UNIVERSIDAD DE EXTREMADURA

TESIS DOCTORAL

Contribución al estudio de la ganadería ecológica en Extremadura: situación actual y perspectivas

ANDRÉS HORRILLO GALLARDO

CIENCIA DE LOS ALIMENTOS

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PHD THESIS

Contribution to the study of organic livestock in Extremadura: current situation and prospects

ANDRÉS HORRILLO GALLARDO

2020

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En Badajoz, a 22 de julio de 2020.

El Autor,

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SUMMARY

The Dehesa is classified as one of the most singular agroforestry systems in the European Union. In the southwest of the Iberian Peninsula it spreads over an area of approximately 6.7 million hectares. In addition to livestock farming production, these systems also contribute environmental, cultural and aesthetical value to the region and they are necessary for the development and settlement of the rural population. The main business activity that is developed in this ecosystem is extensive livestock farming of cattle, sheep and Iberian pigs with low stocking density and few inputs. The sustainable management of these farms is essential in order to ensure the continuity and preservation of their ecosystems, as well as the improvement of their profitability.

In spite of extensive livestock farming production systems being a key element in the sustainability of the Spanish and European Union ecosystems, they are inadequately classified under the same umbrella as generic livestock farming and are described as one of the main reasons for the existing environmental issues. In this regard, it is necessary to clearly differentiate the various livestock farming production systems and promote those that are most sustainable for the natural medium.

Given the need of sustainable livestock farming systems, the implementation of organic livestock production in dehesas can provide interesting benefits. This may seem an apparently easy process from the point of view of compliance to the standards. However, such conversion cannot be limited to the strict compliance of the laws regulating organic production, but it also must promote the development of other business practices and strategies to ensure success.

This doctoral thesis has been developed within the above context by engaging into a deep analysis of the organic livestock farming sector's current situation in the southwest of Spain and the potential conversion of dehesa livestock farming towards organic production models. For this purpose, participative research methodological frameworks, such as the Delphi method and the focus groups, have been used. But also the case study of several organic farms has been developed by means of their

economic and environmental analysis with a focus on financial profitability, carbon footprint, carbon sequestration and economic-environmental balance.

The following describe the contents of this paper: in Chapter I, a Delphi analysis was used with a group of experts in dehesa organic livestock farming production in order to assess the dehesa livestock farming systems' potential to transition from a traditional model to organic production, particularly, in the case of cattle farms. Chapter II presents the development of participative research with the focus group method through four sessions with thirty-three participants, to deal with the barriers for the conversion from the extensive livestock farming system to the organic production model; proposes the establishment of an inventory of the issues in order to find solutions for the improvement of the productivity, sustainability and commercialisation of organic products. Chapter III includes a case study of seven organic farms using the life cycle analysis to measure carbon footprint and carbon sequestration in the farms under study. Chapter IV is a case study of the organic farms in order to calculate an estimate of the maximum price per tonne of CO_2 eq that the various types of organic farms in dehesa and rangelands of the southwest of Spain could bear in three different scenarios. For this purpose, the economic-environmental balance was calculated, taking into account economic balance, GHG emissions and carbon sequestration levels in each case.

Key words: agroecosystems; Delphi method; focus group methodology; economic analysis; carbon footprint; carbon sequestration; economic profitability; agro-environmental policy; agricultural practices; ecosystem services; cattle systems; sheep systems; goat systems; Iberian pig systems; sustainability.

RESUMEN

La dehesa, es un sistema agroforestal considerado como uno de los ecosistemas más singulares de la Unión Europea, se sitúa en el suroeste de la Península Ibérica y se extiende sobre una superficie aproximada de 6,7 millones de hectáreas. Estos sistemas, aparte de sus producciones ganaderas, aportan valores ambientales, culturales y estéticos y son necesarios para el desarrollo y fijación de la población rural. La principal actividad que se desarrolla en este ecosistema es la ganadería extensiva de ganado vacuno, ovino y porcino ibérico con baja carga ganadera y pocos insumos. La gestión sostenible de estas explotaciones es esencial para asegurar su continuidad, la conservación de los ecosistemas y la mejora de su rentabilidad.

Los sistemas de producción ganadera extensiva a pesar de ser un elemento clave en la sostenibilidad de los ecosistemas en España y en la Unión Europea, de forma errónea se engloba con la ganadería de manera genérica y se les considera como una de las principales causas de problemas medioambientales. En este sentido, es necesario diferenciar los sistemas de producción ganadera y promocionar aquellos más sostenible en consonancia con el medio natural.

Teniendo en cuenta la necesidad de sistemas ganaderos sostenibles, la implantación de la producción animal ecológica en la dehesa puede reportar beneficios interesantes. Este proceso es aparentemente sencillo desde el punto de vista del cumplimento de la normativa. Sin embargo, esta conversión no debe limitarse al estricto cumplimiento de la legislación en materia de producción ecológica, sino también debe fomentar el desarrollo de otras prácticas y estrategias empresariales que garanticen el éxito.

En este contexto, se plantea esta tesis doctoral que profundiza en el análisis de la situación actual de la ganadería ecológica en el suroeste de España y las posibilidades de conversión de la ganadería en zonas de dehesa hacia modelos de producción ecológica. Para ello, se han utilizado marcos metodológicos de investigación participativa como el método Delphi y los Focus Group, y el estudio de casos de explotaciones ecológicas en base al análisis económico y ambiental, centrándose en la rentabilidad económica, la huella de carbono, secuestro de carbono y el balance económico-ambiental.

En una descripción de los contenidos del trabajo, en el capítulo I se utilizó un análisis Delphi con un grupo de expertos en producción ganadera ecológica en las dehesas para valorar el potencial que tienen los sistemas ganaderos en dehesas para pasar del modelo tradicional a la producción ecológica y en particular en el caso de las explotaciones de vacuno. El capítulo II, basado en la investigación participativa mediante la metodología de Focus Group, aborda mediante cuatro sesiones y treinta tres participantes los factores que dificultan la transición a un modelo de producción ecológico de los sistemas ganaderos extensivos, establecer un inventario de problemas y encontrar soluciones para mejorar la productividad, la sostenibilidad y la comercialización de productos ecológicos. En el capítulo III se realizó un estudio de casos de siete explotaciones ecológicas donde se evaluó mediante el análisis del ciclo de vida la huella y el secuestro de carbono de las explotaciones del estudio. El capítulo IV, realizó un estudio de casos de las explotaciones ecológicas para calcular una estimación del precio máximo por tonelada de CO_2 eq que podrían soportar los distintos modelos de explotaciones ganaderas ecológicas en las dehesas y pastizales del suroeste de España en tres escenarios diferentes. Para ello se calculó el balance económico-ambiental, considerando el balance económico, las emisiones de GEI y los niveles de secuestro de carbono de cada caso.

Palabras clave: agroecosistemas; método Delphi; metodología Focus Group; análisis económico; huella de carbono; secuestro de carbono; rentabilidad económica; política agro-ambiental; prácticas agrarias; servicios ecosistémicos; sistemas de vacuno; sistemas de ovino; sistemas de caprino; sistemas de porcino ibérico; sostenibilidad.

GENERAL INTRODUCTION

Livestock production is of major importance in the dehesa and rangeland ecosystems of the southwest of Spain. These agricultural systems are part of the agrifood sector and must comply with a double purpose: food provision and the generation of positive externalities such as, for example, the provision of ecosystem services (Ghisellini et al., 2014; Rodríguez-Ortega et al., 2014). Nevertheless, the estimated increase in the population, the growing demand of animal-derived food products, such as meat and milk (Garnett, 2009), the rise of the quality standards and the negative impact of the livestock production systems on the environment, make it difficult for food provision and sustainability to go hand in hand (Godfray et al., 2010). On this account, livestock production systems require redesigning since, in spite of their being a key element for the sustainability of the ecosystems and of society, they are also deemed to be one of the main causes for environmental impact.

In this context, several authors propose the organic production model as a sustainable production option, given that they provide certain advantages in comparison with conventional intensive production, namely: (i) lesser environmental impact on the ecosystems (Tuomisto et al., 2012); (ii) increase of biodiversity (Phalan et al., 2011); (iii) mitigation of desertification (Thomas, 2008); lower energy consumption (Lee et al., 2008); and (iv) potential contribution to local development and economy (O'Hara and Parsons, 2012).

This doctoral thesis intends to assess the current situation and perspectives of the organic livestock farming production systems in Extremadura, at the same time as defining the barriers that prevent their growth, the proposals for improvement that may promote their conversion, their actual economic profitability and environmental impact. And lastly, this paper presents a study featuring a simulation in three different scenarios on how the opening of carbon markets would affect organic livestock farming by establishing a price for CO_2, which would be paid by the farms according to their environmental impact.

The current organic livestock farming situation in Extremadura is also analysed on the basis of the official data registered by the Ministry of Agriculture, Fisheries and Food for the number of farms and the number of livestock heads. Also, in order to approach the future perspectives of this type of livestock farming system, participative analysis methodologies were used, and a deeper analysis was made into the current concern for the environment and climate change through the calculation of the carbon footprint and carbon sequestration.

The organic farming sector in Spain and Extremadura. Inventories and geographic distribution

The organic livestock farming sector in Spain has experienced a general growth in terms of structure and inventories without large variations throughout the last six years. There has been a notable increase in the number of livestock heads of species such as cattle, sheep and poultry, although with specific differences amongst the various species such as, for example, the one-off fall of the organic milk sheep that took place in 2016.

With regards to the volume of this segment, table 1 shows the number of farms by livestock species and by year for the 2014-2018 period.

Table 1. National inventory of organic farms. 2014-2018 period.

Total National	Bovine		Swine	Sheep		Goat	
	Meat	Milk		Meat	Milk	Meat	Milk
2014	2798	76	132	1680	41	509	138
2015	3436	79	155	2084	85	566	211
2016	3538	151	145	2125	56	567	192
2017	3539	175	139	2004	87	536	185
2018	3562	201	155	2033	100	526	193

MAPAMA, (2019, 2018, 2017, 2016, 2015).

Additionally, table 2 shows the national inventory of organic livestock heads for the 2014-2018 period.

Table 2. National inventory of organic livestock heads. 2014-2018 period.

Total National	Bovine		Swine	Sheep		Goat	
	Meat	Milk		Meat	Milk	Meat	Milk
2014	163693	4521	6790	4449543	17936	31312	25154
2015	185445	4779	10741	573989	22220	33444	36004
2016	191889	7834	10311	565574	16943	39923	33477
2017	197851	9270	9938	564845	26055	38097	33097
2018	201593	10473	20196	585920	37038	34807	41699

MAPAMA, (2019, 2018, 2017, 2016, 2015).

With regards to year 2018, the total number of farms in Spain by autonomic region is shown in table 3.

Table 3. Number of organic livestock farms in Spain. Year 2018.

Autonomic Region	Bovine		Swine	Sheep		Goat	
	Meat	Milk		Meat	Milk	Meat	Milk
Andalucía	2266	-	64	1412	43	320	117
Aragón	8	1	3	19	-	3	-
Asturias	176	40	-	30	-	20	-
Baleares	47	4	30	140	3	12	5
Canarias	4	-	4	3	16	-	13
Cantabria	68	24	1	10	-	3	-
Castilla-La mancha	87	1	2	96	16	34	22
Castilla y león	24	1	3	7	5	1	6
Cataluña	470	9	13	109	3	90	17
Extremadura	176	-	16	132	-	22	7
Galicia	165	109	14	33	-	10	-
Madrid	13	2	-	1	-	-	1
Murcia	-	-	-	-	-	-	2
Navarra	14	2	-	19	6	6	2
La Rioja	1	-	1	-	-	-	-
País Vasco	32	8	4	19	8	2	1
Comunidad Valenciana	11	-	0	3	-	3	-
Total	3562	201	155	2033	100	526	193

MAPAMA, (2019).

Extremadura alone has 5.2 % of the farms of the national total (MAPAMA, 2019) and is the fifth region in the Spanish inventory in number of livestock heads by autonomic region, with a total of 19,231 beef cattle; 1,102 pigs; 85,475 meat sheep; 346 and 1,163 meat and milk goats, respectively. It is worth noting that this autonomic region does not have registered milk cows and sheep, which are important species in other regions such as Andalusia (milk sheep) and Galicia (milk cows). On the other hand, it has 176 organic cattle farms, which situates it in the third position together with Asturias at national level, and 132 meat sheep, 22 meat goat, 7 milk goat and 16 pig farms (MAPAMA, 2019).

In spite of the data provided by the inventories, Extremadura continues to an area of major importance in number of organic producers, although it has little relevance in terms of transformation or commercialisation of organic products.

Dehesa and rangeland organic livestock production systems: environmental aspects

According to Reglamento (UE) 2018/848, 2018 on the production and labelling of organic products, organic production is a general agricultural and food production management system that combines the best environmental practices with a high biodiversity level, the preservation of natural resources, the application of demanding requirements for animal wellbeing and a production that is adapted to the specific preferences of a certain type of consumer, who demands products that are obtained from natural materials and processes. Therefore, organic production methods play a double social role, i.e. the provision of organic products to a specific market thus meeting consumer demand, and providing public services that contribute to the protection of the environment, animal wellbeing and rural development.

Additionally, in terms of the environment, it is worth highlighting that these organic livestock production systems apply agricultural environmental practices that contribute to the preservation of the agricultural ecosystems to a greater extent than conventional systems (non-organic). In particular, organic production systems held reduce issues such as the impoverishment of soil (Marinari et al., 2006), the loss of biodiversity (Rahmann, 2011) and eutrophication (Thieu et al., 2011). Also, from the socioeconomic viewpoint, organic livestock production models can help improve the profitability of the livestock farms by applying a price premium for the sale of their products, especially when these are directly sold to the consumer (Wittman et al., 2012), with these facts being essential to reduce the abandonment of farms, the level of unemployment and rural depopulation (Lobley et al., 2009).

In spite of the above and the fact that sustainability is a global concept that includes four pillars (environmental, social, economic and political), organic production is not sustainable by itself (Goldberger, 2011). It is necessary to plan farm layout and management as well as its socioeconomic and environmental context, as sustainability of the production systems depends on many factors that are often interrelated, that depend on the system itself and evolve with time (Ripoll-Bosch et al., 2012; Tuomisto et al., 2012). In fact, there is certain amount of debate with regards to the potential of organic production systems and especially in ruminant farms, since these systems tend to be less productive and efficient than the intensive systems, thus causing their Global Warming Potential (GWP) per kg of product to be high, making it more difficult to combine food provision and environmental sustainability. Nevertheless, these systems usually have lower environmental impact by hectare and contribute notably to socio-environmental sustainability due to their multifunctionality (Casey and Holden, 2006; Ripoll-Bosch et al., 2013).

In the context of dehesas, the implementation of organic systems in dehesa ecosystems follows a line of research that states that the implementation of mixed and diverse agroforestry systems (such as those of dehesa) can be a feasible production option, allowing a balance between production and preservation (Dumont et al., 2013; Smith et al., 2013). Agroforestry production systems combine woodland, rangeland and livestock. This combination creates biodiverse and functional systems that enable the cohabitation of productivity and environmental protection through the provision of certain ecosystem services, as well as environmental and social benefits, such as the preservation of biodiversity, soil regulation, air and water quality and carbon sequestration (Jose, 2009; Torralba et al., 2016). From the socio-economic viewpoint, this translates into a lesser dependence on external factors, diversifying the sources of income, increasing financial stability and stimulating the local economy (Garrity, 2004). This is particularly important within the context described above and in low-input systems such as that of dehesas.

In accordance to the above, and taking into account the close and dependence relationship between livestock production and sustainability (environmental. economic and social), the implementation of grazing-based organic systems in agroforestry systems appears to bring interesting benefits (Bernués et al., 2011). Grazing-based extensive systems are key for the dehesa and rangeland ecosystems of the southwest of the Iberian Peninsula (Ripoll-Bosch et al., 2013), as they help increase carbon sequestration (Horrillo et al., 2020), improve pasture quality, reduce the level of invasion of scrubs and the risk of fire (De Rancourt et al., 2006; Henkin et al., 2011; Jose, 2009). Additionally, organic production systems make a more efficient use of the water resources (Thierfelder and Wall, 2009), prevent soil degradation and increase fertility (Niggli et al., 2007), as well as increasing water retention and resistance to draught (Muller and Davis, 2009; Thierfelder and Wall, 2009). Such aspects are especially interesting in semi-dry land with scarce water resources and poor soils such as the dehesas and rangelands in the southwest of Spain. Due to the complexity of the agricultural systems that are managed through organic models, the level of interaction between the components of the system is high and, consequently, these organic systems tend to be more resistant to plagues and disease (Birkhofer et al., 2008; FAO, 2007; Meyling et al., 2010).

Nevertheless, in spite of these ecosystems enjoying all the aforementioned benefits, they also raise concerns such as increasing soil impoverishment and the reduction of the water reserves (Azadi et al., 2011). These, amongst others, ate two of the main issues that the ecosystems of this region's production systems face, particularly the organic livestock systems that are used in semi-dry areas of dehesas and rangelands in the southwest of Spain. In this sense, it is easy to understand the need for research and studies to be carried out on these organic production systems to help face challenges such as sustainability and food provision.

Qualitative methodology and participative research as a way to approach the organic livestock sector's current situation

The current national livestock farming situation, in terms of environmental preservation and financial profitability, makes it necessary for an imminent intervention aimed at preserving the dehesa and rangeland ecosystems, which in turn must be compatible with productivity levels that allow for proof provision. There are standards that currently regulate the environmental, social and economic components of the livestock production system such as the Common Agricultural Policy (or PAC, in its Spanish abbreviation), which provides economic grants and agro-environmental measures (organic production) and is leading the evolution towards a dehesa organic livestock production model.

Nevertheless, the various amendments to the Common Agricultural Policy (PAC) and the continuous market changes have brought about a decrease in the profitability of conventional extensive livestock farming. As a result, changes have taken place in the use of the land, which have derived in the intensification of production and the abandonment of traditional farms (Gaspar et al., 2009, 2008; Ripoll-Bosch et al., 2013). At the same time, low profitability in dehesa farms has led producers to make changes in order to adapt their production models (Gaspar et al., 2009), a fact that has contributed to increase the number of organic livestock farms. Such increase has come about both due to the peculiarities of these systems and the price premiums the EU producers receive, all in the context of an increasing demand of organic products in Europe and worldwide (Mesías et al., 2012).

Such events, together with the similarities between the dehesa systems and the organic systems, could give rise to dehesa farms being seen as offering optimum conditions for the development of organic livestock farming, although it is the various standards and regulations, as well as the variety of production systems and products, that can determine their conversion to the said production models. As a result, the adaptation of these systems is not the same for all livestock species and crop systems (Blanco-Penedo et al., 2012).

The preservation of dehesa and rangeland systems is necessary and must be compatible with productivity levels that allow for their economic sustainability. We can conclude that there are many different factors affecting the implementation of organic livestock production in dehesa areas and it is not easy to establish clear guidelines as to the future and feasibility of such farms by using quantitative research tools alone. The use of other approaches that may help overcome such difficulties becomes necessary, namely, the Delphi methodology or the focus group method. Such qualitative approaches allow to deal with complex issues by using expert groups or sessions with participants from different specialities (Linstone and Turoff, 2002).

The Delphi method is a qualitative forecasting technique (a method based on human criteria rather than quantifiable data) which emerged in the second half of the 20th century. The Delphi method has been used as a way to generate predictions in uncertain situations where objective data techniques cannot be used (Landeta and Barrutia, 2011). However, Delphi forecasting has been more recently applied to various fields, such as forestry management (Edwards et al., 2011), climate change and food production (Kirezieva et al., 2015), or the prediction of lack of irrigation (Alcon et al., 2014). Additionally, this method has also been recently applied in agricultural systems to, for example, the analysis of animal tracking technologies (Busse et al., 2015), the construction of support systems for the management of farms (Tanure et al., 2013), or the assessment of the ecosystem services provided by agricultural systems (Rositano and Ferraro, 2014). However, this type of analysis can be considered as novel in the assessment of organic livestock farming systems.

On the other hand, the methodology known as "focus group", based on qualitative research with a participative focus, has proven to be a valid approach in the assessment of the organic livestock farming's current situation, as this type of research is often used to understand a problem situation and its motivating factors, as well as being flexible and versatile (Stewart et al., 1994).

This method, which is developed through focus group sessions, is a technique that has been already used in many projects associated with the farming sector, such as that of Alarcon et al., (2017), who used focus group sessions in order to identify the deficiencies and vulnerabilities of the beef meat market in Nairobi city; Ates et al., (2017), who employed the same technique in order to determine the consequences of the decisions associated with the agricultural policies being adopted in Turkey from the point of view of the farmers; Gaspar et al., (2016), who employed this technique to analyse the value society grants to agroforestry systems, and Kaler and Green, (2013), who used it with the purpose of understanding the current and future role of veterinaries in matters of animal health in the sheep farms of the UK from the farmers' viewpoint.

