental



GRAPH 4 Relationship (r) between the economic and social sustainability of primary production in the autonomous communities of Spain (one-way ANOVA; *p*-value ≤ 0.05).



GRAPH 6 Relationship (r) between social and environmental sustainability of primary production in the autonomous communities of Spain (one-way ANOVA; *p*-value ≤ 0.05).



GRAPH 5 Relationship (r) between economic and environmental sustainability of primary production in the autonomous communities of Spain (one-way ANOVA; *p*-value ≤ 0.05).

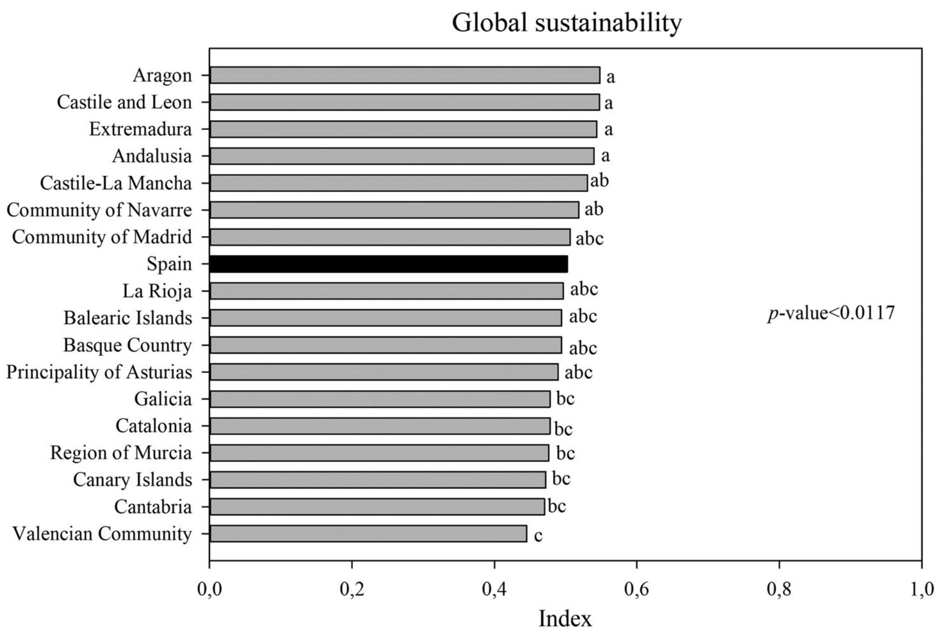
sustainability of primary production in the autonomous communities of Spain. These territories are included in the six theoretical clusters established based on the binomial coefficient obtained from the three components of sustainability. Despite this, the post hoc test (one-way ANOVA, *p*-value < 0.05; LDS test) identified five statistical clusters for economic and social sustainability and three statistical clusters for environmental sustainability, which may be associated with the standard of policies that have to be implemented in each territory.

The first cluster includes the autonomous communities of Andalusia and Castile and Leon. Their primary production stands out in economic and social aspects, but it shows low environmental sustainability. In cluster two are Aragon, Castile-La Mancha, and Extremadura. Their agriculture and livestock production show moderate to high values regarding the balance between economic, social, and environmental sustainability. Cluster three includes the autonomous communities of the Principality of Asturias, Cantabria, the Community of Madrid, and the Basque Country, whose primary production has achieved low economic sustainability, low-to-moderate social sustainability, and high environmental sustainability. In cluster four, the Balearic Islands, Galicia, and the Autonomous Community of Navarre exhibit low to moderate economic sustainability, low-to-moderate social sustainability, and high environmental sustainability of their primary production. In the fifth cluster, we find the Canary Islands, whose agricultural production has been characterized by low economic and social sustainability and high environmental sustainability. Finally, cluster six includes Catalonia, the Region of Murcia, La Rioja, and the Valencian Community, whose primary production shows low to moderate economic, social, and environmental sustainability.

4 | DISCUSSION

The aim of this work was to evaluate the sustainability of primary production in the 17 autonomous communities of Spain. For this purpose, we used a composite indicator justified in previous research to apply a standardization process recommended by institutions such as the OECD and SDC. The composite indicator was composed of 11 economic indices, 13 social indices, and 19 environmental indices, which can be identified in Table 2.

The results of this research suggest the existence of moderate economic, social, and environmental sustainability of primary production in the 17 autonomous regions of Spain (Graphs 1 and 3). The presence of intensive farming systems has expanded the economic weight of agriculture and livestock in the Spanish regional economy, mainly in rural environments (Castillo-Díaz, Batlles-delafuente, et al., 2023;



GRAPH 7 Overall sustainability of primary production in the autonomous communities of Spain. Different letters indicate significant differences between autonomous communities (one-way ANOVA; p-value ≤ 0.05; LSD test).