Climate change and livestock farming: Life cycle assessment and carbon footprint in dehesa and rangeland organic livestock systems

The preservation of the environment through agriculture is a future project currently gaining acceptance in the entire European Community. The fight against climate change has become of the highest importance in current times and is the main reason for the calculation of the carbon footprint (CF) in food products. This trend is due to the growing importance that climate change has attained in the environmental world program (Röös et al., 2011), and how the production of food significantly contributes to the increase of human GHG emissions (Florindo et al., 2017). Such impact has caused consumer growing interest in production methods and other attributes of food products (Forsman-Hugg et al., 2008), which, in turn, has led to an increasingly larger number of media discussions about the impact of livestock production on climate and the differences between intensive livestock production and extensive and rangeland livestock production (Pelletier et al., 2010).

In this sense, measuring the impact of the extensive system's agricultural and farming activities and, specially, the impact of dehesa areas, becomes an important objective, as it helps differentiate extensive livestock and organic production systems from other more intensified systems, which use less natural resources and more food inputs (Eldesouky et al., 2018).

The continuous production of studies on the GHG emissions caused by agricultural practices has shown a variety of opinions up to now. Research studies such as that of Smith et al., (2019) state that the conversion to organic agriculture in a specific area would reduce the GHG emissions, but would also decrease production. Other papers compare organic production systems with high-performance agriculture, arriving at the conclusion that high-performance agriculture is as sustainable as organic agriculture and the selection of the system will be key for the future of biodiversity (Balmford et al., 2018). Others such as that of Muller et al., (2017) propose organic agriculture as an essential part of the future of the food systems, together with a dramatic change in the food culture and a reduction of food waste.

The most popular techniques for the estimation of the GHG emissions in livestock farming are the life cycle assessment (LCA) method and the carbon footprint (CF) calculation. The latter is used to calculate the emissions of any kind of product and is becoming increasingly popular. The carbon footprint method provides an estimate of the total GHG emissions produced during part or the entire life of a good or service, expressed as CO_2eq (Galli, 2015). This method has been increasingly used in food chain products, defining the amount of GHG emissions produced at each stage of the production process and, additionally, extensible to the distribution and use stages (Jones et al., 2014).

Ecosystem services: carbon sequestration as an indicator of environmental sustainability

Up to the present time, conventional agriculture has been mainly valued for its capacity to provide food and other resources for society, while its efficiency has been assessed in financial terms from the start. However, the future perspectives tend to adopt a more holistic approach for the evaluation of agriculture that requires research into the level of services unrelated to food supply that it must also provide.

The concept of ecosystem services (ES), made popular by MEA, (2005), refers to the direct and indirect benefits people can obtain from ecosystems. The ES can be classified into four groups: i) food supply services, which are the material benefits people obtain from the ecosystems, for example, the supply of food, water, fibres, wood and fuel; ii) regulation services, which are the benefits obtained from the regulation of the ecosystem processes; for example, the regulation of air quality and soil fertility, the control of floods and disease and the pollination of crops; iii) cultural services, which are the immaterial benefits people obtain from the ecosystems, as for example, the source of inspiration for aesthetical representations and engineering works, cultural identity and spiritual wellbeing; and iv) basic support services, also defined by TEEB, (2010) as habitat services, which are necessary for the production of all the other ecosystem services, for example, the provision of spaces for plants and animals to live, allowing for diversity of species and maintaining genetic diversity.

The majority of these services are public benefits and therefore they do not have a price and cannot be privatised, as they do not have market value (de Groot et al., 2012). Therefore, farmers are offered few incentives to provide these public services and this is even more notable in the extensive farming systems, as the livestock farming systems based on rangelands tend to be less productive.

As mentioned in previous sections, *dehesa* and rangeland livestock production systems are complex and integrate numerous factors that are interrelated and affect their sustainability (Jaksic et al., 2006; Veysset et al., 2010). These ecosystems require adequate management due to their important role in the protection and regulation of the main ecosystem services (carbon sequestration, preservation of biodiversity and water resources) (Beauchemin et al., 2010; Maya et al., 2017; Olea and Miguel-ayanz, 2006; Soussana et al., 2007). In this sense, the regulation of these livestock farming systems and the maintenance of the number livestock heads allow for the existence of positive externalities or ecosystem services, in particular environmental services, which can play a major role in the preservation of the landscape (Alemu et al., 2017; Florindo et al., 2017), the improvement of biodiversity (Kanyarushoki et al., 2009; Robertson et al., 2015), the prevention of forest fires (Pardo et al., 2016) and carbon sequestration in their soils (Noya et al., 2018), amongst others.

In this respect, the farms analysed in this paper provide numerous ecosystem services and amongst all of them, carbon sequestration plays a priority role in the fight against climate change (Ripoll-Bosch et al., 2013; Wiedemann et al., 2015). The carbon sequestration concept refers to the changes in the soil in terms of the composition of the carbon levels (C). Such changes take place in the soil due to the addition of residues such as manure, crops and rangelands. Specifically in organic extensive farming systems, rangelands and crop lands can be considered as a form of carbon sequestration and an option to mitigate the carbon footprint of these types of production systems (CNMC, 2018; Eldesouky et al., 2018; Huijbregts et al., 2016; IPCC, 2006; Stanley et al., 2018).

<u>The carbon market as a strategy to support dehesa and rangeland organic livestock systems</u>

As we have seen, the fight against climate change has become one of the major challenges in current society. Agricultural production, livestock production systems and food processing systems are currently being questioned. On this account, the CO_2 market in livestock farms is an issue that must be presented to the public sector for consideration, as an emissions market based on charging the cost of pollution to the parties responsible for contamination so that, as the costs increase, they may feel tempted to stop contaminating.

In this sense, the economic and financial instruments can become a valid tool to reduce CO_2 emissions, minimise environmental impact and compensate for that externality in the most environmentally-efficient farms. Amongst the potential instruments, the carbon markets propose to establish a price for CO_2 emissions, which is promoted by many countries with initiatives such as the European Union Emissions Trading Scheme (EU ETS). The EU ETS works on the "cap and trade" principle and has proven that establishing a price on the carbon emissions can be an very efficient tool in the fight against climate change and the reduction of contamination (Dougherty et al., 2019; Stanley et al., 2018).

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OBJECTIVES

The objectives of this thesis are:

1. Evaluation of the potential of *dehesa* livestock systems to change from a traditional production model to an organic model. In particular, the case of beef cattle, as this is the main type of farm animal being reared in the *dehesas*.
2. Study of the barriers for the conversion of extensive livestock farming systems to organic production models, establishing an inventory of the barriers and proposals for improvement in order to optimise productivity, sustainability and commercialisation of their organic products to allow the redesign the livestock systems of the current *dehesa*.
3. Development of a case study with actual organic farms in order to calculate the balance of the greenhouse gas emissions (GHG), taking into account both carbon footprint and carbon sequestration in the organic livestock production systems of Extremadura's *dehesas*.
4. Estimation of the maximum price per tonne of CO_2 eq that the various models of *dehesa* and rangeland organic livestock farms in the southwest of Spain could bear through the study of the findings from the three different scenarios.

GENERAL METHODOLOGICAL FRAMEWORK

The structure of this thesis is based on a set of four interrelated scientific articles within the topic of agriculture and livestock farming, with organic livestock farming and the environment being the main topic. Additionally, this thesis explains the findings of a research project on the current and forecast situation of organic livestock farms in Extremadura, which is in line and continues previous research studies developed by the research group on livestock production systems in the region of Extremadura.

Figure 1 describes the general methodological framework, including the data sources and the specific methods for data collection and analysis that helped achieve the objectives. This figure also includes the main methodologies, although some previous tasks such as interviewing, questionnaire design and database building have not been included.

The aforementioned objectives are met in the chapters of the thesis. In Chapter I, a Delphi analysis was used with a group of experts in dehesa organic livestock farming production in order to assess the dehesa livestock farming systems' potential to conversion from a traditional model to organic production, particularly, in the case of cattle farms. In Chapter II, participative research was used through a focus group approach in order to study the barriers for the conversion of extensive livestock systems to an organic production model, establishing an inventory of issues and finding potential solutions. In Chapter III, seven different livestock systems and four zootechnical species were selected to calculate, using the life cycle analysis, carbon footprint and carbon sequestration in the selected cases. Chapter IV used the data from six farms in order to calculate their profitability by application of the Integrated Accounts System method to the Economic Accounts of Agriculture and Forestry and the environmental analysis of Chapter III in order to estimate the maximum price per tonne of CO_2 eq that the various organic livestock farm models could bear in the deshesas and rangelands of the southwest of Spain.

General methodological framework

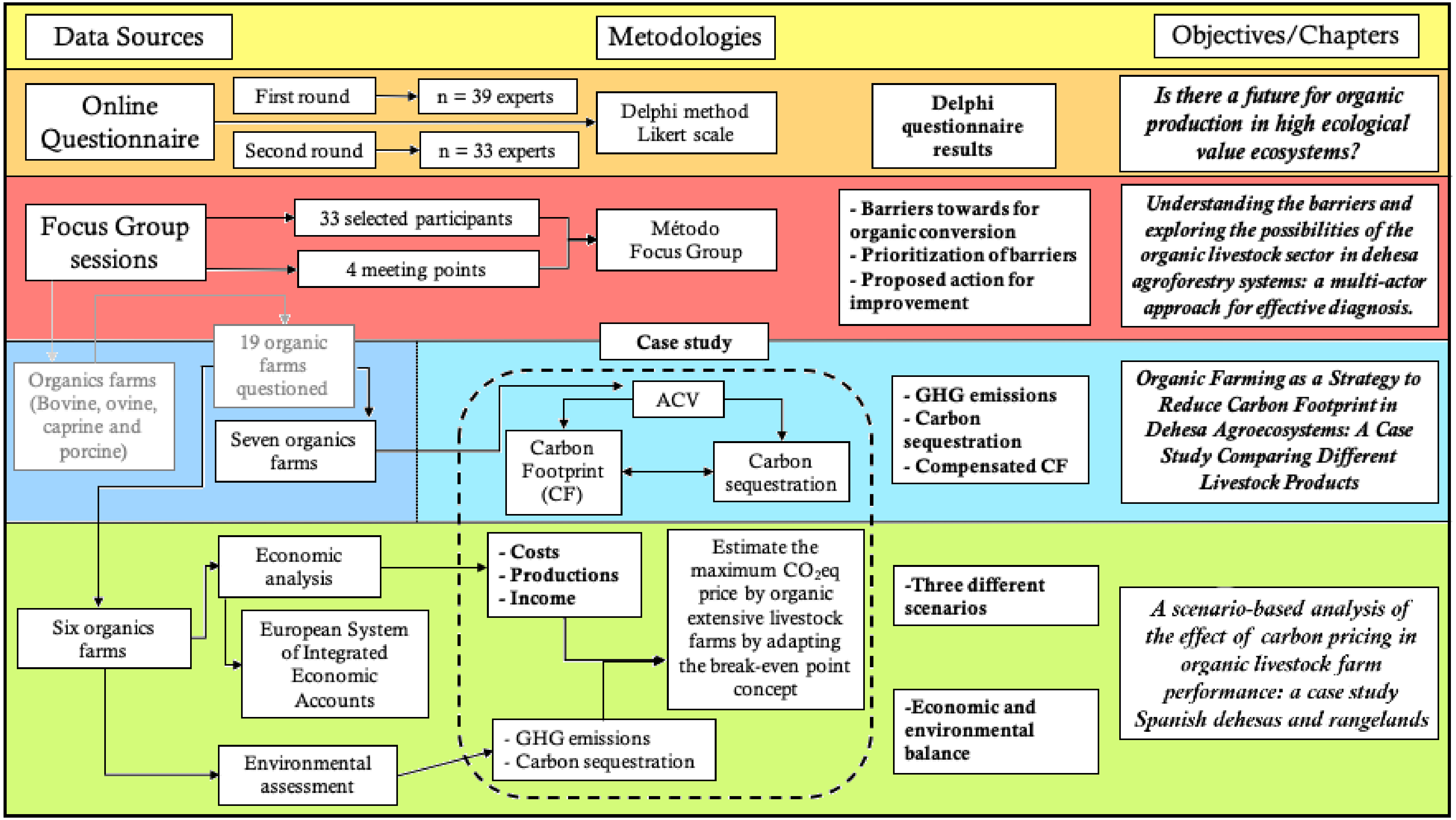

Figure 1. Objectives, methodologies, and data sources of the thesis

Chapter I. Is there a future for organic production in high ecological value ecosystems?

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Is there a future for organic production in high ecological value ecosystems?

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Abstract

Dehesas (rangelands typically located in the Southwest of Spain) are agro-silvo-pastoral systems traditionally used in agriculture and livestock farming, where livestock uses large pasturelands in wooded regions. These systems stand out for their high environmental and socio-economic value, where livestock farming plays an essential role in their maintenance and conservation. The dehesa is located in the SW quadrant of the Iberian Peninsula, occupying a total area of 5.8 million hectares in Spain and 0.5 million hectares in Portugal.

Within this context, this paper analyses the potential these systems have to switch from the traditional model to organic production, in particular in the case of beef, as cows are the main livestock being reared in dehesas. For this purpose, we have used a Delphi analysis with a panel of experts in organic livestock production on dehesas. A total of 47 experts were selected from public institutions, farming, research bodies, agricultural organisations and companies in the industry.

After a two-round study, some of the most relevant aspects for the future of organic beef production in dehesas were analysed: the evolution of its productive system, the marketing of the produce and the positive or negative effects-either as a stimulus or a deterrent-that the EU Common Agricultural Policy its agri-environmental

measures would have. The experts highlighted some relevant aspects that hinder the implementation and/or the transition from a traditional farm to an organic model, i.e. sales of the final product becoming stagnant, the lack of self-sufficiency in organic feed and the difficulty of access to organic certified slaughterhouses.

In this sense, the implementation of specific lines of subsidised funding that encourage the production of organic beef in dehesas would be desirable. These support schemes, together with marketing improvements and the increase of market prices, would guarantee the continuity of the holdings in this production segment.

It has also been agreed that the transition from traditional farms to organic production systems will result in a reduction in the use of non-renewable resources, thus decreasing stocking rates and finally increasing the environmental externalities of the dehesas, which would therefore enhance their conservation.

Key words: Dehesa; High-ecological value; Organic; Beef farms; Delphi.

1. Introduction

The dehesa is the oldest and most extensive agro-silvo-pastoral system in Europe (Moreno and Pulido, 2008). It is traditionally used in agriculture and livestock farming and is characterised by livestock grazing on large pasturelands in wooded areas. These production systems stand out for their high environmental and socio-economic value (Escribano et al., 2001), where livestock plays an essential role in their maintenance and conservation. These systems are based on the use of autochthonous livestock species being able to effectively exploit natural resources by grazing. The joint rearing of cattle, sheep and Iberian pig is a common practise that allows a more efficient use of the grazing resources provided by the dehesas (Gaspar et al., 2009). Human intervention has been crucial in the maintenance of dehesa ecosystems, as the use of cultivation methods has preserved the arboreal layer, thus preventing the invasion of scrub and increasing the efficiency of the system (Coelho, 1994; Escribano and Pulido, 1998).

The dehesa is located in the SW quadrant of the Iberian Peninsula (Fig. 1), occupying a total area of 5.8 million hectares in Spain and 0.5 million hectares in Portugal (Gaspar et al., 2008; Joffre et al., 1999). The predominant tree species are the holm oak (Quercus ilex subsp Ballota.) which is found in 80% of the dehesa lands, followed by the cork oak (Quercus suber), and, to a lesser extent, the Pyrenean oak (Quercus pyrenaica), the gall (Quercus faginea) and the kermes oak (Quercus coccifera) (Mapa Forestal de España, 2001a, 2001b). Dehesa soils are acidy and shallow, with low fertility due to their insufficient content in organic matter and a significant lack of phosphorus. Such characteristics make them inappropriate for cultivation of cereals (San Miguel, 1994).

The climate is continental Mediterranean, and the average annual temperatures vary from 16 to 17 °C. The summers are long, hot and dry; July temperatures are usually over 26 °C on average, with the highest temperatures exceeding 40 °C. The winters tend to be mild, with an average temperature of 7.5 °C. Rainfall is distributed unevenly and it varies between 300 and 800 mm/year, with large variations from year to year (Espejo and Espejo, 2006; Hernández, 1998). Average altitudes range from 300 to 700 m above sea level.

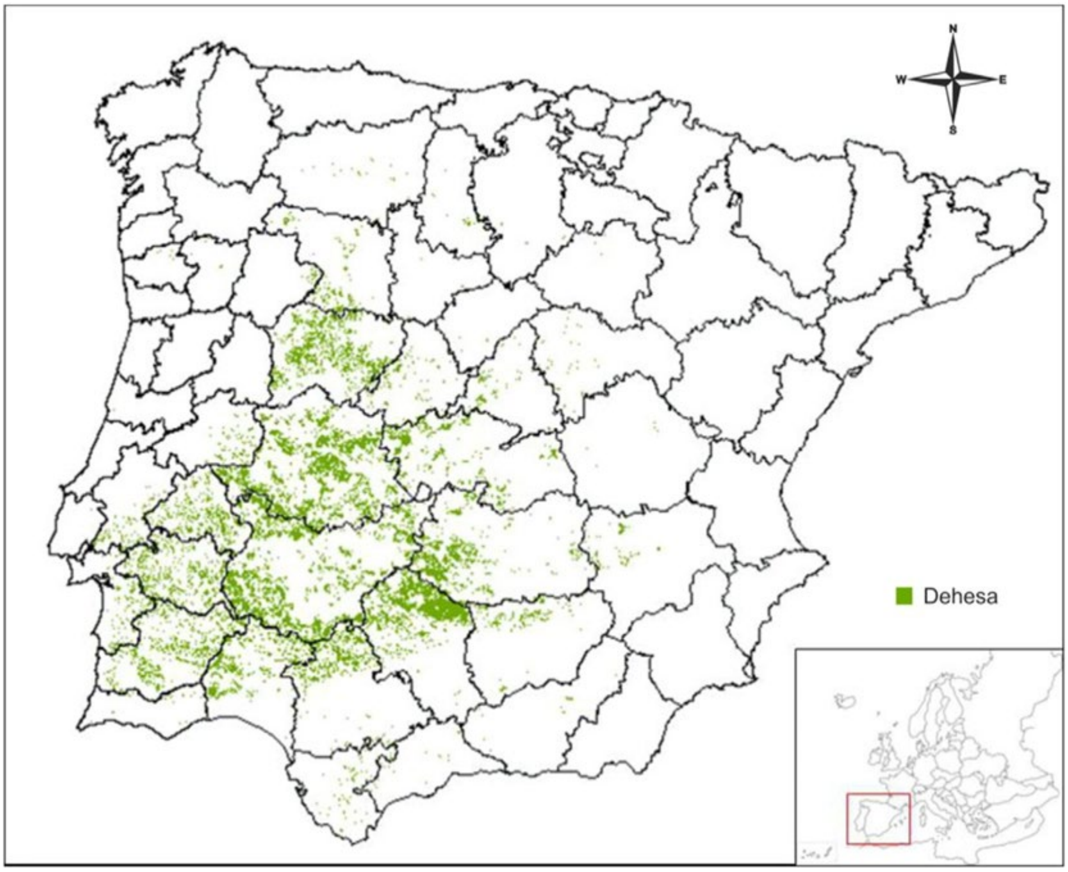


Figure I. 1. Location of the dehesa areas in the Iberian Peninsula.

The successive reforms of the Common Agricultural Policy (CAP) and the continuous changes in the market have led to a decrease in the profitability of these types of farms. As a result, there have been changes in land use which have led to production intensification and abandonment of farms (Gaspar et al., 2009, 2008; Ripoll-Bosch et al., 2013). The low profitability of dehesa farms has forced producers to make adaptive changes to their production model (Gaspar et al., 2009), a fact that has contributed to an increase in the number of organic cattle farms. Nowadays, the number of organic cattle farms located in dehesa areas is 1845, which represents 64% of the Spanish organic cattle farms. The area covered by these holdings accounts for 106,599 ha (MAGRAMA, 2013).

This rise has been due both to the peculiarities of such systems and to the EU premiums received by producers, all in the context of a growing demand for organic products both at a European and global level (Mesías et al., 2012).

Due to the ease of conversion from extensive to organic systems, one would think that dehesa farms offer optimal conditions for the development of organic livestock. Nevertheless, it is the different standards and regulations as well as the varied production systems and products which have shaped their transition to these production models. As a result, the adaptation to these systems is not the same for all livestock species and farming systems (Blanco-Penedo et al., 2012). Table 1 shows the main characteristics of dehesa beef production systems both under conventional and organic conditions.

Table I.1. A comparison of organic and conventional dehesa cattle farms.

Key aspects	Conventional*	Organic**
Transition period		• Two years for pastures and forages • 12 months for livestock (can be included in the transition period for pastures)
Breed	• Suckler cows of native breeds and their crossbreeds	• Native breeds adapted to local diseases are recommended
Diversity of farm animals	• Generally more than one species grazing simultaneously (pigs, sheep and cattle)	• Organically and non-organically reared animals must be kept apart. • Extensive systems allow other species or non-organically reared animals to graze when organically reared animals are not present in this pasture at the same time.
Stocking rate	• Very low. Between 0.3 and 0.5 Livestock Units per ha.	• The total stocking rate may not exceed the equivalent to 170 kg of nitrogen per ha of agricultural area (2.5 LU/ha). However, regional regulations lowered this limit in dehesa areas to a maximum of 0.5 LU/ha
Farming system	• Extensive, based on free grazing of animals. Constrained by climate and pasture production. • Animals weaned at 6 months of age and 200 kg in weight. • Reproduction usually by natural breeding.	• Extensive. With the limitations indicated by the EU regulation • Minimum age for livestock weaning is 3 months • Reproduction by natural breeding or artificial insemination. Hormonal treatments or artificial reproduction cannot be used • All animals must be born and reared in the farm or must undergo a transition period.
Facilities and buildings	• Scarce and adapted to extensive farming	• Facilities and outdoor areas are regulated by EU organic regulation
Feeding	• Feeding on grazing resources of the farm. • In time of shortage, supplemented with fodder and conventional feedstuff purchased out of the farm	• At least 60% of the ration should be forages • Off-farm raw materials used for animal feed must come from certified organic farms • Preferably phytomedicinal and homoeopathic treatments
Sanitary treatments	• Almost non-existent due to lack of diseases • Mainly preventive vaccinations and deworming	• Treatments with synthetic drugs are limited to 3 per year
Final product	• Calves are mainly sold when they have been weaned with 200 kg in weight and 6 months of age to intensive feedlots	• In those farms that complete the organic production cycle, the final product is the fattened calf with 500 kg in weight and 15 months of age. However, most organic farms sell their calves when they are 6 months old and through conventional market.

* Source: Own elaboration from Milán et al., (2006) and Gaspar et al., (2007).

** According to EU Regulation CE 834/2007.

Fig. 2 sets out the main factors affecting organic cattle production in dehesa rangelands. On the one hand, the preservation of these systems is necessary and it must be compatible with productivity levels, which allow their economic viability. On the other hand, there are different regulatory standards affecting the environmental, social and economic components of the system. Thus, the present CAP, through its subsidies and agrienvironmental measures—including those promoting organic production—are determining the dehesa's production model and especially organic beef production.

Therefore, it can be concluded that there are many different factors affecting the implementation of organic livestock production in dehesa areas. This means that it is extremely complicated to establish guidelines about the future and viability of these holdings using quantitative research tools. It is hence necessary to use other approaches that allow overcoming these difficulties, such as the Delphi methodology. This qualitative methodology allows dealing with complex problems through the use of a group of experts (Linstone and Turoff, 2002).

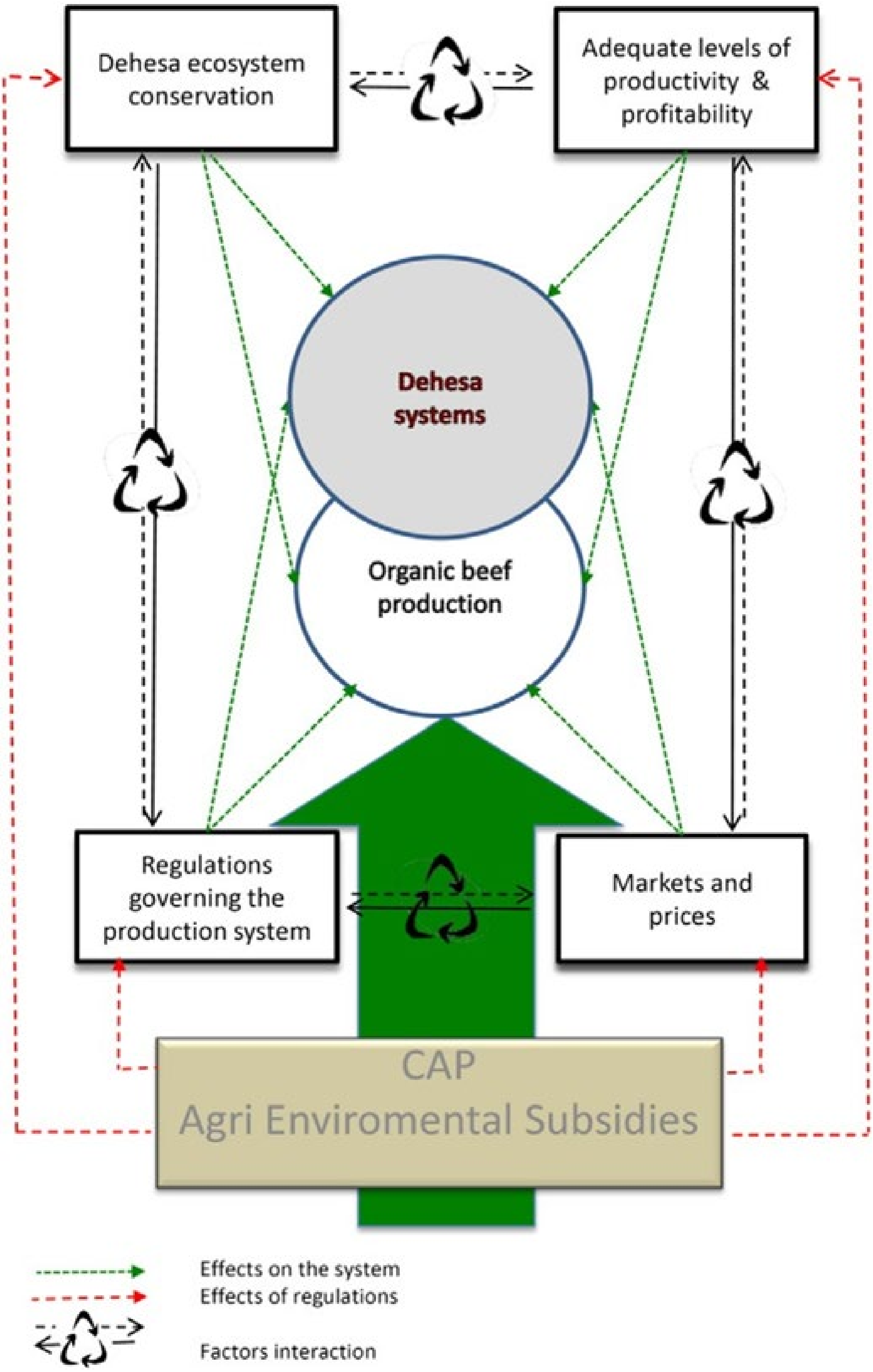


Figure I. 2. Main factors affecting the organic cattle production in dehesa extensive areas.

This methodology may allow forecasting the behaviour of these holdings, as well as their expectations in the year 2020. Hence, this paper will attempt to point out the most relevant aspects for the future of organic beef farms in dehesa systems. We will thus analyse the evolution of this productive system, the marketing of its production and the positive and negative effects that the CAP and its agrienvironmental measures may have.

2. Material and methodology

2.1. The Delphi method

The Delphi method is perhaps the most popular of a number of qualitative forecast techniques (methods relying on human judgement instead of on measurable data) developed in the second half of the 20th century. It emerged after the Second World War from a United States Defence project called "Project Delphi", and initially its use was primarily confined to aerospace and electronic industries, where forecasting was difficult due to rapid technological developments. The Delphi method has been used subsequently as a way to generate predictions in uncertain surroundings, where one cannot resort to techniques that use objective data (Landeta and Barrutia, 2011).

However, Delphi forecasting has been applied more recently in various fields, such as forest management (Edwards et al., 2011), climate change and food production (Kirezieva et al., 2015), or the prediction of deficit irrigation adoption (Alcon et al., 2014). The Delphi methodology has also been lately applied in agricultural systems, for example in the analysis of animal monitoring technologies (Busse et al., 2015), in the modelling of systems supporting farm management (Tanure et al., 2013), or in the assessment of ecosystem services provided by agro-systems (Rositano and Ferraro, 2014). However in the case of assessing organic farming systems, this can be considered as a novel approach.

The Delphi method is traditionally based on the use of a representative group of experts to whom a series of issues are raised by means of a questionnaire. The experts are requested to indicate likelihood of occurrence or agreement/disagreement with the statements shown. Selected experts should not communicate among each other, and their opinions are obtained either by mail, telephone or through internet tools.

Since the methodology seeks to obtain a unique prediction, the procedure is aimed at achieving a consensus among the experts. To do this, after the replies from the first questionnaire are received, they will be summarised and included in another questionnaire. This second questionnaire will be sent and the participants will be required either to review their original estimates in the light of the answers of the group, or to give specific reasons for refusing to move to a situation of consensus. The process continues until an acceptable consensus is reached, although it is not frequent to develop more than two or three rounds (Wentholt et al., 2009). Though the pursuit of consensus was initially essential, subsequent applications of the methodology have removed that restriction. Nowadays, what is sought is to obtain a reliable (and therefore agreed at least to some extent) opinion from a group of experts (Landeta, 2006). The answers to the final questionnaire are the Delphi predictions. Fig. 3 explains the 2-round Delphi methodology followed in this paper.

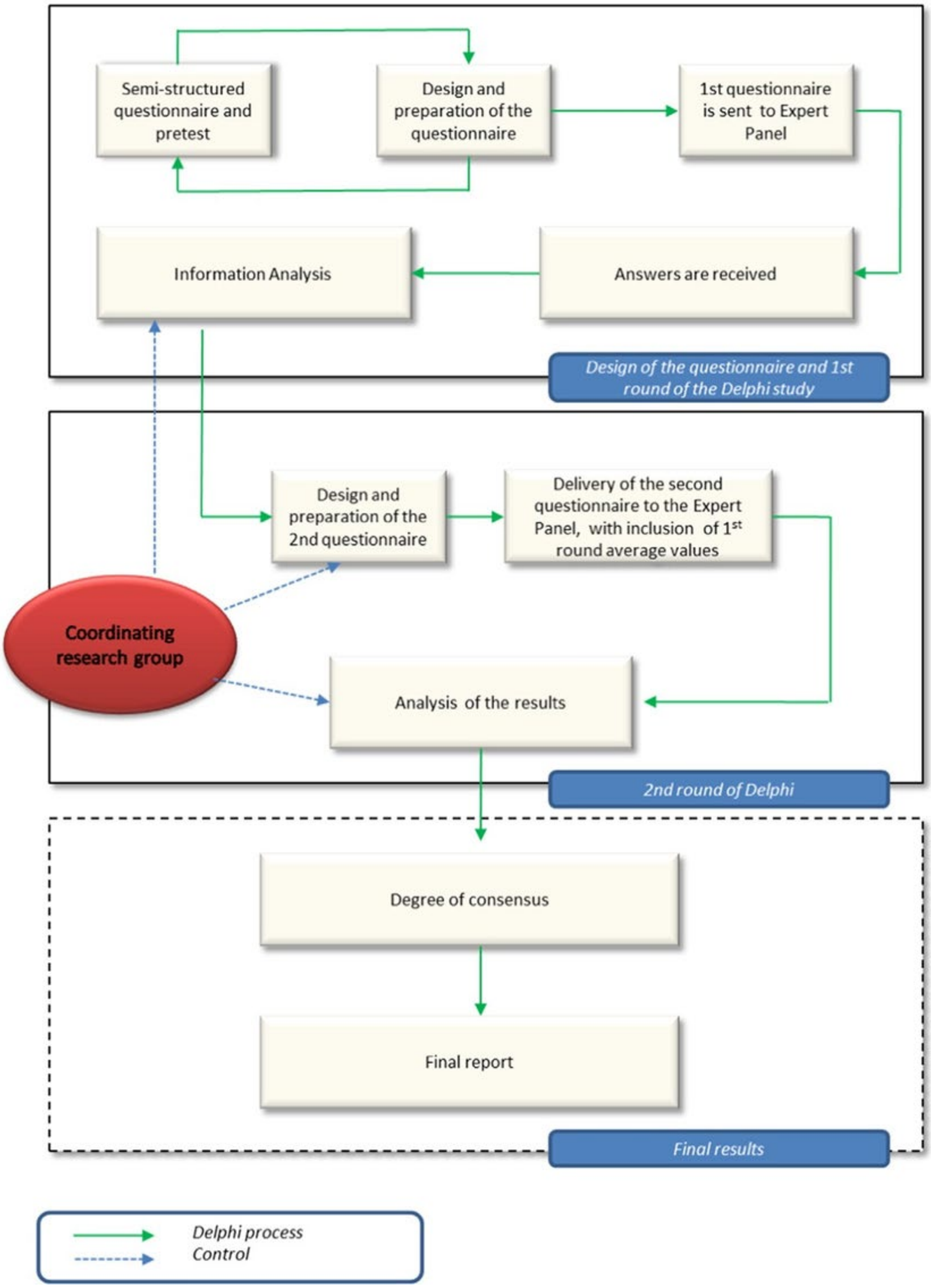


Figure I. 3. Delphi methodology.

2.2. Questionnaire design

In order to design the questionnaire used in this work, the starting point was a set of in-depth interviews conducted with four experts in extensive livestock systems and organic production. These interviews, along with the previous experience of the research team, and a deep review of the available literature, allowed generating the first version of the questionnaire. Subsequently, the questionnaire underwent a first review by the experts and the research team.

The final structure of the questionnaire was divided into different blocks relating to prospects of future regarding organic cattle in dehesa rangelands in the year 2020. This time frame was selected due to the foreseen development of the present CAP (in force until 2020). The various sections of the questionnaire, together with a description of their contents, are shown in Table 2.

Table I. 2. Structure of the 1st-round Delphi questionnaire.

Section	Contents
Evolution and future of organic beef farms	Increase of fattening; regression of organic farms to the traditional model; possible increase in the number of organic farms.
Factors that hinder the conversion to the organic model in dehesas	Analysis of the potential impact of some factors that can probably limit the implementation of the organic model farms of cattle in dehesas (feeding costs; lack of EU organic standards; increasing food controls…).
EU Agricultural and Rural Development policies	Aspects relating to the present EU CAP and Rural Development policy that could benefit and encourage the transition from dehesa cattle farms to an organic system (agrienvironmental measures; native breeds; crop diversification…).
Environmental benefits of the switch to the organic production	Benefits that an ecosystem could obtain if the farming model was changed to the organic model (reduction in pesticides use; improved biodiversity; landscape preservation…).
Changes in social and management aspects derived from the switch to organic production	Social and management aspects were included in order to study the potential effect of the conversion model (farmers' training; labour equity; generational replacement…).
Marketing and sales	Potential strategies that could be used to reach the organic price-premium goal (short supply chains; trade fairs; information campaigns…).

The second-round questionnaire came from the one used in the first round, but adding to each question the average score of the panel in the previous round. As stated previously, this information would allow the participants to reconsider their previous ratings in the light of the average score of the 1st round.

According to other research using Delphi, a 5-point Likert scale was used in all questions in order to assess the degree of agreement or disagreement of the panellists (Almansa and Martínez-Paz, 2011; Kirezieva et al., 2015; Olaizola et al., 2012). The scale used in our questionnaire was the following: -2 (strong disagreement or very unlikely occurrence), -1 (disagreement or unlikely occurrence), 0 (indifference), +1 (agreement or likely occurrence) and +2 (strong agreement or very likely occurrence). This scale was selected as we considered that it would allow the panellists to express more easily their points of view with respect to the different issues raised.

2.3. Selection of experts

The selection of experts is considered one of the aspects that most influence the quality of Delphi studies (Almansa and Martínez-Paz, 2011) and therefore special care was paid to this phase. In this research, panellists were required to show a sound knowledge of extensive and organic traditional cattle production in SW Spain. Experts could be farmers or be linked to public institutions, research bodies, agricultural organisations and companies. The final names were obtained by internal conference within the research team, subsequently making personal contact with each of the 47 selected experts in order to explain the objectives and principles of the research and obtain a commitment to participate. In the first round 39 replies were obtained and 33 in the second. Table 3 shows the composition of the panel for both the first and the second rounds.

Table I. 3. Composition of the panel for the first and second rounds.

Stakeholder group	Round 1		Round 2	
	N	%	N	%
Public institutions	8	20.5	5	15.2
Cattle farmers/businesses within the cattle secto	10	25.6	8	24.2
Research centres	14	35.9	14	42.4
Associations	7	18.0	6	18.2
Total	39	100	33	100

The average experience in the sector of the panellists was 22 years, with a minimum of 7 years and a maximum of 50 years.

2.4. Data collection - development of the panel

The development of the panel was based on the online tool Google Docs (www.docs.google.com), in which the questionnaires for the first and second rounds were designed and through which the responses from the panellists were collected. Online questionnaires are an increasingly used tool in research, since they allow quick and economic data collection (Eldesouky et al., 2015), although they are not exempt from weaknesses, especially relating to the validity of sampling (Koutsimanis et al., 2012; Wright, 2005), but that does not affect the development of this type of methodology. A preliminary 1st-round questionnaire was sent to 3 experts (not included in the final sample) in order to revise the validity of questions in the questionnaire.

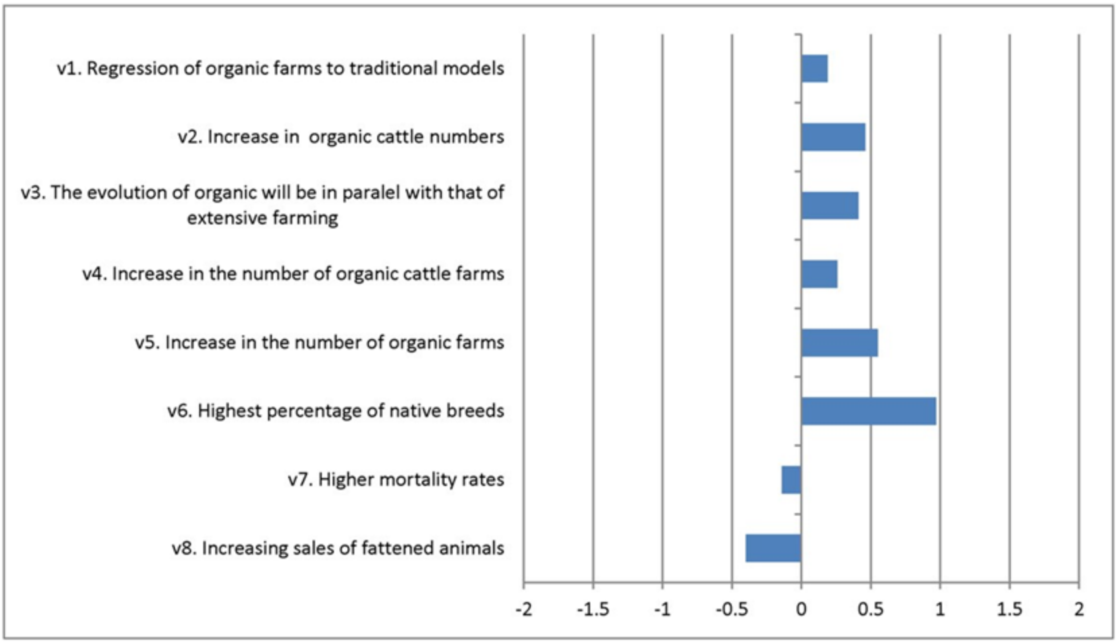
2.5. Consensus

The results of the second round of the study were used to determine the consensus by comparing them with those of the first round. In this paper, and in line with the measurements used in other Delphi studies (Alcon et al., 2014), the consensus has been calculated for each variable as the difference between the standard deviation of the ratings of the first and second rounds. The indicator thus calculated will provide positive values when the consensus among the panellists has increased between the two rounds, and negative otherwise.

3. Results

3.1. Evolution and future of organic beef farms

The first section sought to present to the experts some of the most relevant questions about the evolution of organic beef farms in dehesa ecosystems. Fig. 4 shows the average ratings of this first part of the questionnaire.