TABLE 3 Results of the cluster analysis based on the social, economic, and environmental subcomponents of sustainability.

Cluster	Territories	Economic sustainability	Social sustainability	Environmental sustainability
1	Andalusia, Castile and Leon	0.5546 ± 0.0525 a	0.6203 ± 0.0354 a	0.4752 ± 0.0766 c
2	Aragon, Castile- La Mancha and Extremadura	0.4676 ± 0.0505 b	0.5655 ± 0.0526 b	0.5555 ± 0.0982 b
3	Principality of Asturias, Cantabria, Community of Madrid and Basque Country.	0.2788 ± 0.0441 e	0.4338 ± 0.0361 c	0.6648 ± 0.0861 a
4	Balearic Islands, Galicia and the Foral Community of Navarra	0.3582 ± 0.0474 d	0.3898 ± 0.0618 d	0.629 ± 0.1010 a
5	Canary Islands	0.2486 ± 0.0409 e	0.2519 ± 0.0693 e	0.6671 ± 0.0700 a
6	Catalonia, Region of Murcia, La Rioja and Valencian Community	0.4214 ± 0.0397 c	0.4286 ± 0.0201 c	0.5351 ± 0.089 bc
	p-Value	0.0000	0.0000	0.0000

Note: Different letters indicate significant differences between autonomous communities (One-way ANOVA; p-value ≤ 0.05; test LSD).

Castillo-Díaz, Belmonte-Ureña, et al., 2023; Heider et al., 2022; Honoré et al., 2019; MAPA, 2022a; Valera-Martínez et al., 2017). This is the case of some areas of Andalusia, Castile-La Mancha, Castile and Leon, the Region of Murcia, Catalonia, Aragon, or Extremadura, thus explaining the results obtained in this research. In addition, these territories obtained high values in indices such as the availability of arable land, the weight of agricultural production in GDP, productivity per employee, or the value of plant or animal production (MAPA, 2022a; 2022b; Maudos & Salamanca, 2022a) (Table S2). The agricultural subsectors that could bring the greatest economic benefit would be greenhouse crops, olive groves, grapevines, tropical and subtropical fruit trees, white-coat pork, Iberian pork, dairy or meat cattle, and dairy or meat sheep/goat farms, among others. Some of them have differentiated quality seals following the production principles established by European Union regulations or strict specifications specifically designed for the territory and approved by the European Administration (e.g., organic agriculture and protected designation of origin). These quality seals can increase the selling price of the products (MAPA, 2018; Maudos & Salamanca, 2022a; Reisman, 2022). Thus, these subsectors have developed local productive systems based on the utilization of endogenous resources, which favors the creation of both direct and indirect employment, the latter from the proliferation and settlement of the auxiliary industry that supplies the products and services demanded by the farms. Indeed, in some cases, large multinationals, both in the agrotech and biotech sectors, have been attracted to establish headquarters in the area and offer their products and services to the agrosystems (Castillo-Díaz, Belmonte-Ureña, et al., 2023; Valera-Martínez et al., 2017). Therefore, innovation is a fundamental factor in the prosperity of food production and rural environments, where companies committed to implementing innovations in their food production increase their exports to third world countries (Esparcia, 2014; Martos-Pedrero et al., 2022). This would explain the direct relationship between the economic and social indices identified in this study (Graph 2). The commercial openness of local production systems may also have influenced the results. In this sense, greenhouse agriculture in the southeastern peninsular of Almeria exports an average 80% of its production to European Union member states, collecting more than 2.9 billion euros annually. This figure represents

30.1% of the nominal GVA generated by agriculture and fisheries in Andalusia (Cajamar, 2022; Honoré et al., 2019; Maudos & Salamanca, 2022a). In addition, even though some autonomous communities are lagging in the economic ranking (e.g., the Canary Islands), different farming and livestock systems benefit local economies. For example, the Canary Islands have the Platano de Canarias denomination of origin, which provides wealth and employment to the regional economy and acts as a tourist attraction (ASPROCAN, 2021; Bianchi, 2004; González-Concepción et al., 2008).

The economic benefit and the employment generated by primary production lead to the enrichment of agricultural and livestock farming environments, which are mainly located in rural areas. Thus, the employment generated by this activity and the destination of aid through the CAP increases the sustainability of agricultural systems. Our work has identified a direct relationship between economic and social sustainability, which can be explained for this reason (Graph 4). The territories that have achieved greater social sustainability are Castile and Leon, Extremadura, Andalusia, and Aragon. In these territories, there may be a greater availability of agricultural and livestock subsectors. European aid from the Community Agricultural Policy (CAP) contributes to the survival of these sectors because of the importance of primary production in these territories. These subsectors include cereals, herbaceous crops, cotton, olive groves, and various species of fruit trees (Picazo-Tadeo et al., 2011; Terres et al., 2015).