V= Variable. Scale: 0➔indifference; 0 to – 2➔ disagreement/unlikely occurrence; 0 to + 2➔agreement/likely occurrence

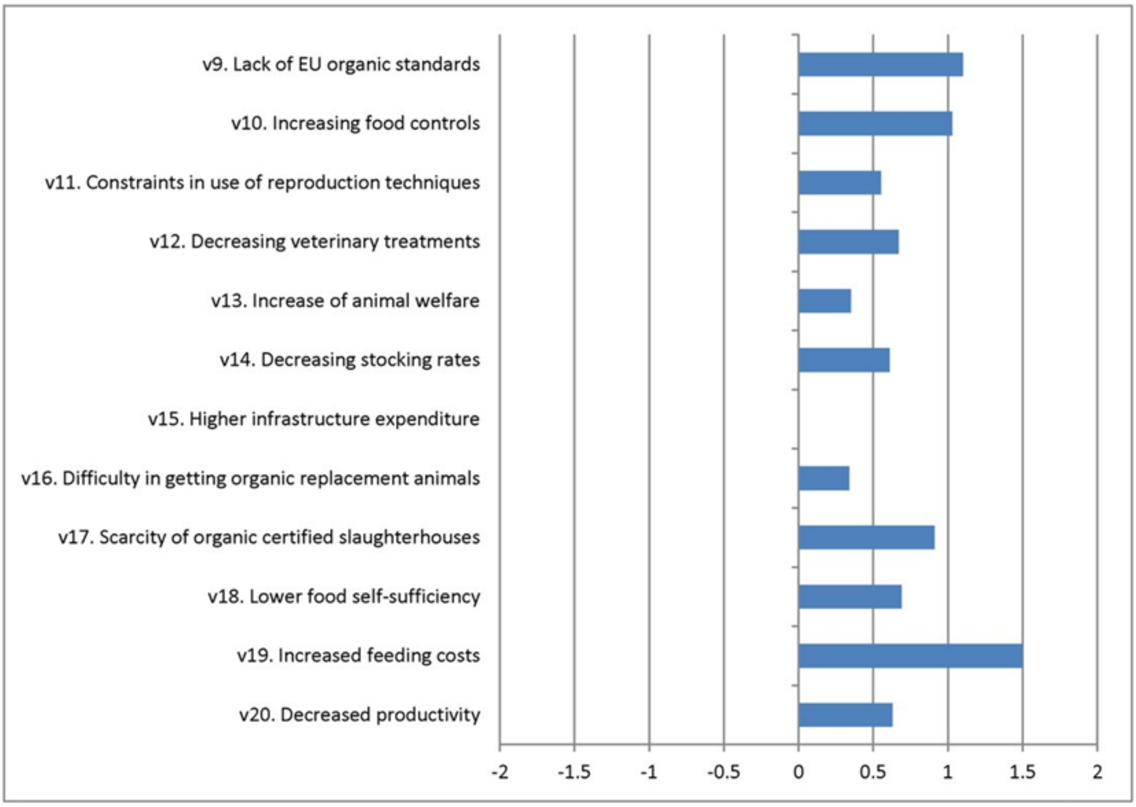
Figure I. 4. Evolution and future of organic beef farms.

Results in Fig. 4 show that the aspect for which the greatest agreement has been reached was the increase in the percentage of native breeds, with all its implications for the preservation of biodiversity. There is also moderate agreement in terms of the increase of organic farms as well as the number of organic cattle.

It is noteworthy that, despite forecasts of increasing organic livestock farming, the panel has shown a slight negative score with respect to the increase in sales of fattened animals, assuming that they will decrease slightly. This implies that, although conventional farms will continue to switch to organic models due to the aforementioned similarities, they will keep on selling their calves at weaning-to non-organic fattening farms-without increasing the level of organic fattening.

3.2. Factors that hinder the conversion to the organic model in dehesas

Fig. 5 shows the average ratings for those questions regarding the factors that can constraint the implementation of the organic model.



V= Variable. Scale: 0→indifference; 0 to – 2→ disagreement/unlikely occurrence; 0 to + 2→agreement/likely occurrence

Figure I. 5. Factors that hinder the conversion to the organic model.

The highest consensus has been reached in the increased costs of food, together with the intensification of food controls deriving from organic regulation. Both factors are considered to be the ones that will constraint the reorientation of farmers towards an organic model of production to the greatest extent.

In relation to the above is the consensus of the experts about the greatest difficulties for organic producers to be self-sufficient in feed.

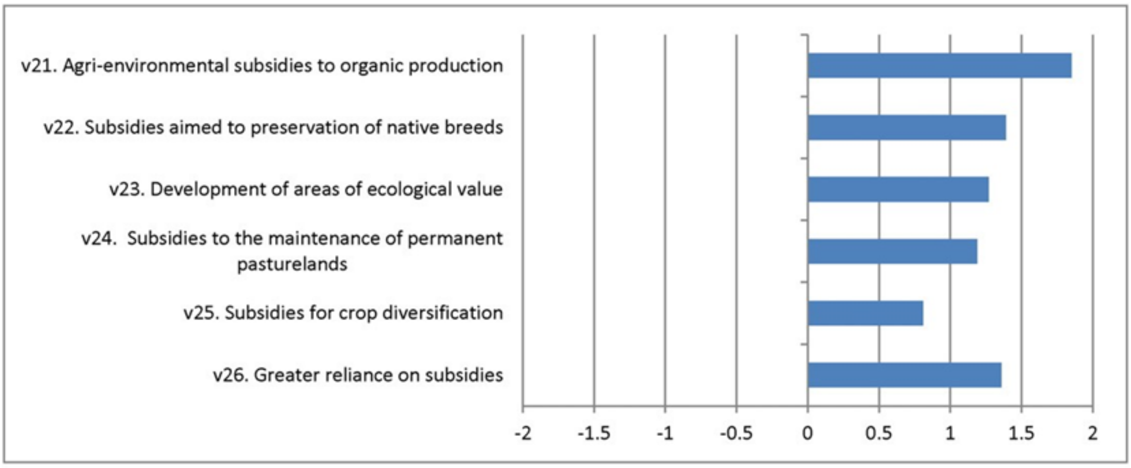
This is due to the growth of food purchasing outside the farm, which increases costs and decreases profitability.

The lack of specific regulations for extensive systems (within the legal framework of organic production) is seen as one of the factors that mostly hinder the transition. This has been one of the traditional claims of extensive producers at least with regard to conversion periods and slaughter ages, given the proximity of these productive systems to the organic one. As it can also be observed, another important obstacle to organic livestock farming is the scarcity of slaughterhouses where organic cattle are authorised to be culled.

3.3. EU Agricultural and Rural Development policies

In this section of the questionnaire (Fig. 6) the panellists were presented with various items related to the present Agricultural and Rural Development policies that could be beneficial for dehesa cattle farms and that could therefore encourage their transition to organic systems or promote the existing organic farms.

As Fig. 6 shows, the need for agrienvironmental support to organic production is the aspect where panellists most agreed, which leads to assume that this type of production must be subsidised in all its sectors.



V= Variable. Scale: 0→indifference; 0 to – 2→ disagreement/unlikely occurrence; 0 to + 2→agreement/likely occurrence

Figure I. 6. EU Agricultural and Rural Development policies.

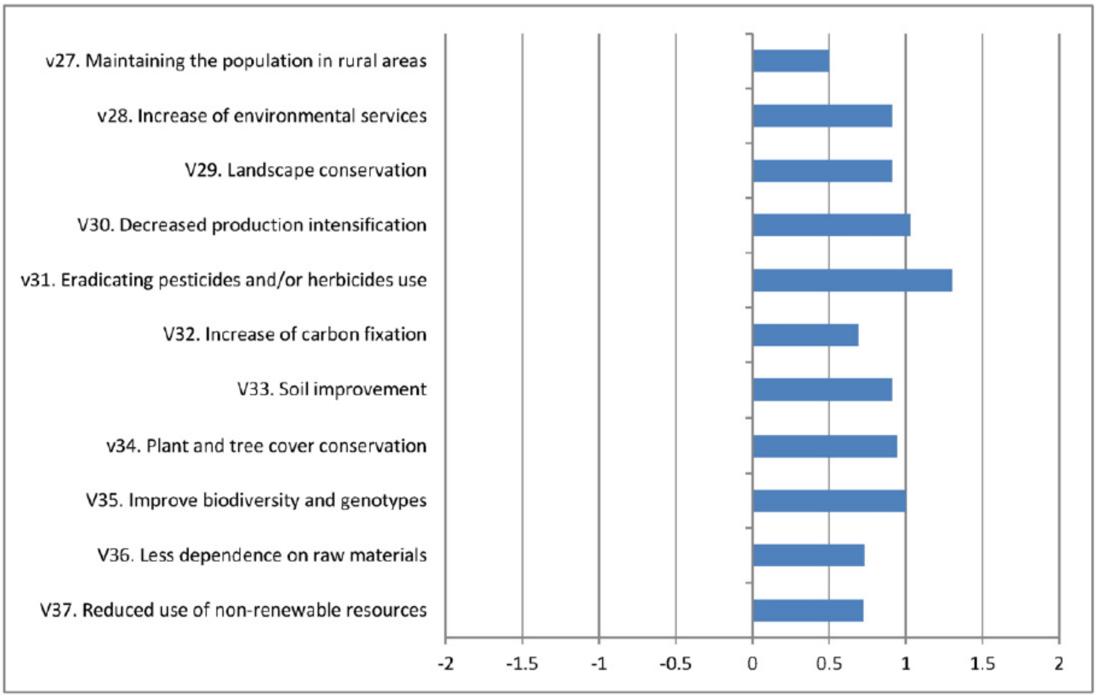
Closely related to this, there was also high consensus regarding the fact that cattle farms will be more reliant on subsidies with the change to the organic model.

Two other measures that stand out and are linked to defining characteristics of a dehesa system are the maintenance of permanent pasture-due to its intrinsic environmental value-and the promotion of native breeds-due to its great adaptation and use of the dehesa ecosystem.

3.4. Environmental benefits of the switch to organic production

In terms of the potential benefits that the ecosystem could obtain from the conversion to the organic model (Fig. 7) according to the opinion of the experts these would start by a reduction in the use of pesticides and herbicides, a fact that is associated to a less intensive production model.

The preservation of the vegetation cover is another clear benefit being identified by the experts. The panel also agreed upon the improvement of soil quality and the increase of carbon fixation, although in the latter case consensus was lower. On the other hand, and in relation to aspects related to the improvement of the rural environment, the members of the panel also considered that the conversion of these farms into organic farms would improve landscape conservation, also contributing to maintaining the population in rural areas.

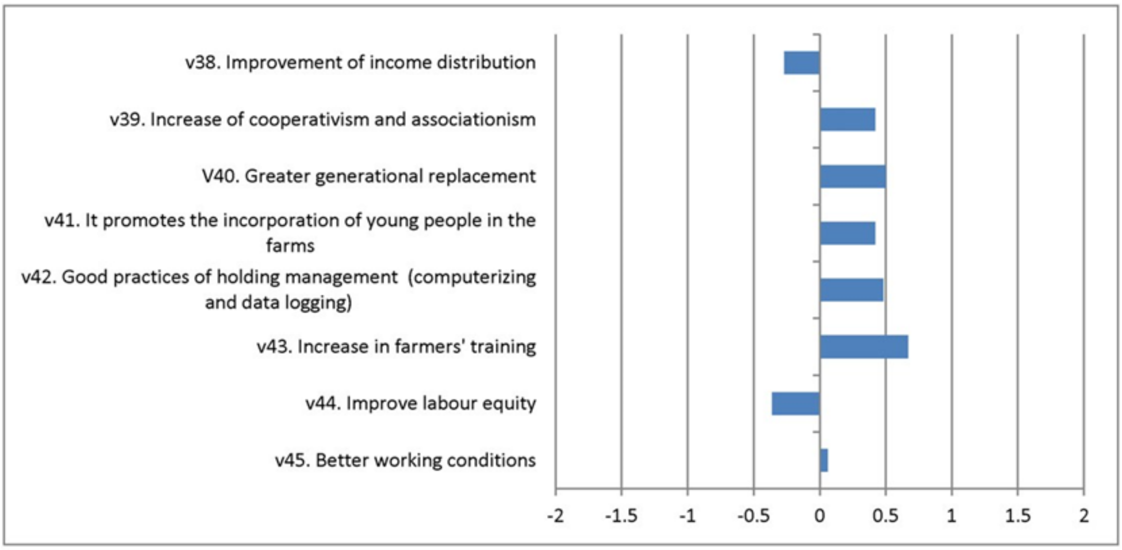


V= Variable. Scale: 0→indifference; 0 to – 2→ disagreement/unlikely occurrence; 0 to + 2→agreement/likely occurrence

Figure I. 7. Environmental benefits of the switch to organic production.

3.5. Changes in social and management aspects derived from the switch to organic production

Results regarding social and management aspects (Fig. 8) were not as explicit as those in other sections. The results showed that only one of the questions presented an average score greater than 0.5.



V= Variable. Scale: 0→indifference; 0 to – 2→ disagreement/unlikely occurrence; 0 to + 2→agreement/likely occurrence

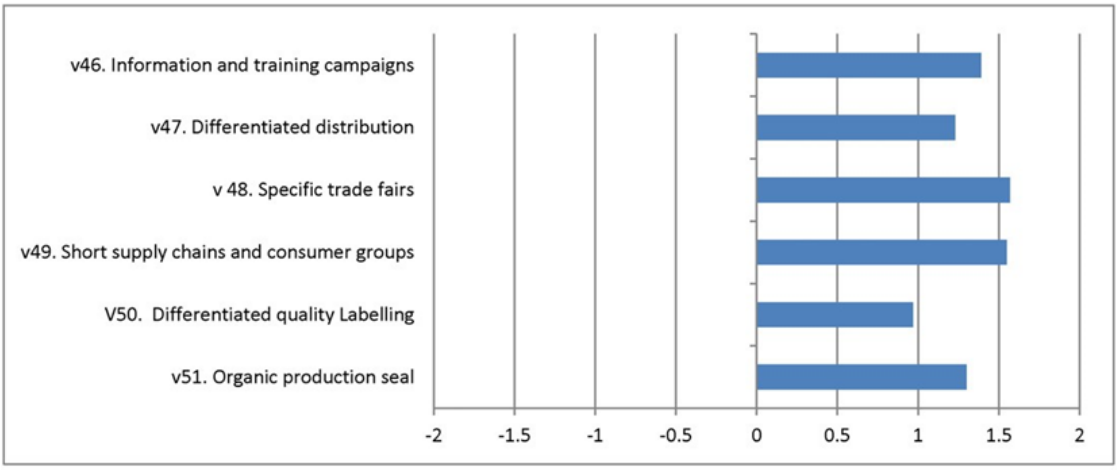
Figure I. 8. Changes in management and social aspects deriving from the switch to organic production.

Within this block the most outstanding aspect was the possibility for the farmers to increase their knowledge in order to acquire new skills that are required under the organic regulation.

3.6. Marketing and sales

One of the key aspects in organic cattle production is to obtain a price-premium or margin over conventionally-produced beef. Different marketing and sales tools can be used in order to achieve this goal.

As Fig. 9 shows, all the proposed tools received a high level of acceptance from the panel. The experts agreed that this type of product is really undervalued in the conventional market. Hence, more specific marketing channels are needed to achieve the organic premium.



V= Variable. Scale: 0➔indifference; 0 to – 2➔ disagreement/unlikely occurrence; 0 to + 2➔agreement/likely occurrence

Figure I. 9. Marketing and sales tools to achieve eco-premium.

3.7. Analysis of the consensus achieved between the two rounds

As the goal of a Delphi study is to obtain a perspective or prediction of future events, an important aspect of its development is that panellists reach a certain level of agreement on their forecasts. For this reason, increasing consensus between different rounds is often considered as an indicator of the proper functioning of the panel (Linstone and Turoff, 2002). In this study, the second-round questionnaire included feedback from the first-round average score in order to improve the degree of consensus. Table 4 presents the results of the consensus indicator for the variables included in the study.

Table I. 4. Indicator of consensus for the variables included in the study.

Var.	S.D. round 2	Consensus	Var.	S.D. round 2	Consensus	Var.	S.D. round 2	Consensus
v1	1.07	0.04	v18	0.89	0.34	v35	1.03	0.28
v2	1.13	0.05	v19	0.51	0.16	v36	1.03	0.35
v3	1.07	0.09	v20	0.97	0.05	v37	0.81	0.33
v4	1.21	0	v21	0.46	0.09	v38	0.91	0.12
v5	1.15	0.05	v22	0.91	0.09	v39	0.93	0.31
v6	0.93	0.42	v23	0.8	0.23	v40	0.98	0.24
v7	1.09	0	v24	0.82	0.07	v41	1.09	0.12
v8	1.08	0.27	v25	0.7	0.31	v42	0.83	0.39
v9	0.74	0.35	v26	0.82	0.24	v43	0.89	0.28
v10	0.64	0.43	v27	1.32	0.06	v44	0.99	0.15
v11	0.86	0.59	v28	0.76	0.49	v45	0.96	0.39
v12	0.95	0.47	v29	1.02	0.16	v46	0.82	0.03
v13	1.17	0.19	v30	0.72	0.42	v47	0.77	0.07
v14	0.98	0.2	v31	0.68	0.49	v48	0.57	0.03
v15	0.91	0.33	v32	0.93	0.29	v49	0.57	0.34
v16	1.18	0.13	v33	0.92	0.24	v50	0.8	0.11
v17	1.08	0.21	v34	0.99	0.17	v51	1.2	0.06

V = Variable; consensus has been calculated for each variable as the difference between the standard deviation of the ratings of the first and second rounds.

Although there was no increased consensus for some variables (variable 4 and 7), positive rates of consensus were achieved in the remaining variables (in most cases greater than 0.20). This can be considered a good indicator of the correct functioning of the second round of the study.

4. Discussion

4.1. Evolution and future of organic beef farms

One of the important highlights in this regard is the consideration that the relative importance of local breeds will increase in organic beef farms. This is explained by the general association between organic production and native breeds/varieties. Native breeds can get better results than other breeds or varieties because in the absence of fertilisers or synthetic additives in organic production they can be better adapted to the environment (Escribano et al., 2014).

With regard to the increase of organic farms and organic cattle numbers, experts agree with different researchers who have indicated that organic production can be especially interesting in systems of high ecological value (Díaz, 2013; Rodríguez-Estévez et al., 2010) asis the case of dehesas. In those systems it can also help prevent the degradation and loss of soil fertility (Niggli et al., 2007), increasing water retention and resistance to drought (Lotter et al., 2003; Muller and Davis, 2009; Thierfelder and Wall, 2009). These aspects are of particular concern in semi-arid areas, with scarce water resources and poor soils, such as dehesas (Escribano, 2014). The similarities between the extensive and organic systems are clearly visible, which makes the transition from an extensive system to an organic one relatively easy (Nardone et al., 2004; Pauselli, 2009).

An interesting aspect is the consideration that these types of holdings will not be able to consolidate the added value, which implies the fattening of animals to be sold as organic directly to slaughterhouses or consumers. Although one of the fundamental objectives of farmers who are becoming organic producers should be the price premium that consumers are usually willing to pay for organic food, this is complicated in the case of extensive dehesa farms. In this type of farms, calves have traditionally been sold at weaning through the conventional market (Mateos, 2008). Organic farmers benefit mainly from the subsidies granted to organically-reared cows under the agrienvironmental measures. The higher price of organic feedstuff, as well as the need for specific infrastructure, can stress this trend, according to expert opinion. This fact is reflected in various papers, such as those of Tzouramani et al., (2011) and Sahm et al., (2013). Both studies indicate that one of the main issues faced by organic producers is their inability to obtain an adequate price premium against conventional production.

4.2. Factors that hinder the conversion to the organic model in dehesas

The higher costs of organic feeding, together with the lower productivity of organic farms, are some of the weaknesses of organic vs. conventional systems. The reduced production of organic farms has been pointed out by Godfray et al., (2010) while other authors (Blanco-Penedo et al., 2012; Gillespie and Nehring, 2013; Hrabalova and Zander, 2006; Veysset et al., 2009) have stated that the production costs of organic cattle are higher than those of conventional production due to the costs of feedstuff. Additionally, Blanco-Penedo et al., (2012) and Benoit and Veysset, (2003) confirmed the reduced productivity and the increased production costs in organic production due mainly to the cost of organic feed.

While other factors can be expected to be diluted over time (by increase of the organic market, growing number of organic producers, new commercial channels...) the very nature of organic farming does not make very feasible neither a growth in the productivity nor a decline of the feeding costs.

The regulatory deficit arising from the lack of specific organic legislation for extensive systems complicates the inherent facility of dehesa systems (Nardone et al., 2004) and causes excessive transition periods when producers try to convert their farms to organic production systems. It is obvious that in systems with low profitability the transition period becomes a huge burden for farm survival, since investments are undertaken without the capacity to reap the benefits.

4.3. EU Agricultural and Rural Development policies

One of the main aspects highlighted by the panel is the fact that the productivity of organic farms is lower and will continue to be lower than that of conventional farms. Due to these losses in production, the profitability of the farms after their conversion will largely depend on CAP subsidies and on specific grants to promote organic production. The greater reliance on the subsidies received by organic farms against the conventional ones, with its negative connotations from the point of view of farm sustainability, is an issue that has been widely discussed in the literature (Blanco-Penedo et al., 2012; Gillespie and Nehring, 2013; Hrabalova and Zander, 2006; Veysset et al., 2009) and that experts consider will remain in the near future.

The maintenance of permanent pastures is one of the main points in the feeding of cattle in extensive systems, as it allows reducing the expenditure in food supplementation, therefore increasing the profitability of these holdings. Subsidies encouraging the maintenance of grazing resources will largely contribute to the consolidation of both extensive farms and organic farms, as the reliance on off-farm food will be reduced to some extent.

The implementation of support schemes to native breeds would correct a situation originated with the 1992 CAP reform, when individual ceilings for the perception of the suckler cow premiums were settled without taking into account the breed of the animal. That meant a change in the breeds being reared due to both the better fattening behaviour of non-native breeds and the increased consumer preference for the meat from these breeds.