The greater availability of subsidized crops in these territories may have influenced the achievement of these results (Table S3). On the other hand, despite the direct relationship between economic and social sustainability, the territories at the top of the economic ranking have changed their position in the social ranking. This can be explained by the presence of specific agricultural or livestock subsectors that receive a greater volume of direct aid or by the total number of potential beneficiaries that may exist in each autonomous community (Graphs 1–7) (European Council, 2021; FEGA, 2023; MAPA, 2023a).

In addition, this work has identified an inversely proportional relationship between the economic and environmental sustainability of primary production in the autonomous communities of Spain (Graph 6). Thus, the degree of intensiveness of the farms, which expands the demand for inputs, could have a negative influence on the results due to the higher consumption of fertilizers, phytosanitary products, veterinary services, areas protected under plastic, or the increase of animals raised in intensive farms (Graph 7 and Table S4) (De Carvalho et al., 2022; Valera-Martínez et al., 2017). The low integration of the environmental capabilities of companies has also had an influence, since the expansion of this parameter favors the integration of the supply chain in the environmental performance of the organization (Tarifa-Fernández et al., 2023). This behavior has generated significant environmental impacts on Spanish ecosystems. For example, the Mar Menor (Region of Murcia) has been eutrophicated from nutrients discharged into it from activities of diverse nature, such as intensive horticulture (Díaz-Martínez et al., 2023). Increases in heavy metals have been recorded in soils where intensive crops have been grown under plastic (Gil et al., 2018). The application of a dissimilar environmental policy among the autonomous communities may have also played a role due to the transfer of powers by the central government in these territories. It has also been shown that different penalties are applied among the Spanish autonomous communities for the same environmental damage (Román-Sánchez & Belmonte-Ureña, 2013). Therefore, autonomous communities such as Andalusia, Castile and Leon, Catalonia, and the Region of Murcia are lagging. Despite this, a strong commitment is being made in these territories to farming systems framed within the principles of organic agriculture in the European Union, where the addition of inputs of chemical origin is prohibited (European Union, 2018; MAPA, 2022a). In addition, European consumers have a better perception of products that have organic certification, and they are willing to pay up to 50% more for an organic product than for one obtained through the conventional system (Etuah et al., 2022; Smith et al., 2021). Thus, the expansion of organic agriculture in primary production in Spain could not only improve the environmental sustainability of the activity but also the economic sustainability. This could also be helped by the inclusion of the principles of circular economy and bioeconomy, a political commitment of the European Union to the use of by-products that reduce production costs and reduce the addition of synthetic fertilizers (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; European Commission, 2020a; Mazur-Wierzbicka, 2021). In addition, it would be necessary to rethink the current production system based on the continuous growth of production, which has already begun to exceed the biophysical limits of ecosystems (Rizos et al., 2017). To this end, it is necessary to implement an agri-food production system based on sustainable development while ensuring the sovereignty and food security of states.

The cluster analysis performed in this work, where the total number of clusters was set from the binomial number offered by the three components of sustainability, identified the need to apply five different degrees in the application of economic and social policies and three for the environmental ones. Therefore, the results of the research suggest that the transition to a sustainable agri-food production model requires a specific territorial policy implemented at different speeds to achieve a common objective: to transform Spain's food production into a resilient and environmentally friendly sector. The Government of Spain should help to increase the export share of specific agri-food subsectors linked to territories with less economic sustainability while betting on production framed in organic agriculture to increase the producer expense accounts (European Commission, 2020a; Maudos & Salamanca, 2022b). At the same time, public and private entities should promote the creation of nationally and internationally recognized brands based on differentiated quality seals under the principles established in the European Organic Production Regulation. It is a fact that consumers pay more for products with this type of quality certification (Castillo-Díaz, Batlles-delafuente, et al., 2023; Castillo-Díaz, Belmonte-Ureña, et al., 2023; Etuah et al., 2022; Smith et al., 2021). In addition, the share of processed products in the agri-food supply should be boosted by increasing the quota of transformation from primary products to processed products with a higher market value and greater profit margins. Expansion of artisanal products should also be promoted since they influence consumer perception of purchases (Prados-Peña, Gálvez-Sánchez, Núñez-Cacho, et al., 2022). The electronic sales channel should be enabled and improved in order to increase its market share in other parts of Spain. The implementation of this sales channel may present difficulties in the case of the agri-food sector due to the perishable nature of food, but this problem could be solved if marketing is carried out through short channels, such as direct sales. Likewise, the technological tools offered by digitalization (i.e., tools for calculating irrigation, fertilization, robotization, e-commerce, etc.) can increase the profitability of agri-food farms and their development should, therefore, be encouraged. In this regard, the Spanish Government is making a significant economic effort to promote the modernization of the primary sector. At the same time, digital transformation can be a suitable instrument to allow new generations to access a more competitive sector with better social and labor conditions. This could accelerate the generational handover in the agri-food sector, where only 0.5% of Spanish farm owners are under 25 years old (INE, 2022; MAPA & Cajamar, 2022).