Support to areas of ecological interest through targeted assistance is in line with that indicated by other researchers. For example, (Grandi and Triantafyllidis, 2010) claim that organic systems are particularly suitable for protected areas because they are not sources of external pollution for the ecosystem and also due to their high biodiversity, which is essential for the environment.

4.4. Environmental benefits of the switch to organic production

The various reforms of the CAP and the reliance on subsidies have led to production intensification in extensive livestock systems that had a negative impact on the environment (Martín et al., 2001). This impact was particularly undesirable in systems such as the dehesa, the maintenance of which largely relies on a proper stocking rate and where overgrazing generates lack of renewal of the arboreal layer and erosion, among other problems. The transition to organic in these systems would entail a reduction of the stocking rate, with the corresponding drop in the required inputs. The resulting elimination of pesticides, herbicides and the use of mineral fertilisers will provide not only environmental benefits but will also make the ecosystems more resistant to pests and diseases, thanks to the interactions among the components of the system (FAO, 2007; Meyling et al., 2010).

With respect to the environmental benefits, such as the conservation of the vegetation cover, soil improvement or increase of carbon fixation, Ripoll-Bosch et al., (2013) argue that the extensive and grazing-based systems, such as the dehesa, enable a better conservation of the ecosystem than that of the more intensive models. Niggli et al., (2007) and Pimentel et al., (2005) claimed that organic systems fixed carbon to a greater extent than conventional ones, in addition to preventing soil degradation and increasing its fertility.

In terms of the role of organic production in the development of rural environments, various authors (Bernués et al., 2011; Nardone et al., 2004; Pauselli, 2009; Pugliese, 2001) have considered it vital, since organic premium price means an added value that benefits the creation of job opportunities, improving farm profitability. As it has been already mentioned, organic farmers in dehesa systems mainly receive the subsidies granted to organic cows, while the added value is obtained by the last links of the processing and distribution channels.

4.5. Changes in social and management aspects derived from the switch to organic production

The aspect for which the greatest consensus was reached, i.e. the better training of organic farmers, does not seem to be supported by other research. For example, (Escribano, 2014) did not find significant differences in training between organic and conventional livestock managers. However, the panel may have considered that the application of new techniques in order to switch to organic production (reproduction, diseases management, etc.) will contribute to improve the general training of the farmer.

It is worth commenting two striking findings, such as the negative scores obtained in the "improvement of income distribution" and the "improvement of male/female employment equity". Both aspects are included in the Principle of Justice, one of the pillars of organic production (IFOAM, 2005); however, experts have considered that organic cattle farms will not have a better income distribution than conventional ones, or will there be improved employment equity. These results may be related to the characteristics of the ecosystem and the stocking rate. As it has been previously discussed, a reduction of stocking rates after the transition to organic can be expected, which would imply lower labour requirements. This outcome is in line with other research (Morison et al., 2005) which also found lower labour requirements in organic farming. The distribution of the income generated by the holding among fewer employees will result in a worst distribution of income, as has been stated by the experts.

Escribano, (2014) found higher indicators regarding gender equity (measured as a percentage of female work and management) in organic farms, although these differences were not significant with regard to conventional farms. These authors have not found significant differences in job satisfaction or in the degree of association among conventional cattle farms and organic ones. All this comes to justify the indifference of the panel regarding these issues.

4.6. Marketing and sales

The achievement of a premium price for organic products largely represents the success or failure of the introduction of these production systems on dehesas. The failure to achieve this goal will reduce the profitability of these holdings to a level where they will not be sustainable. It will also make them more reliant on subsidies.

This may happen because a great part of organic production still uses conventional marketing channels. These channels are characterised by weak domestic consumption, supply concentration and the export of most of the production. (Willer and Hedlung, 2010).

The panel has considered that the use of different marketing channels and points of sale for organic beef is the way to achieve an added value that will distinguish it from conventional meat. Thus the role of middlemen will be reduced and the added value for the producer will be increased. Some authors such as Seyfang, (2006) and Wittman et al., (2012) also agree with this idea, as they consider that it is not so much to produce under the organic model as to sell the product through short marketing chains which bring benefits to organic farmers.

The experts also highlighted the importance of training and information initiatives, issues for which they agree with previous research. Thus, Verbeke and Ward, (2006) indicated that consumer information campaigns can change the value that consumers attach to certain brands or aspects present in meat labelling, although it depends on their degree of experience Banović et al., (2012).

5. Conclusions

In the present context of evolving markets and policies it can be intricate to foresee the evolution and future developments of agricultural systems. This is even more difficult when one deals with a complex and ecologically-valuable ecosystem such as the SW Spanish rangelands (dehesas). This paper has therefore used the qualitative Delphi methodology, based on the opinion of a panel of experts linked to production, research and public sectors, in order to establish the future developments that can be expected in these agricultural systems with a horizon in the year 2020.

One of the main outcomes of the panel is that organic cattle farms in dehesas will increase in number, although the increase will be only slight. However, this will not imply greater sales of fattened beef, which is ultimately the final product. This factor, coupled with the lack of self-sufficiency in food supply (need of organic concentrate) and the scarcity of organic certified slaughterhouses, will hinder the implementation and/or the transition from traditional farms to the organic production model.

Furthermore, it would be desirable for specific lines of support to be implemented, as they would stimulate the production of organic beef dehesa farms. These measures, together with improved marketing strategies and higher market prices would guarantee the continuity of these farms.

This is undoubtedly an important fact, as the transition from traditional to organic farms has been seen to result in an improvement of the use of non-renewable resources, less productive intensification and eventually, the increase of the environmental externalities provided by dehesas. Additionally, other benefits would be associated to the improved training of farmers and to an increase in the incorporation of young people to the farms.

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Chapter II. Understanding the barriers and exploring the possibilities of the organic livestock sector in dehesa agroforestry systems: a multi-actor approach for effective diagnosis.

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Understanding the barriers and exploring the possibilities of the organic livestock sector in dehesa agroforestry systems: a multi-actor approach for effective diagnosis.

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Abstract

The dehesa agroforestry system is classified as one of the most singular ecosystems in the European Union. In the southwest of the Iberian Peninsula, it spreads over an area of approximately 6.7 million hectares, contributing major environmental, cultural, aesthetic and economic value to the region. The main agricultural activity that is developed in this ecosystem is the extensive farming of cattle, sheep and Iberian pigs with low stocking density and few inputs. Sustainable management of these ecosystems' existing production farms is essential in order to secure their continuity, as they face a difficult situation on account of their low profitability. One of the strategies that could be employed to attain a sustainable situation is the proposition of an organic production model. In order to explore this option, a participatory research process has been proposed and developed in the Spanish region called Extremadura (Spain). The aim of this process is to investigate the potential of extensive farming systems in moving toward a sustainable organic production model, identifying the main barriers preventing livestock farmers from converting to the organic model and seeking specific improvement measures that would reduce such barriers. For that purpose, four focus group sessions were run with a total of 33 participating stakeholders. For the analysis of these focus groups, Atlas.ti qualitative software was used to categorize and quantify the main ideas proposed during the sessions. The findings revealed that the main barriers can be classified into three groups: barriers that are inherent to the production processes and the structure of the specific sector, barriers associated with administration and management issues and lastly, barriers relating to education and training of the various actors involved. We consider this paper may contribute to policy makers' decisions to focus on specific actions for improvement that are customized for the socio-economic and environmental conditions of the region.

Keywords: Conversion; extensive livestock farming; organic; participatory research

1. Introduction

Dehesa is the most common agroforestry system in Europe, and in the Iberian Peninsula in particular, it contributes approximately 5.5 million hectares in Spain and 1.2 million hectares in Portugal (den Herder et al., 2017). Extremadura is the Spanish region with the largest dehesa area (Gaspar et al., 2008). The most recent estimates of forest areas being considered as dehesas throw a figure of 1.9 million hectares of dehesa in Extremadura, where a large number of the farms within the region are situated (CAYMA, 2003).

These agroforestry systems are based on extensive livestock production where the farms use the large so-called dehesa areas with low stocking density and autochthonous breeds that are well adapted to the environment (Horrillo et al., 2016).

In this context, dehesa proves to be a unique ecosystem in the European territory, not only on account of the extension of its area, but also because of its contribution of environmental, cultural, aesthetical and economic values. Nonetheless, these systems are currently constrained by low profitability (Oviedo et al., 2013), which can affect their sustainability (Gaspar et al., 2007).

All actors currently involved question the profitability of dehesas and argue that the implementation of sustainable management techniques in extensive farming systems and their transition toward other production models, such as the organic model, would secure the economic sustainability of dehesas and the efficient collection of its produce (López-Sánchez et al., 2016).

The latest official statistics (year 2016) reveal that Spain accounts for 7836 organic farms with a total of 1,683,682 animals (MAPAMA, 2016a). These figures translate into 1.57 and 3%, respectively, of the total number of the country's farms and animals in Spain. An analysis of the situation in the various regions sets Andalusia as the largest producer of organic products with 4.4% of the livestock farms and 9.75% of the certified animals, which represents 62.96% of the country's organic farms. Extremadura, on the other hand, with 211 certified farms represents only 0.48% of the certified farms with 0.97% of the organic animals in Spain (MAPAMA, 2016a). The 211 certified farms in Extremadura house 62,886 animals. Their breakdown by species is the following: the number of organic cattle represents 1.46% of the total number of cattle heads in Extremadura; the number of sheep represents 0.21%; goats are 0.078% and pigs are 0.0028%. These figures prove the low level of livestock conversion in the region (MAPAMA, 2016a; SITRAN, 2016). This low level of development of organic production in the central areas of dehesa (in comparison to other areas with similar edaphoclimatic characteristics, such as Western Andalusia) suggests the existing need to understand the circumstances that prevent the development of a productive model which seems to be close to that of extensive livestock farming.

In this sense, the purpose of this paper is to analyze the key aspects that must be taken into account for the conversion of the extensive livestock farms in dehesas into organic/sustainable livestock production models. The interesting aspect of this research is the diagnosis of the difficulties-both technical and regulatory-that these types of farms encounter for their conversion to organic production systems, in spite of the fact that such farming systems are very close to the organic production models (Horrillo et al., 2016). Additionally, the commercialization of products certified as organic is a tool that could add value to all the livestock farms in these systems, and therefore increase their profitability.

With this background in mind, a qualitative piece of research with a participatory focus proved to be a valid approach to be used in this project, as this kind of research is often employed to understand a problem situation and its motivating factors, as well as for being flexible and versatile (Stewart et al., 1994). The research was developed through focus group sessions, a technique being employed in various projects relating to the farming sector, such as that of Alarcon et al., (2017), who used focus groups in order to identify deficiencies and vulnerabilities in the beef market in the city of Nairobi; Ates et al., (2017) who employed the same technique to ascertain the implications of the farming policies' decisions being taken in Turkey from the farmers' point of view; Gaspar et al., (2016) who employed the same technique to analyze the value society places in agroforestry systems and Kaler and Green, (2013) who employed it with the purpose of understanding the current and future role of veterinaries in matters of animal health in the sheep farms of the UK from the farmer's standpoint.

The purposes of this paper can be described as (i) understand the barriers faced by the farming sector in the region in order to convert to organic systems and (ii) explore the possibilities of implementing specific actions for improvement in the systems in order to adapt them to a sustainable model. The reason for the regional scope of this study being Extremadura is due to the fact that dehesa is the predominant agroforestry system in this area; the low number of certified systems in the region compared to other regions of similar edaphoclimatic and socio-demographic characteristics; and lastly, the fact that the Autonomous Community of Extremadura is an administrative unit with its own management.

2. Materials and methods

2.1. Area of study

The Spanish region of Extremadura, situated in the south west of Spain, is an area with low population density and 1.9 million hectares of the so-called dehesa areas, representing over 48% of the farming areas. Figure 1 shows the distribution of the dehesa ecosystem, both in the whole of Spain and in the Extremadura region.

In this ecosystem, the predominant three species is the genus Quercus with the holm oak (Quercus ilex subsp. Ballota) being present in 80% of dehesas, followed by the cork oak (Q. suber) and the Pyrenean oak (Q. pyrenaica), the gall (Q. faginea) and the kermes oak (Q. coccifera) (Pérez and Del Pozo, 2001). Dehesa soils consist of shallow acidic sandy loam of little fertility due to the lack of sufficient organic matter and a severe absence of phosphorous, which makes them only appropriate for cereal crops (San Miguel, 1994).

The climate of the area is continental Mediterranean and the annual average temperatures range from 16 to 17°C. Summers are long, hot and dry, with the average temperatures in July being above 26°C and the top temperatures often surpassing 40°C. Winters are usually mild, with an average temperature of 7.5°C from December to January, although during the coldest nights temperatures may descend several degrees below zero (-2°C). Rainfall is distributed irregularly and ranges between 300 and 800 mm a year with large variations from one year to the next (Espejo and Espejo, 2006; Granda et al., 1991; Hernández, 1998).

Such climatic conditions make the extensive grazing of ruminants (suckler cow herds and dual-purpose sheep and/or goat) an optimum use of dehesa in conjunction with the extensive breeding of the Iberian pig, which helps use the acorn and produce Iberian products. The stocking density of these systems is low (<0.5 livestock units ha^{-1}) given the above described characteristics.

2.2. Design of the study

The study was based on a qualitative research with a participatory focus (Focus Group). The implementation of the participatory research techniques is a methodology approach that provides an innovative and realistic view of a specific situation (Cuéllar-Padilla and Calle-Collado, 2011), which is the reason such techniques were selected and applied to the study of the dehesa region in Extremadura.

The focus group is a technique based on group dynamics, where a trained moderator conducts a discussion that is stimulated by the exchange of comments amongst participants (Galvez and Resurreccion, 1992). The main advantage of the focus group is that it enables participants to have greater freedom of expression at the same time as proving to be an adequate technique for studies involving aspects such as the identification of problem situations, service improvement or strategic plan development (Chalofsky, 1999).

2.3. Participants to the focus groups

The stakeholders in the farm sector of the region were invited to join in this dynamic research. A total of 33 participants were selected by way of convenience sampling (Kinnear, 1993). The sessions were held in January and February 2018.

Four sessions were planned with an average of 6-12 participants each, following the suggestions of Malhotra and Birks, (2006). The sessions were held in four strategically-selected municipalities, which helped attract stakeholders from the various parts of the entire region, where it was especially trying to gain the participation of relevant actors, such as organic producers and technical staff from the regional government (at a distance of <100 km from the departure point). Figure 1 shows the location where each session was held.

Participants were 72.8% men and 27.2% women, aged 30–65. In their vast majority, they all held university degrees or professional training associated with livestock farming. The profiles represented and distributed in all sessions were: technical and consultancy people (8), conventional farmers (7), organic farmers (12), technical staff from the regional government (2), researchers (4) and members of livestock farming associations (16). Some of the participants combined more than one of the above characteristics, for example: organic farmers and members of livestock farming associations.

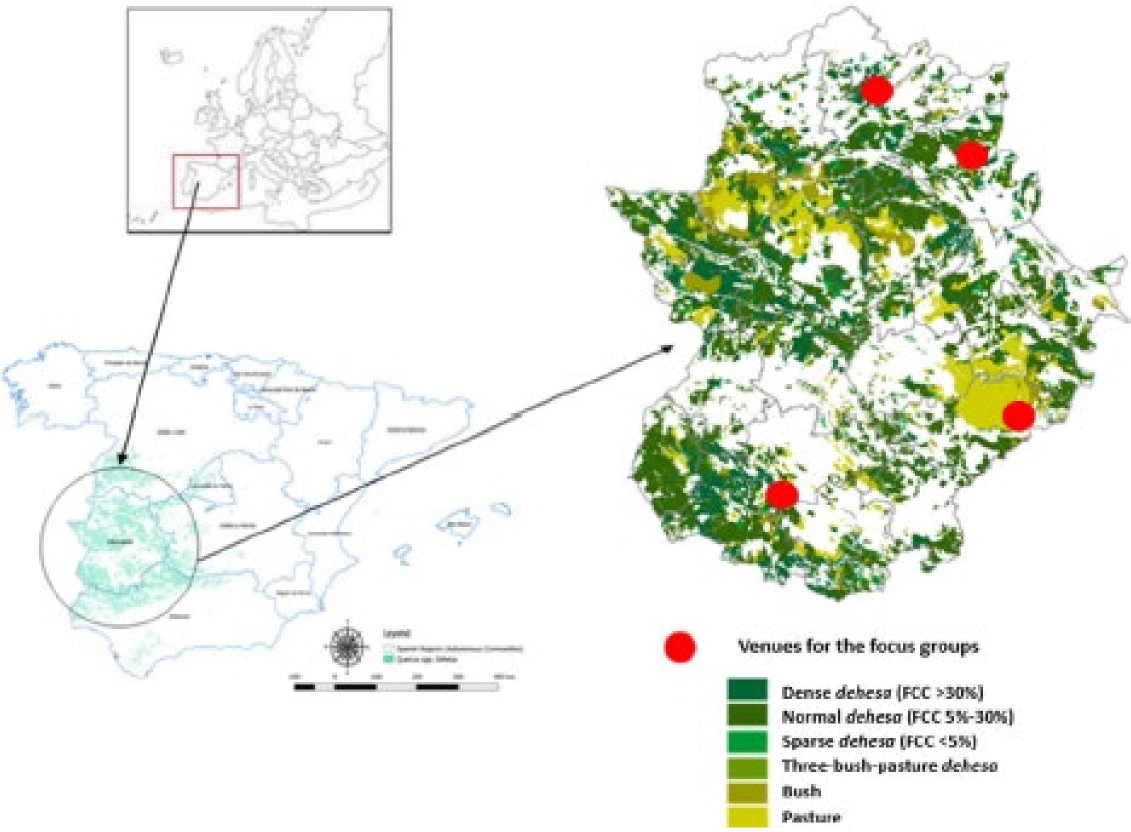

Figure II. 1. Situation of the dehesa areas in the Autonomous Community of Extremadura and the venues used to hold the focus groups.

2.4. The focus group process

Four focus group sessions were held with the design of various activities requiring involvement and interaction amongst the participants. Each session followed a common protocol that had been developed by the research team. Such protocol was previously provided to the moderator of the session. Each session began with a briefing of the research project in which the activity was included (Research Project GanEcoEx reference: IB16057), which provided the participants with the necessary preliminary information. Then a three-block structured discussion was initiated. During the first block, an open discussion was promoted based on an Ishikawa diagram with the purpose of identifying the barriers preventing the Extremadura's livestock farming sector from converting to a sustainable organic model.

For this purpose, the moderator proposed a poster (90 × 90 cm) showing the lines of a diagram with each line representing a category under which the barriers for the farming sector in the region to convert to organic farming could be classified, as well as any others arising during the discussions. The initial categories that were defined by the research team were: supply, production techniques, regulations, transformation, commercialization and consumption.

During the second stage, participants were asked to prioritize the barriers identified in the Ishikawa diagram according to how easy it was to eliminate or reduce them. The third stage focused on the proposed specific improvements that would reverse or minimize the barriers identified.

The moderator conducted the group discussions, the discussion times and the change of subject to be discussed in order to ensure that the data being collected were solid. Various strategies were employed, including the extension and rewording of questions as well as a summary of the discussions provided by the moderator, once every discussion was partially finished (Ates et al., 2017; Krefting, 1991; Krueger and Casey, 2009).

The sessions were recorded on video and audio for the purposes of analysis at a later stage. All the participants provided their written consent after reading an informative document which detailed the purposes of the study, the methods to be used for data collection, the recording of audio and video evidence and the confidentiality of their data. The total time employed in each session was 120 min on average.

2.5. Data analysis

The video and audio recordings of the four sessions were transcribed and made anonymous for subsequent analysis. The analysis of the information collected was carried out using the content analysis technique (Stewart and Shamdasani, 1991). The content analysis technique attempts to obtain valid and replicable inferences from texts, with an aim to reduce the source material (Flick, 2009).

The information was initially processed and organized into common subjects using the Atlas.ti 7.0 software program to analyze the qualitative data. The ideas and concepts repeatedly mentioned during the sessions were classified under each subject matter and then coded according to the profile of the participant who provided the idea in order to produce a count. Once all the transcriptions were coded, they were classified as barriers or proposals for improvement, which is the format employed in this paper. The means of measure used is the frequency of mention, which is the number of times that each barrier comes up in all four sessions.

Given the qualitative nature of this study and with the purpose of improving the validity of the findings, triangulation was used to carry out the analysis. This procedure is frequently used in qualitative surveys (Antmann et al., 2011; Da Silva et al., 2014; Dundar, 2013; Eldesouky et al., 2018). Figure 2 shows a diagram of the full methodological process.

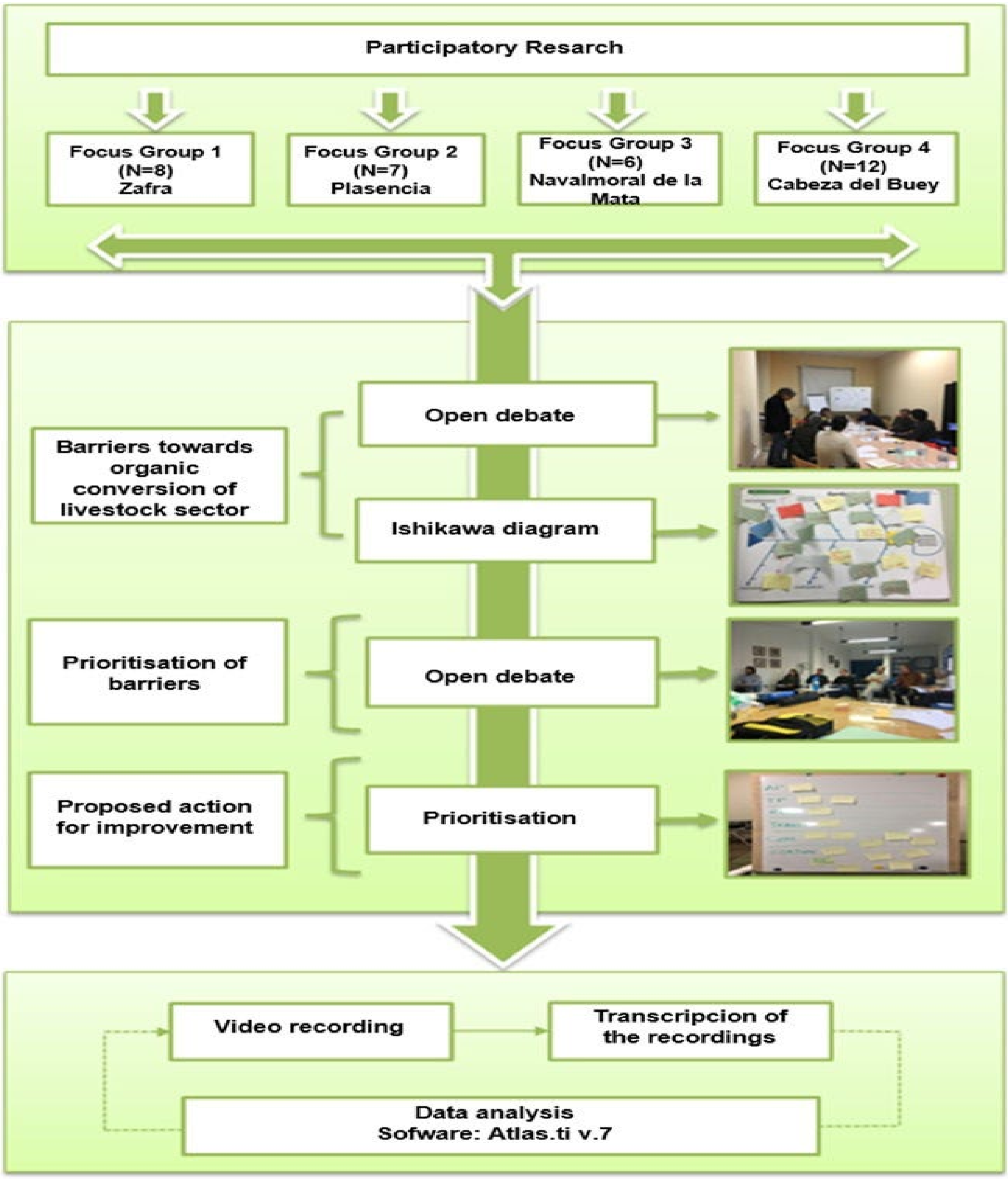

Figure II. 2. Methodological process used. It shows a diagram with the main activities of the process.

3. Results

The results are presented into three core subjects for a better understanding of the study. The first one deals with the issues hindering production and the transformation processes in organic livestock farms, as well as the issues associated with the structure of the organic livestock sector. At the same time, the improvement actions that could be implemented to the system are considered at this stage. With a similar structure in terms of content, the second core subject deals with the administration and management of the organic livestock farming systems. Lastly, the third one focuses on the education and training of the various stakeholders, which are key aspects for the analysis of the demand and consumption of organic products.

3.1. Barriers inherent to the production and transformation systems in organic livestock farms and to the relationships amongst the stakeholders of the sector

3.1.1. Factors which affect the production and the transformation of the products

Figure 3 shows the barriers identified in the production and transformation processes of organic livestock farms and those deriving from the relationships amongst the stakeholders of the sector. Every variable in the figure is a barrier and the scale represents how often they are mentioned.

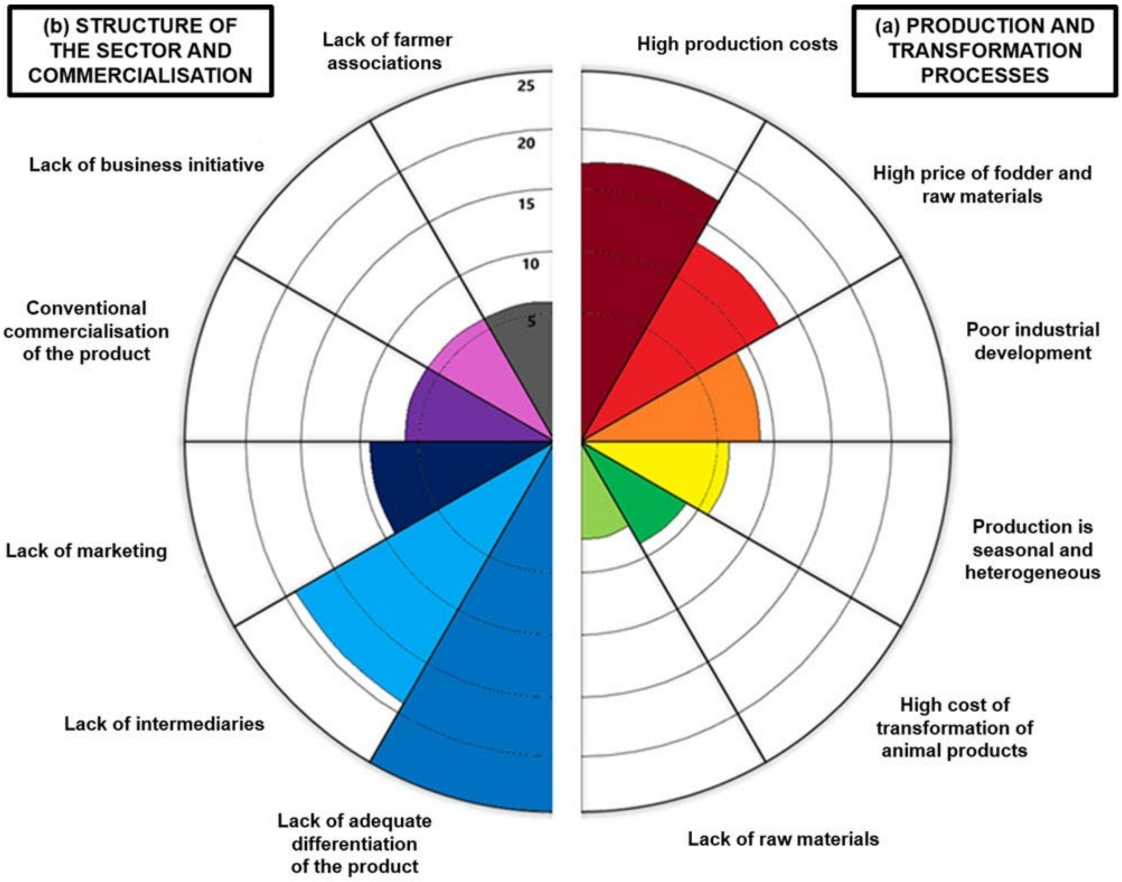

Figure II. 3. Factors with an impact on the production, transformation, sector structure and commercialization of organic livestock farms (scale: frequency of mention).

With regards to the production and transformation processes, Fig. 3(a) shows the main barriers identified in the sector are the high production costs and the high prices of organic fodder, which are partly caused by the lack of availability of these raw materials in the region.

In this sense, the comments made by the participants in the focus groups were:

> *'The inputs are more expensive, organic fodder is very expensive compared to conventional fodder and conventional fodder is already quite expensive'. Male farmer, 35 yrs old.*

The following factor that was mentioned in order of importance was the poor level of development of the agroforestry industry for animal products originating in organic farms, which increases the costs with respect to conventional production.

With regards to the production techniques, the main barriers of the respondents pointed out were the fact that the production was seasonal and the difficulty in obtaining homogeneous organic meat production. In one of the participants' own words:

> *'These products are clearly seasonal, we must program animal birth timings for the herd in order to be able to produce kids all year round, but without synchronisation methods, this is very hard'. Female farmer, 40 yrs old.*

The relevant proposals for improvement that were raised in the focus groups have been put together in Table 1. The outstanding ones among them are the promotion of self-sufficient farms by way of extensification. A participant whose animals or livestock farm is undergoing the conversion process stated:

> *'In order to be absolutely organic we must start from way before, we must change the way we manage our farms and make them capable of feeding our animals without the need for the high amount of inputs that conventional farming has created us, then I would start by changing the model'. Male farmer, 45 yrs old.*

Table II. 1. Proposals for improvement of the production and transformation processes in organic livestock farms and the relationships amongst stakeholders in the sector.

Proposals for improvement of the production and transformation processes	Frequency of mention[a]	Difficulty of implementation[b]
Promotion of self-sufficient farms by means of extensification	17	Medium
Application and improvement of production techniques (improved pastures, permanent prairies, corn silage, animal births programs...)	11	Medium
Implementation of a mobile slaughterhouse in the region	6	Medium
Reopening slaughterhouses	6	High
Improvement of the sale formats of organic meat products	4	Medium
Promotion of the growth of organic raw materials in the Autonomous Community of Extremadura	3	High
Building specific facilities	3	High
Building shared workrooms	2	Medium
Proposals for improvement of the structure of the sector and product commercialisation		
Promotion of direct sales and short commercialisation channels	9	Medium
Increase of the advertising produced by the organic livestock sector (social media, new technologies …)	9	Low
Promotion of cooperation amongst the organic livestock farmers	7	Medium
Selling organic products at a higher price (higher quality)	5	Low
Making organic products on request	4	Low
Drafting a “guide” of user groups (at the District Agroforestry Offices) to be used by farmers	4	Low
Creation of a pricing board for organic products	4	Low
Implementation of an organic livestock farming cluster	4	Medium
Extension of commercialisation in the EU and other countries	3	High
Promotion of associations of existing organic livestock farmers	3	Medium

[a] Frequency of mention: In this section, the times the concept is mentioned in all the sessions is shown.
[b] Difficulty of implementation: In this section, we describe the difficulty of implementing the action and classify it into three categories according to the degree of consensus obtained in the focus group: Low, Medium and High.

Some of the techniques being mentioned in order to attain this purpose were: improvement of pasturelands or producing own corn silage in order to feed the livestock. Another potential measure that the respondents pointed out was to promote the growth of organic raw materials in order to feed organic livestock, such as winter cereal or corn. In this context, a female organic farmer stated:

> *'This option should already be implemented and would benefit the entire sector. An increase in the growth of such raw materials would lead to an increase in stock and would lower the price of fodder'. Female farmer, 50 yrs old.*

Another improvement proposal that some respondents commented on was programming animal births in the farms, as the seasonality of the livestock production remains a barrier for organic livestock farming. Calving and lambing seasons are very concentrated in one period of time due to the climatic conditions in the dehesa systems. Some participants understood that for commercial purposes, it is very important to continuously provide products to the market in order to achieve better prices and maintain good contracts with retailers. For organic producers, this is very difficult to achieve for two reasons: (i) the availability of food for livestock is very seasonal since it depends to a great extent on pasture production and, (ii) fertility is also seasonal due to photoperiod issues and to the extreme climate conditions in the summer (it leads to the avoidance of births at this time of the year and their concentration usually in spring). For organic farm participants, this seasonality is an added constraint compared to conventional farmers, since they are not allowed to use hormones (e.g., induction or synchronization of the oestrus).

With regards to the poor industrial development in organic farms, the participants proposed the construction of specific facilities, such as a classification center for the exclusive use of organic lambs, or shared industrial infrastructures, such as workrooms that can be used by several organic farmers, making the start of organic production more affordable for small and medium-size businesses. In this sense, an organic farmer pointed out:

> 'We should reopen all the small slaughterhouses in the villages where there is demand from livestock farmers'. *Male farmer, 40 yrs old.*

This respondent stated that he finds great difficulty to slaughter his animals in slaughterhouses certified for organic production.

Another proposal was the implementation of a mobile slaughterhouse in the region. This option is not currently authorized by the regional council, as an attendee pointed out:

> *'In other Autonomous Communities these are allowed for the production of chicken and they are working well'. Female farmer, 31 yrs old.*

Lastly, some respondents also argued that the sale formats of organic meat products can be greatly improved. Unlike the conventional packaged meat products, the impossibility of using certain food additives makes this packaging task very complex for the sector. The idea of seeking alternatives in order to improve these formats was frequently mentioned during the four sessions.

3.1.2. Structure of the sector and product commercialization

Figure 3(b) also shows the barriers associated with the structure of the livestock farming sector and the commercialization of organic products. As the figure points out, the main barrier identified is the lack of adequate differentiation of the product, followed by barriers associated with the lack of intermediaries in the value change and marketing strategies. An organic producer selling all his products under the organic meat label stated:

> *'The product is in demand, but the real issue remains that production is not organised in order to meet the demand. And I think the issue is also the fact that there is no sector, an actual sector that can defend itself'. Male farmer, 56 yrs old.*

The lack of an organized sector for organic livestock farm products also implies a lack of commercial initiative. Another participant argued:

> *'No target market? Ok, but I sell my product little by little, and thus I am opening my own way into the market. And this is the actual issue, we cannot sit and wait. I insist, the major problem here is that we complain again and again, but we do nothing about it. We are just waiting for a large foreign company to come and buy all our production'. Female farmer, 31 yrs old.*

On the other hand, the participants also suggested that commercialization using conventional markets is a huge problem for the organic sector with the loss of the product's added value. Another commercialization problem was associated with inadequate advertising or the lack of marketing in the organic livestock sector. From the participants' standpoint, such a lack of marketing is caused by a poorly developed intermediary sector in the commercialization chain and the insufficient industrialization of the region.

Table 1 also contains the corrective measures to the barriers previously identified. A few of them can be highlighted, such as, the promotion of new commercialization channels such as direct sales or short commercialization channels, which were proposals that were well received by small and medium-size businesses. However, this idea was not supported equally by those participants representing larger farms and businesses. Another business model that was mentioned was at-request or on-demand selling, that is, the preparation of a product once the price and quantity have been agreed. In this sense, one of the participants said:

> *'I intend to produce organic pigs, but only provided that I have previously agreed the terms and conditions of the sale'. Male farmer, 42 yrs old.*

Other ways the participants thought could help commercialize the products of organic livestock farms is the association or grouping of farmers of the sector, either by promoting cooperation or the creation of associations amongst the existing organic farmers. These organizational structures would be created with the purpose of supporting farmers, facing issues together and participating in sector meetings and events.

They also suggested ideas that would be of great interest on the regional level, such as the implementation of an organic livestock farming cluster, where all the stakeholders in the chain would be in touch. This would mean an improvement of their projection and would make certain activities easier, such as sourcing suppliers, selling end products, raw materials, etc. A participant stated:

> *'The idea of a cluster is good, because all suppliers would also share a space'. Male farmer, 56 yrs of age.*

In addition to the cluster, another proposal was the implementation of a Price Board to provide price guidance and prevent sale discoordination.

Lastly, the creation of a 'Farmer's Guide on Consumer Groups' would help with the commercialization and distribution tasks for the farmers and organic producers.

3.2. Barriers related to administrative aspects and governance of organic production systems

This section deals with the findings associated to the way the Government of Extremadura administers organic livestock farms and the procedure used to manage these production systems, in terms of the way the various administrations involved interact with the producers, the organizers and other stakeholders. The regulations governing organic livestock farming in Extremadura at the time of drafting this paper are: (EC) Regulation no. 834/2007 of the Council of 28th of June 2007 and (EC) Regulation no. 889/2008 of the Commission of 5th of September 2008 and Animal Health Act 8/2003 of 24th of April.

Figure 4 shows the various barriers mentioned in this respect.

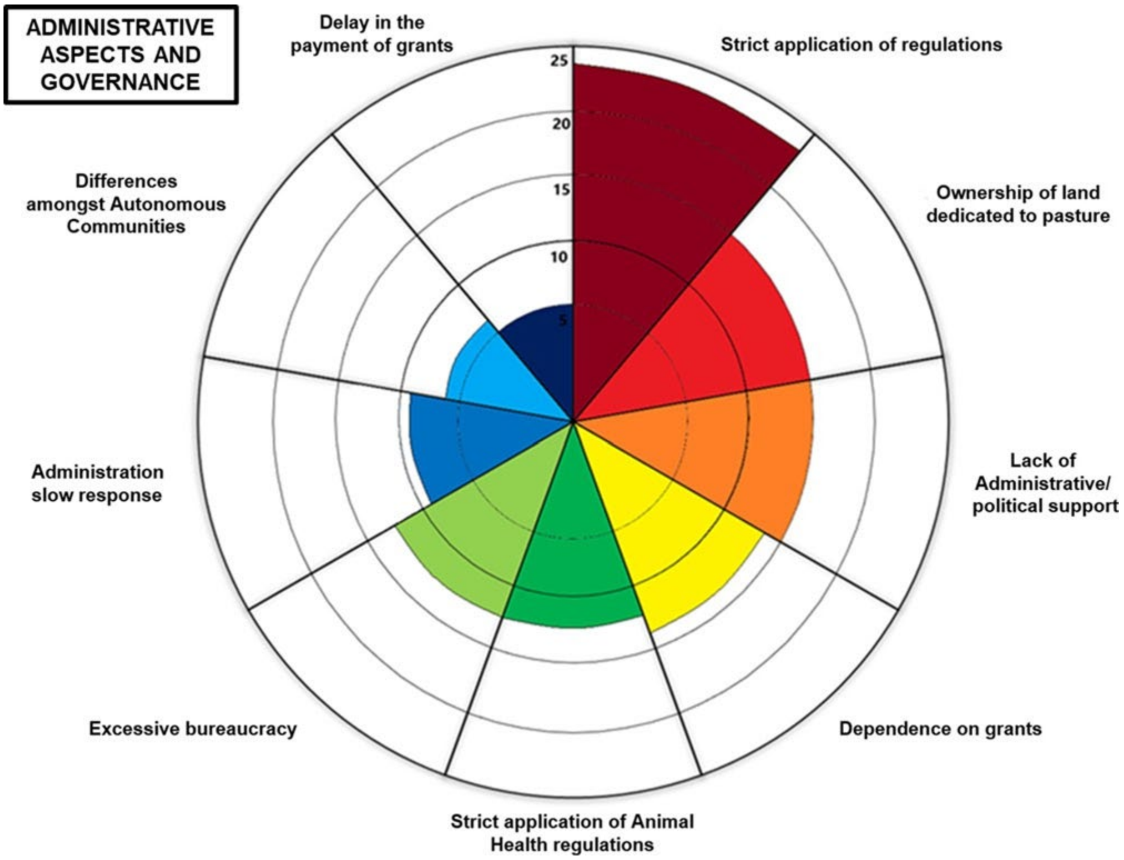

Figure II. 4. Diagram of the factors mentioned in relation to the administration and management of organic production systems (scale: frequency of mention).

As shown, the barrier that was mostly mentioned was the way the Government in Extremadura applies and interprets European regulations, which was considered excessively strict in all its areas. The participants commented that this particularity was evident in issues such as the reduction of the stocking density, the introduction of certified raw materials from other Autonomous Communities or other countries in the EU, the conversion timeframes, mobility of studs between farms or the minimum times required to approve the slaughter of chicken.

Another barrier that was also frequently mentioned was the issues associated with the ownership title of the farm land. The attendees stated that currently the majority of the livestock farmers do not own the land they use, but they own it on a rental basis. Provided that the change to organic cannot be made fast (the European regulations establish specific timeframes for reconversion) and since, as tenants, they can only own the land for the term of the contract, the strictness of the regulation brings uncertainty toward making a decision on whether changing to organic or not (what would happen when, as a way of example, the contract on one or several plots of land is not renewed?). This complaint was particularly frequent in the mentions amongst the sheep extensive farmers.