From the environmental point of view, the objective should be to eliminate the inverse relationship between economic growth and environmental sustainability. In this sense, promoting digitalization and ecosystem-friendly techniques could be the best alternative. The selective application of inputs should be favored, which would improve the environmental subcomponent of our synthetic indicator. In addition, it would help monitor the critical points of farms, especially those that contribute most to greenhouse gas emissions. Implementing a digital farm logbook can help improve the environmental indices of this type of operation. Through this device, it is possible to identify which farmers are the most and least efficient and to apply corrective measures. Undoubtedly, information is the most helpful element to improve the environmental footprint of food production (MAPA, 2023b; MAPA & Cajamar, 2022; Ministerio de la Presidencia, 2023). The expansion of renewable energy sources—mainly agrivoltaic energy—in agriculture and livestock farming should be encouraged (Carrausse & De Sartre, 2023; Schallenberg-Rodriguez et al., 2023; Willockx et al., 2022). Introducing practices framed within the principles of the circular economy should be favored. However, such practices must go beyond improving the recycling rate. In particular, production under the principles of the circular economy must also entail a reduction in the supply of inputs (Kirchherr et al., 2017; Mazur-Wierzbicka, 2021). For example, in the case of intensive greenhouse agriculture, it has been demonstrated that reusing agricultural biomass leads to the reduction of up to 100% of inorganic fertilizers in a tomato crops (García-Raya et al., 2019). Finally, the Spanish government could apply an input-restriction policy modulated by the autonomous community to reduce inputs such as fertilizers and phytosanitary or zoosanitary products in those territories with an upward trend in consumption to meet the target set by the European Commission for 2030.

5 | CONCLUSIONS, LIMITATIONS AND FUTURE LINES OF RESEARCH

The results of this research, based on the analysis of a composite indicator made up of 42 indicators, suggest the existence of moderate sustainability of primary production in Spain. Aragon (0.5482), Castile and Leon (0.5473), Extremadura (0.5438), and Andalusia (0.5399) top the overall sustainability ranking, while the Region of Murcia, the Canary Islands (0.4719), Cantabria (0.4701), and the Valencian Community (0.4451) have the lowest values. In addition, we detected an inversely proportional relationship between economic and environmental sustainability. Therefore, the economic prosperity of the Spanish agricultural and livestock systems is associated with a high consumption of agricultural inputs. This means the efficiency of their use must be improved within the framework of the circular economy.

The cluster analysis made it possible to classify the 17 autonomous communities into the six groups proposed. It showed the need to apply five levels of economic and social policies and three levels for environmental policies. Thus, it is necessary to implement a policy adapted to the needs of each territory to eliminate the inverse relationship detected in this research between economic and environmental sustainability. Thus, the Spanish Government should be more restrictive in those regions that are less environmentally sustainable and less compliant with EU environmental requirements. However, the effects on food security and sovereignty, both for Spain and other European Union countries, should be assessed given Spain's importance as an exporter of agri-food products. The sector should also be made more attractive to young farmers and ranchers to achieve the desired generational replacement needed. The digital transformation of the agri-food sector can make the primary sector more attractive to young people. These innovations would improve working conditions, increase the productivity of the countryside, and reduce the environmental footprint of food production. Additionally, the results of this research suggest the need to increase the competitiveness of the Spanish primary sector. To this end, it is necessary to increase the commercial openness of the sector and to strengthen food brands that carry differentiated quality seals.

Despite this, research advancing the knowledge of the sustainability of primary production in the autonomous communities of Spain is not free of limitations. It has been influenced by the availability of updated indicators that were evaluated over several consecutive years, affecting the scope of the work. Institutional repositories should be updated periodically to facilitate immediate decision-making by analyzing the information. Finally, it should be noted that updating the databases used may modify the values obtained in this work.

Future research should identify the sustainability of the most important agricultural subsectors of primary production in Spain based on a composite indicator with the objectives of applying tailor-made policies for each farming system and improving their efficiency.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The source of the data is referenced in the materials and methods section.

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SUPPORTING INFORMATION

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