Another barrier that was mostly discussed was the fact that the organic livestock farming sector greatly depends on grants at present. In the words of a participant:

> *'Currently, organic production would be very hard without grants. Generally, there are only very few organic farmers with farms that are financially viable in themselves'. Manager, 58 yrs old.*

Another barrier that was the delay in the payment of the grants specifically destined to organic production and agroforestry grants. Lack of political/administrative support was also mentioned as a burden for farmers since the origins of organic farming. A participant highlighted:

> *'In the 18 years I have been an organic farmer, i.e., since year 1999, I have yet to be convinced that the Administration believes in the term "organic"'. Female farmer, 42 yrs old.*

Excessive bureaucracy, this is, the administrative procedures or formalities required to obtain organic certification and maintaining organic farming were considered as an obstacle for the progress of the sector. Additionally, administrative slow responsiveness, especially when dealing with requests to urgently treat sick animals, authorizing non-organic food in times of extended summer, etc., were mentioned. With regards to these issues, participants also mentioned that in other Autonomous Communities of the Spanish territory, some of these formalities are sorted differently and in their opinion perhaps in a more agile and convenient manner. For example, a participant stated:

> *'In Andalusia everything is managed by an external company, not the Government. Perhaps we could consider this option'. Female farmer, 40 yrs.*

Animal health-related barriers were said to affect livestock farming and, in particular, the measures adopted as a result of the application of the National Plan Against Tuberculosis in Spain, affecting all types of ruminant farms. According to the participants, the restrictions on animal transfers and the reduction in health certificates deriving from the increasing cases of animal sickness in extensive farms are affecting negatively the cattle and goat organic farms.

The participants also contributed to potential solutions that are shown in Table 2.

Table II. 2. Proposals for improvement related to administrative aspects and governance of organic production systems.

Proposals for improvement in the administration and management	Frequency of mention[a]	Difficulty of implementation[b]
Establishing an initial economic grant to help until the market takes off	13	Medium
Establishing a computer registry between farmers and the Administration	5	Low
Meetings between the Administration and the organic livestock farmers	4	Low
Promotion of an Organic Agriculture Committee in Extremadura as the element to aid the sector	3	Low
Flexibility of the organic regulations	3	Low
Flexibility of animal health regulations	2	Low
Improvement of the certification processes and public control	1	Medium

[a] Frequency of mention: In this section the times the concept is mentioned in all the sessions is shown

[b] Difficulty of implementation: In this section we describe the difficulty of implementing the action and classify it into three categories according to the degree of consensus obtained in the focus group: Low, Medium and High.

As shown, the solution proving most consensual and also mentioned most times by the participants was 'Establishing an initial economic grant to help until the market takes off'. Some of the ideas the participants suggested during the session were:

> *'An initial grant from European funds to help until the market takes off'. Manager, 58 yrs old.*

> *'Once the organic product commercialisation becomes profitable and the market is prepared to pay the right price for such products, the initial grants can be withdrawn, but while the situation remains as it is, the production shall be impractical without grants'. Male farmer, 56 yrs old.*

With regards to the currently-effective regulations, participants referred to a need for flexibility in organic production as well as animal health matters (National Plan Against Tuberculosis) as participants saw that:

> *'The regulations exist to be interpreted and not to be used to create obstacles for farmers'. Male farmer, 36 yrs old.*

In general, the participants thought there was a need to reinforce the relationships between the Regional Government and the farmers and they proposed that a number of professional meetings were held between the agri-food stakeholders and the Regional Government in order to clarify some issues and make decisions in specific cases. As a participant stated:

> *'The solution I see would be a meeting between the Administration and the farmers in order to analyse specific matters and find a joint solution'. Male civil servant, 35 yrs old.*

One of the specific ideas proposed in order to speed up and solve issues such as the above-mentioned 'excessive bureaucracy' and 'administrative slow responsiveness' was the creation of a computerized register. This would help the Regional Government deal more quickly with farmer's enquiries and requests, as well as inform them of their obligations in a secure and instant manner.

Another potential solution that was proposed was the reinforcement of the Organic Agriculture Committee in Extremadura as an intermediary between the agri-food stakeholders and the administration by improving its organization and structure.

3.3. Barriers in the training/education and consumption

3.3.1. Training and education as drivers for awareness

Figure 5 shows the findings associated with education and training, two factors with a direct impact on awareness, which is necessary to drive the change to organic.

During the focus group sessions, five barriers associated with training and education were summarized [Fig. 5(a)]. The most frequently mentioned aspect was farmers not being knowledgeable of organic production techniques. This is attributed to a lack of qualified technicians in the sector in the region. Some participant comments in this respect were:

> *'After all, the issue is the existing lack of training, as many people start up an organic farm business unaware of what it entails and that ends up being a problem for everyone… consumers, Administrations, etc.' Female farmer, 31 yrs old.*

'In my opinion there is a need for technical training, because when one becomes an organic farmer, one finds issues and sometimes you don't have many people to go to'. Female farmer, 40 yrs old.

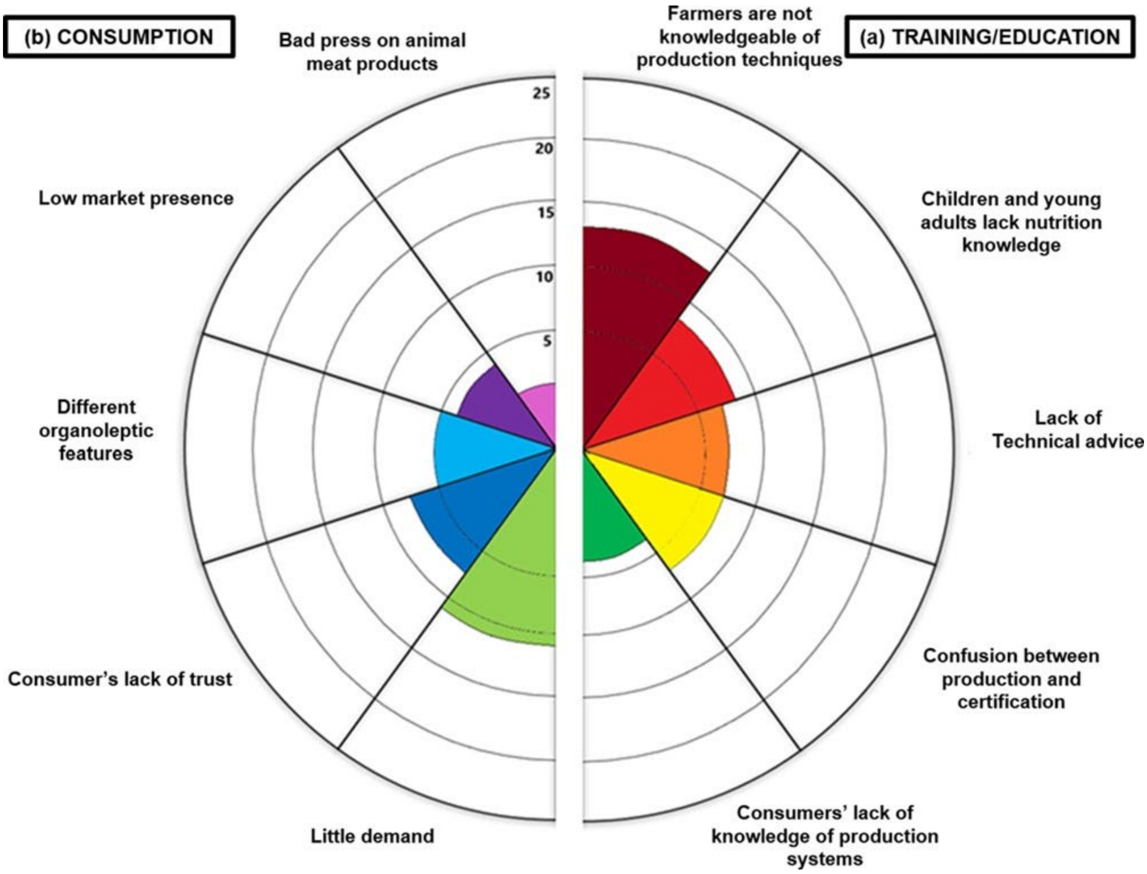

Figure II. 5. Diagram of the barriers mentioned in association with education and training, demand and consumption (scale: frequency of mention).

Another barrier mentioned by the participants was the controversy between organic production as a production system or as a concept, and having a farm or a plot of land that is certified as organic, that is, the dichotomy between production and certification. The strict European regulations are not equally applicable to the reality of all systems and this causes issues that are not easily solved by many farmers. Consumers on their side are not even aware of these issues and therefore they are not prepared to compensate them on that account.

Society is not knowledgeable of livestock farming in general and of the various production systems in particular. Participants highlighted that without the appropriate information and education basis, especially addressed to young people who are increasingly less attached to the rural areas and even less to livestock farming, the necessary selling differentiation of animal organic products proves very hard.

In the same way as with the previous sections, these sessions concluded with the identification of potential solutions, which are shown in Table 3. As the table shows, the aspect that seems to be the pillar to solve the majority of the issues identified earlier on is the reinforcement of the knowledge that society generally has of organic livestock farming, but also raising awareness in public administration staff, the producers and the intermediaries (e.g., slaughterhouses and companies in charge of producing the food of animal origin).

Table II. 3. Proposals for improvement of education and training, demand and consumption.

Proposals for improvement in education and training as a factor to raise awareness	Frequency of mention[a]	Difficulty of implementation[b]
Training of the producer	7	Medium
Training of society	5	Medium
Training of the Administration	2	Medium
Training in matters of organic production to be provided to slaughterhouses and companies making meat products	2	Low
Proposals for improvement of demand and consumption		
Increasing the information provided to consumers on organic livestock farming products	21	High
Promoting "Organics, Alimentos de Extremadura", as a differentiating brand name for this sector	6	High
Promoting research to gain consumer trust in the organic meat product	4	High
Increase the number of antifraud control procedures for organic meat products	3	High

[a] Frequency of mention: In this section the times the concept is mentioned in all the sessions is shown
[b] Difficulty of implementation: In this section we describe the difficulty of implementing the action and classify it into three categories according to the degree of consensus obtained in the focus group: Low, Medium and High.

The findings shown in Table 3 are followed by some comments made by the participants:

> *'The consumer requires more training, there must be more information and more communication …' Male farmer, 48 yrs old.*

'The key is consumer education, because consumer preferences vary and come and go like fashion; only when you carry out a comprehensive piece of research and manage to reach your clients, you can sell. If your products are not demanded, you will have to stop producing'. Technician, 40 yrs old.

As one of the participants stated with regards to the training of the public administration staff:

'The public administration staff requires improved training which could be delivered through training courses; teachers and civil servants receive training courses which are delivered internally, that is, courses they are forced to attend and everyone is required to undergo them, therefore technicians and personnel in charge of this should also be able to do the same'. Technician, 45 yrs old.

Finally, with regards to training producers and businessmen with businesses in this sector, the participants stated:

'Farmer training, not only in the criteria to follow in order to secure their sales, but also in every aspect, because there are techniques that help produce more and better and they are well tested (shepherds school, sales techniques, etc.)'. Male farmer, 43 yrs old.

'Conventional slaughterhouses should be informed and told that they can slaughter organic animals so that they may prepare the necessary documents and so that we, the organic farmers, may slaughter our animals once a week, and then things would be much easier for us'. Farm Manager, 42 yrs old.

3.3.2. Demand and consumption

The findings deriving from core subject 'demand and consumption of organic animal products' are shown in Fig. 5(b). First of all, the scarce demand for animal organic products is the barrier most frequently mentioned, especially in the case of organic meat. A participant said:

> *'It is hardly being commercialised; all the organic lamb meat being produced goes in the same batch as conventional lamb, there is no market for organic lamb'. Technician, 48 yrs old.*

According to the participants, this lack of demand is also having an impact because there is no sufficient physical presence yet of such animal products or organic meat in the market. Some of the comments along the lines were:

> *'The issue with consumption is that you can only have consumers if you are present in the market, if you don't, you cannot have consumers'. Technician, 48 yrs old.*

Another barrier that was mentioned was the lack of consumer trust in organic products and in particular those of animal origin. Some participants mentioned that the lack of consumer awareness of the organoleptic characteristics of organic products cause contradictory effects in consumers, who think their appearance or look is less appealing than that of conventional products.

Some also commented on the fact that the bad press affecting meat products in general (diminishment of conventional animals' production systems, such as feedlots, encaged hens, slaughterhouses, slaughter methods, etc.) is also extended to organic products due to the above-mentioned consumer lack of knowledge.

One of the potential solutions that was raised at the focus group session (Table 3) was the reinforcement of the training provided to consumers with scientifically-based information. The development of a piece of research in order to prove that organic meat has benefits that meat produced in intensive or traditional systems do not have. As a way of example here is the comment made by one of the participants:

> *'Some studies have come out of recent comparing intensively and extensively produced meats, with the conclusion that these two types of meat are not equally healthy as they vary in protein content, etc. This is an aspect the consumer should be able to appreciate, but the consumer needs to be told first'. Female researcher, 53 yrs old.*

Another solution that was contributed in this respect was the need to increase the information that is provided to the consumer, both in terms of the number of media employed as well as the frequency of use. People involved in organic livestock farming at any level can certainly understand the benefits that these organic production systems bring to the environment, but the majority of ordinary people are not aware of this and this lack of information translates into mistrust when shopping.

Lastly, another potential solution for the issue of demand and consumption of organic products relates to the fact that the region needs a distinctive brand for this sector. During several of the sessions the brand name ‘Organics, Alimentos de Extremadura’ came up. This brand name could become the quality label for organic products manufactured in Extremadura provided that sufficient support and promotion were provided.

4. Discussion

Following an analysis on the barriers affecting the production processes in organic farms, it was considered that the high prices of organic fodder were one of the main reasons preventing extensive farms from converting into organic production systems. In this context, several authors state that the costs of production associated to organic livestock farms are higher than those in conventional farms, especially due to the higher cost of fodders (Blanco-Penedo et al., 2012; Gillespie and Nehring, 2013; Hrabalova and Zander, 2006; Veysset et al., 2009). This situation also becomes more complex due to the reduction in productivity of organic livestock farms compared to conventional farming methods (Benoit and Veysset, 2003; Blanco-Penedo et al., 2012).

One of the solutions aiming at reducing the high costs of feeding the animals in livestock farms was the introduction of a greater degree of extensification and self-sufficiency in farms. But, the reality is that self-sufficiency in extensive farms is a complex task (Dantsis et al., 2009) and the use of external inputs in extensive livestock farming is already high (Toro-Mujica et al., 2011). In this sense, an increased growth of organic raw materials by farmers in the region could reduce prices as availability and the number of offerings increase. This idea, which fully fits into the philosophy of organic production, is controversial, as the conversion from conventional farming to organic farming can mean a reduction of 19.2% in the profits, although this change would be compensated by higher selling prices and would be the necessary step to reduce the costs of organic fodder (Ponisio et al., 2015).

The implementation of such changes (increased growth of organic raw materials by farmers in the region and a greater degree of extensification as well as self-sufficient farms) is a complicated task due to the lack of association and organization in the farming sector in general and in the organic sector in particular. This fact proves to be the main barrier but is also the one on which most future expectations are based.

The solution to some of these shortcomings could be the creation of associations between professionals through an organic production cluster, which can help combine synergies form various organic producers, not only meat producers, but also other farm products such as raw materials for animal feeding. This option might well be able to relieve some of the existing barriers and work toward the search for adequate production development paths. But this is not an innovative solution (Colom Gorgues and Colom Espada, 2010). Spain can already provide examples of how such clusters have helped solve basic issues of organic production, such as is the case of Catalonia and the projection of its organic food products (Valls, 2017). At the time, this paper is being drafted and Operational Group, a project funded by the EU Rural Development policy of the European Commission (EIP-AGRI Service Point, 2014), has recently been set up with the purpose of creating a platform for organic production in Extremadura Region (PTAEEX). The group has commenced to develop its activities, including the creation of a specific working group integrating the main stakeholders within the livestock farming sector.

With regards to the aspects relating to demand and consumption of organic food, we are currently undergoing a global crisis of the agri-food system where the traditional production methods are being questioned. This is having a major impact on the demand and consumption of food. Consumer trust in certain food products is based on ethical aspects such as respect for animal wellbeing, and the growing concern for consumer health. These aspects are key in terms of promoting organic meat products. Although in the short run, the demand of such products will not see an increase, the future trend will be a positive one as the current search of sustainable food production systems and the fight against climate change (Eldesouky et al., 2018; Escribano et al., 2018) are certainly contributing to the increase of the organic sector.

Success also depends on the review of the consumption patterns and the ability to make such products accessible, as the high prices and the reduced distribution restrict development and expansion. In this sense, various strategies have been developed with the purpose of improving consumption within the food sector, as for example, the European quality system implemented in relation to organic production (Bollani et al., 2019) and the certification and labeling schemes that highlight sustainability of a food product (Van Loo et al., 2014).

Another important barrier that was pointed out was the commercialization of organic animal products, due to the inability to identify an adequate channel to generate added value for these products. This difficulty makes farms incapable of attaining a premium price for their products and prevents farmers from deciding upon conversion (Sahm et al., 2013; Tzouramani et al., 2011).

The solutions that the participants contributed to this study in order to help improve the commercialization of organic livestock products in Extremadura focused on exploring other sales channels, such as direct selling or short commercialization channels, which may contribute to the reduction of market prices. These proposals were in line with the opinions of other authors such as Lee and Yun, (2015) and McCabe and Nowlis, (2003).

On the other hand, this study has proved that farmers and producers feel a lack of trust of consumers in organic products, which may be associated with the lack of knowledge of the productive systems used. In their view, it is essential to train the consumer in the knowledge of organic food and reduce the existing high level of uncertainty. Quality brands certifying the geographical origin of a product (PDI and PDO European Union quality schemes) and certified organic products contribute to generate trust in the consumer. However, although consumers from Extremadura value the brands that certify their geographical origin, they do not grant the same value to organic certified products (Mesías et al., 2008). This is because many of these consumers believe organic products are also some traditional or local products (Mesías et al., 2011). The brand name Organics has been created by the Regional Government of Extremadura for products that belong to the organic agri-food sector and are produced by companies from Extremadura. They combine those two certifications of geographical origin and production system, but are yet insufficiently developed, especially products of animal origin as only a few companies use them.

The participants also pointed out the lack of demand for organic products. Nevertheless, this idea disagrees with recent studies (EcoLogical, 2018; IFOAM, 2016; MAPAMA, 2016b) which reveal a sustained increase in production as well as in demand for organic products not only in the Spanish market, but also in the global markets.

At the same time, other consumer research (Calatrava Requena and González Roa, 2012; MAPAMA, 2012) states that the difficulty in finding organic products at the usual establishments is one of the main barriers for the consumption of said.

This leads us to the conclusion that the 'lack of demand' farmers pointed out and the 'lack of supply' stated by consumers could be indicative of the disassociation between supply and demand, which causes dissatisfaction to both parties and creates unbalance and disagreement in the organic product market. This would seem to be one of the main obstacles of the organic product market in Spain, although it is being solved by the development of a specialist channel as well as the greater implementation of bio foods in large distribution chains (EcoLogical, 2018).

In this sense, a solution would range from promoting associations of the existing organic farmers in order to enable more competitive commercialization through a collaborative approach. On the other hand, the creation of an efficient database of organic products' consumer groups in the region and the use of the social media as new channels for commercialization (Elghannam et al., 2017) could also be complementary to the above-mentioned strategy. In this respect, it is essential to develop the commercialization channel's intermediary sector in the region. In order to do so, the Regional Government of Extremadura is already offering incentives to agricultural associations dealing with organic production within its Strategic Plan.

Apart from offering incentives to promote the creation of associations, this Strategic Plan also considers a set of grants to be awarded within the Rural Development Programme 2014–2020. Approval of this Strategic Plan is very recent, and took place after the fieldwork developed in order to write this paper; therefore, it is only logical to think that the effects on the sector will take some time to emerge. These support lines are similar to those developed in other Autonomous Regions: Andalucía saw the first Andalusian Plan for Organic Agriculture back in 2002 (currently the Plan in effect is called III Plan), whereas Aragón and Castilla y León (the Autonomous Regions with most extensive farming in Spain, together with Andalusia and Extremadura) already approved their respective strategic plans at the beginning of the 2014–2020 program.

The findings reveal that the difficulties posed and the requirements established by European regulation for organic production to be adequately certified are a huge barrier for conversion. This issue is further aggravated by the diversity of the European production systems, which generates some differences in the way regulations are applied in the various European regions or territories.

Specifically, within the Spanish territory, the Extremadura dehesa, is, as previously highlighted, one of the ecosystems with most transformation potential into a sustainable and organic model. However, the lack of regulations that can be applied to the peculiarities of this system prevents in many ways its conversion into an organic production system.

In addition to the regulatory issues, the grants and aids allocated to producers continue to raise discussions, especially those deriving from inadequate administrative and management procedures (e.g., in terms of delays in the materialization of the grants, slow processing of formalities or lack of response to requests and applications). All of the above occurs in a context of organic farms which depend on grants more than traditional farms would (Blanco-Penedo et al., 2012; Gillespie and Nehring, 2013; Hrabalova and Zander, 2006; Veysset et al., 2009), a factor that makes it essential to rely on efficient and adequate management.

5. Conclusions

Participatory research and its development through focus group sessions is a tool which allows the diagnosis of the current situation and the prognosis of the future of organic animal production in dehesa agroforestry systems. The participation of the main stakeholders in the sector in such systems reveals the reality of this production model and its economic, social and environmental implications.

The transformation of dehesa extensive systems into organic models could improve the economic expectations of these production systems at a time when traditional methods of agri-food production are the point of debate in the EU, which is currently looking for more sustainable production models based on ethical reasons, conservation of biodiversity or human health. However, in order to promote the increase in the number of organic systems, it is necessary to analyze the barriers that these production systems encounter and the potential proposals for improvement which would encourage their adequate conversion from conventional livestock farming systems into organic systems.

Although in principle a close link between dehesas and organic systems could be seen, in the practice there have been important barriers that go beyond the production method that limit the latter's expansion, such as: in the organic production model, the high market prices of organic fodders, the scarce development of the agri-food industry and the lack of slaughterhouses and cutting plants are also key factors which slow down the implementation of this production model. In this sense, self-sufficient animal feeding and the improvement of certain infrastructures could attempt to improve the stability and competitiveness of organic farm production. Added to these factors are the classical elements encountered in other green or sustainable products, such as the need for differentiated marketing, and the higher price compared to conventional products as limiting factors. At the same time, the lack of structure of the sector and deficient commercialization has a negative impact on the promotion and development of organic livestock production, while there is a need to create farmer associations and marketing actions to secure the adequate pricing of these products.

In this sense, the improvement of the income made by organic farms will certainly require higher market prices for their products. This is difficult to achieve through the traditional channels. Currently, the demand for these products is restricted to a very sensitive consumer with a specific purchasing power.

At present, we think that the public administrations and the regulations for the sector play a decisive role in their development. The most sustainable production systems with the least impact on the environment that somehow contribute to the fight against climate change have an important potential for compensation in the new CAP.

The development of an adequate organic production model involves the necessary actions to promote education and training of both consumers and the livestock farming sector, which at the same time can secure the demand and consumption of organic products. A sense of trust in the organic product must be reinforced and the promotion of the brand image of organic products. In this sense, adequate advertising efforts and Government support have a transcendental role.

Future research steps will necessarily be looking for certain successful models of organic production in dehesas that allow exporting to potential replicating farms, and explain how to face the transition from one production model to another, how to approach self-sufficient farms and how to do make them economically sustainable.

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Chapter III. Organic Farming as a Strategy to Reduce Carbon Footprint in Dehesa Agroecosystems: A Case Study Comparing Different Livestock Products

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Organic Farming as a Strategy to Reduce Carbon Footprint in Dehesa Agroecosystems: A Case Study Comparing Different Livestock Products

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Simple Summary: This paper attempts to analyze the impact of organic livestock farming in dehesas through the analysis and review of the carbon footprint of seven extensive organic farming systems in various dehesas in the southwest of Spain. The method used was life cycle assessment, taking into account both greenhouse emissions and carbon sequestration. Greenhouse emissions estimated are those derived from livestock digestion, manure management, soil management, and off-farm inputs (feeding, fuels, and electricity). Carbon sequestration calculations consider carbon fixation due to pasture and crop waste and carbon fixation in soil due to manure fertilization. The farms under study represent all the species bred in the farms and all the habitual farming systems existing in dehesas, with the following types being under analysis: beef cattle, sheep for meat, Iberian pigs, and dairy goats. The emissions identified in the farms under study have been found to be lower than those from conventional farms, with values of 16.27 and 10.43 kg CO_2eq/kg of live weight for beef cattle, 13.24 and 11.42 kg CO_2eq/kg of live weight for sheep, 1.19 kg CO_2eq/kg of milk for goats, and 4.16 and 2.94 kg CO_2eq/kg of live weight for pigs. The levels of carbon sequestration are also noticeably higher, with compensation being up to 89% in meat producing ruminants' farms, 100% in dairy goats' farms, and values compensating the total emissions in the case of Iberian montanera pig farms.

Abstract: This study employs life cycle assessment (LCA) for the calculation of the balance (emissions minus sequestration) of greenhouse gas emissions (GHG) in the organic livestock production systems of dehesas in the southwest region of Spain. European organic production standards regulate these systems. As well as calculating the system's emissions, this method also takes into account the soil carbon sequestration values. In this sense, the study of carbon sequestration in organic systems is of great interest from a legislation viewpoint. The results reveal that the farms producing meat cattle with calves sold at weaning age provide the highest levels of carbon footprint (16.27 kg of carbon dioxide equivalent (CO_2eq)/kg of live weight), whereas the farms with the lowest levels of carbon emissions are montanera pig and semi-extensive dairy goat farms, i.e., 4.16 and 2.94 kg CO_2eq/kg of live weight and 1.19 CO_2eq/kg of fat and protein corrected milk (FPCM), respectively. Enteric fermentation represents 42.8% and 79.9%of the total emissions of ruminants' farms. However, in pig farms, the highest percentage of the emissions derives from manure management (36.5%–42.9%) and animal feed (31%–37.7%). The soil sequestration level has been seen to range between 419.7 and 576.4 kg CO_2eq/ha/year, which represents a considerable compensation of carbon emissions. It should be noted that these systems cannot be compared with other more intensive systems in terms of product units and therefore, the carbon footprint values of dehesa organic systems must always be associated to the territory.

Keywords: organic livestock; extensive management; carbon footprint; life cycle assessment; carbon sequestration; dehesa.

1. Introduction

Dehesa, situated in the southwest of the Iberian Peninsula, is one of the largest managed agroecosystems in Europe. However, their current environmental situation is alarming, with natural resources, such as the soil, water, and biodiversity, being under great pressure. In spite of this, livestock farming and agriculture can highly contribute to their preservation, although it can be the cause of their accelerated deterioration (Horrillo et al., 2019), unless management of the systems is also adequate.

With the increase of the food demand and climate change as the main actors, the dehesa ecosystem will be required to adapt to an increasing lack of natural resources and the reduction of greenhouse gas emissions (GHG) (Gerber et al., 2013). GHG emissions and climate change represent two of the world's greatest environmental concerns, with the reduction of GHG emissions being one of the main challenges the European farming industry will face in the forthcoming years.

The fight against climate change has become a current main concern. In this sense, measuring the impact of farming and the agricultural activities of the extensive systems and specifically, of the dehesa areas, is a major objective, as there are major differences between the more extensive and organic production systems and the more intensified systems, which use less natural resources and more animal feeds. These systems are a priori, more sustainable, since they could also generate added value from an economic and environmental point of view (Eldesouky et al., 2018).

In this context, the proliferation of studies on farming GHG emissions provides many well-founded opinions. Papers such as that by Smith et al., (2019) indicate that the conversion to organic farming in this specific area would reduce GHG emissions, although it would also reduce production, which would require other areas to increase production in order to offset the lack of supply, and net emissions would therefore become higher. Other papers compare organic sustainable production systems and high-performance farming with the purpose of meeting the increasing food demand, with the conclusion that high-performance farming is as sustainable as organic farming and the choice of system will be fundamental for the future of biodiversity (Balmford et al., 2018).

Other papers such as that of Muller et al., (2017) propose organic farming as an essential part of the future of the food systems, together with a dramatic change in the food culture and a reduction in food waste. Reports such as Research Institute of Organic Agriculture (FIBL) and International Federation of Organic Agriculture Movements (IFOAM EU) (FIBL and IFOAM EU, 2016) highlight the contribution of organic farming to the mitigation and adaptation to climate change, pointing out that a future scenario where organic farming increased by 50% in 2030, would yield a potential reduction of 12% - 14% in the GHG emissions from the farming industry in the European Union. Such changes would derive from the increase in the soil's organic matter and a reduction in the use of mineral fertilizers.

For such temporal framework, the southwest of the Iberian Peninsula will be required to accept the coexistence of multiple production models, where organic farming must take part as an alternative to the other models. But, can organic farming production in such ecosystems be one of the strategies to mitigate climate change?

Although the GHG emissions deriving from farming systems are complex and heterogeneous, the management system proposed by organic farming based on the simplification and adoption of certain practices leading to improving pastures and soils, can mitigate the GHG emissions of the farming systems (Gerber et al., 2013; Sobrino, 2016).

Several methods can be used to calculate the carbon footprint (CF) of the various production systems, although one of the most popular and internationally-recognized ones is the life cycle assessment (LCA) (Buratti et al., 2017). Recent papers such as that of Gutiérrez-Peña et al., (2019) which analyzes dairy goat farms in the south of Spain, that of (Eldesouky et al., 2018) which analyzes cattle and sheep farms in the southeast of Spain, or one analyzing the dairy cattle farms in the north of Spain by (Noya et al., 2018) are some of the examples. Such papers focus on conventional production farms, whereas the present paper measures the CF in organic extensive farms.

One of the main problems when comparing GHG emissions between different livestock production systems is the use and implementation of different methodologies, as well as the level of variation generated by the different emission factors considered. Emission factors provided by default by the Intergovernmental Panel on Climate Change (IPCC) (2006) generate a high level of uncertainty compared to others that are more local or directly measured on-site. In addition to these factors, different results can be found from the allocation of global warming potentials (CH_4 and N_2O) and the system limits established. The results may vary if the limits of the system remain on the farm itself or, as in our case, to the entire life cycle of the inputs (harvesting, transport, manufacturing, etc.). Similarly, results may differ depending on the functional units considered, e.g., it would seem clear that measuring the CF per unit of product (kg or L) is less appropriate than doing so per farm area (ha) in extensive systems. For that reason, it is necessary to incorporate carbon sequestration in the GHG emissions balance when we study extensive livestock systems.

Within this context, it becomes necessary to approach a detailed study of the GHG emissions deriving from the rearing of organic cattle, specifically the one reared in dehesas. Such analysis will be performed by species, providing details of the origin of the carbon footprint generated by each aspect associated to production, with the purpose of determining its contribution to the global carbon footprint and establishing the possibility of proposing this sustainable farming model as an environmentally-friendly alternative against the increasing industrialization of this segment.

The dehesa of the southwest of Spain represents over a million of hectares (Sánchez Martín et al., 2019) and comprises various farming systems. This paper will focus on the organic livestock production system. The purpose of this paper is to estimate the balance of GHG emissions and CF in seven ruminants and Iberian pig organic farms taking also into account their carbon sequestration potential.

And lastly, the reduction of the carbon footprint is also closely associated with the increase in the efficiency of the production system and, therefore, its profitability (Dougherty et al., 2019; Jones et al., 2014). This is the reason why future research should include carbon footprint in a system in order not only to improve system sustainability, but also to financially reward the reduction of GHG emissions.

2. Materials and Methods

Life cycle assessment (LCA) is one of the methods most frequency used to calculate the balance of greenhouse gas emissions (GHG) in livestock farms, as it is a standard and internationally-accepted means to effectively quantify the environmental impact of a product, and also allows to take into account carbon sequestration (Buratti et al., 2017; Eldesouky et al., 2018; Stanley et al., 2018; Vagnoni and Franca, 2018). This was the basis for its selection as the most appropriate method for this study. The calculation of the carbon footprint was performed following the UNE-EN-ISO 2006 standards (ISO, 2006a, 2006b), the IPCC guidelines (IPCC, 2006a) for national GHG emissions and their subsequent amendments (IPCC, 2014, 2007), the atmospheric emissions national inventories (MAPA, 2012), and also an adaptation of the technique to the Spanish Ministry of Agriculture's method for the characteristics of the areas under analysis (MITECO, 2019).

2.1. Case Studies Selection and Data Collection

This research is based on a case studies methodology developed by Yin, (1984) on his work titled "Case Study Research: Design and Methods" and it is mainly characterized by an intensive approach to an object of study or unit. It is used for the description of real situations and is applicable, for example, to problems related to the management of enterprises, being in the case of this research, the livestock enterprise as the unit of study.

The farming system under study in this paper can be considered unique: an agro-ecosystem grazed by different livestock species under extensive conditions and giving rise to different products depending on the management that the owners of the farms decide to adopt. All these farms are management units subject to the same soil, climate, and socio-political conditions located in the Spanish region of Extremadura, an administrative unit of governance.

The selection of seven organic farms for in-depth study has been considered as the appropriate method for achieving the objectives of the study, since each of them is characteristic of a representative management system in the region of Extremadura (the regional area on which the study is focused). It should be mentioned that the number of organic farms in the region is very low, in fact, in the case of organic pig and goat farms, the region only has three farms registered in 2017 and they were all included in the study.

In the recent literature, there are numerous studies that use the case study approach for the analysis of livestock farm management from both environmental and technical–economic approaches, for example, Bernués et al., (2017) study the environmental impact and ecosystem services of sheep in Spain, Vellenga et al., (2018) compare the use of conventional and organic beef cattle water, and (Eldesouky et al., 2018) analyze the carbon footprint in dehesa farms in Spain. Works with a technical-economic bias are for example those of Neira et al., (2014), Asai et al., (2018), and Regan et al., (2017).

Data were collected from each of the seven farms by way of one-to-one interviews with the farmers or proprietors of the farms during the first semester of 2018.

2.2. Features of the Seven Production Systems

In Table 1 we can see the main characteristics and technical indicators of the seven case studies. The data refers to year 2017.

Table III. 1. Main features of the production systems included in the case study.

System Types Description	Photograph
Beef cattle farm (calves): Average-size extensive beef cattle farm of 140 ha, with 7.1% of the area dedicated to crops. The expense in feed is approximately 266.7 kg of fodder */reproductive animal and 357.3 kg of concentrates/reproductive animal. The end product of this farm is the sale of weaned claves of approximately 200–250 kg of live weight.	
Beef cattle farm (yearlings): Small-size extensive beef cattle farm (105 ha) where 2.9% of the area is dedicated to crops. The expense in feed is approximately 136 kg of fodder */reproductive animal and 325.6 kg of concentrates/reproductive animal. The end product of this farm is the sale of finished yearlings with an approximate weight of 500 kg of live weight for males and 400 kg of live weight for females.	
Meat sheep farm (lambs 23 kg live weight): Extensive sheep farm of 370 hectares of land and 13.5% of the area dedicated to crops. The expense in feed per sheep is 44.4 kg of fodder */reproductive animal and 103.7 kg of concentrates/reproductive animal and the end product is the sale of sheep of 23 kg of live weight 3 months old.	
Meat sheep farm (lambs 18.5 kg live weight): Extensive sheep farm with a total area of 500 hectares. The area dedicated to crops is 18% a year. The expense in feed is 58.8 kg of fodder */reproductive animal and 85.9 kg of concentrates/reproductive animal. The end product is the sale of sheep of 18.5 kg of live weight approximately from 2 to 2.5 months old.	
Dairy goat semi-extensive farm: Small-size farm (80 ha), with an area of 10% dedicated to crops. The expense in feed per reproductive animal is 72.7 kg of fodder */reproductive animal and 353.8 kg of concentrates/reproductive animal. The end product is the sale of organic milk.	
Iberian pig montanera[1] fattening farm: Iberian pig farm with 50% pure breed pigs, of an area of 300 hectares and 13.3% of the area dedicated to crops. The farm buys its piglets. The end product is the sale of pigs of approximately 160 kg of live weight (age from 14–16 months) which have been fattened on the montanera system.	
Iberian pig closed herd farm: 100% pure Iberian pig farm, with a total area of 230 ha, and 2.2% of the area dedicated to crops. The expense in feed per animal in this farm is 484.4 kg. The end product is the sale of fattening pigs of 40 kg (age from 3–4 months) and montanera pigs of 170 kg in live weight (age from 16–18 months)	

* Fodder refers to straw and hay. 1 Montanera is the local name for the free-range fattening of Iberian pigs whereby animals are free to roam in the dehesa and mainly eat acorns (aprox. 10 kg/day) and pasture (aprox. 3–4 kg/day). This covers period from November to February (Rodríguez-Estévez et al., 2009).

2.3. System Boundaries and Functional Unit

The scope of this study covers the entire process until the finished product, which will vary subject to the type of farm. The limits selected for the organic systems included all the on-farm and the off-farm emissions, understanding them as a dynamic set of activities. The on-farm emissions are all the emissions caused by the cattle (enteric fermentation, CH_4), manure and soil management, and (CH_4 y N_2O). Off-farm emissions are emissions associated with the manufacture and transport of feed for the cattle, the use of fuel, electricity, transport, etc.

Emissions are indicated in two functional units: the first one uses the main type of product in each system, i.e., the kg of live weight per sold animal (in meat farms) and the kg of fat and protein corrected milk (Fat and protein corrected milk (FPCM) in dairy farms) (IDF, 2015) and the second one is based on 1 ha of the total hectares of the farm.

2.4. Estimation of GHG Emissions and CF Level in Farms

The method used for the estimation of the GHG emissions is the guidelines established by IPCC for the national GHG inventories (IPCC, 2006a). All the emissions are expressed in kg CO_2eq depending on their potential global warming. These global warming potentials proposed by (IPCC, 2014, 2007) are 1 for CO_2, 25 for CH_4, and 298 for N_2O.

2.4.1. On-Farm Emissions

In order to estimate the on-farm emissions, the following have been taken into account: enteric fermentation, manure management, and soil management. The emission factors were taken from the National Greenhouse Gases Inventory for agricultural processes. Additionally, the existence of more specific emission factors, according to the type of farm and location, provided the opportunity of adapting the methodology and introducing more specific emission factors to the features of the areas under analysis, as well as the manure and soil management (Bochu et al., 2013; MITECO, 2019).

As can be seen in Table 2, different emission factors have been used for GHG estimation, choosing local emission factors and/or their adaptation to dryland pasture systems whenever possible. The objective has been to be as close as possible to a Tier 3 level. In this sense, for example, the factors used in the Spanish national inventories are at a Tier 2 or 3 level. This objective has been met in the on-farm emission factors; however, in the off-farm emission factors (system inputs), different sources have been used and in some of the cases, were more distant from the Tier 3 objective.

2.4.2. Off-Farm Emissions

The emission factors of the inputs brought onto the farms were obtained from Bochu et al., (2013) and the Spanish National Commission for Markets and Competition (CNMC, 2018). As all of them are organic products, the emission factors were recalculated from an estimate of the factors proposed by Bochu et al., (2013). These factors were calculated by discounting the emissions attributed to transport. In order to calculate this proportion, the ReCiPe 2016 Midpoint (H) V1 (Huijbregts et al., 2016) method was used with the Agri-footprint mass allocation (Durlinger et al., 2014) and Ecoinvent 3 allocation (Frischknecht et al., 2007) databases.

In terms of fuel emissions, both the emissions generated and the combustion emissions were taken into account. The electricity used in these types of farms is mainly for lighting purposes.

The main emission factors used by species are shown in Table 2.

Table III. 2. Emission factors used to quantify greenhouse gas emissions (GHG).

Emission and Source	Type of GHG	Emission Factors	Unit
On-farm			
Enteric fermentation	CH_4	51.06 kg CH_4/cow a year [a]	kg CH_4/year
	CH_4	7.64 kg CH_4/sheep a year [a]	kg CH_4/year
	CH_4	5 kg CH_4/goat a year [a]	kg CH_4/year
	CH_4	2.75 kg CH_4/breeding pig a year [a]	kg CH_4/year
	CH_4	0.62 kg CH_4/growing-finishing pig a year [a]	kg CH_4/year
Manure management			
Manure management CH_4	CH_4	6.91 kg CH_4/cow a year [b]	kg CH_4/year
	CH_4	0.28 kg CH_4/sheep a year [b]	kg CH_4/year
	CH_4	0.21 kg CH_4/goat a year [b]	kg CH_4/year
	CH_4	18.76 kg CH_4/breeding pig a year [b]	kg CH_4/year
	CH_4	7.59 kg CH_4/growing-finishing pig year [b]	kg CH_4/year
Manure management direct N_2O	N_2O	0.005 kg N_2O eN/kg N solid storage system [c]	kg N_2O/year [d]
Manure management indirect N_2O	N_2O	0.01 kg N_2O eN/volatilized [c]	kg N_2O/year [d]
Soil management			
N from urine and dung inputs to grazed soils in Cow (Iberian swine)	N_2O	0.02 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
N from urine and dung inputs to grazed soils in Sheep	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
N from urine and dung inputs to grazed soils in Goat	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
Indirect emissions soil management	N_2O	0.01 kg N_2O eN (kg % N volatilized/leaching)$^{-1}$ [c]	kg N_2O/year [d]
Off-farm			
Concentrates Meat Cow	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat Calf	CO_2	0.445 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat sheep	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat Lamb	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Dairy Goat	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Piglet, 2nd stage feed	CO_2	0.227 kg CO_2eq/kg [e]	kg CO_2eq/year
Straw	CO_2	0.100 kg CO_2eq/kg [e]	kg CO_2eq/year
Hay	CO_2	0.170 kg CO_2eq/kg [e]	kg CO_2eq/year
Wheat	CO_2	0.335 kg CO_2eq/kg [e]	kg CO_2eq/year
Barley	CO_2	0.305 kg CO_2eq/kg [e]	kg CO_2eq/year
Pea	CO_2	0.116 kg CO_2eq/kg [e]	kg CO_2eq/year
Electricity	CO_2	0.410 kg CO_2eq/kWh [f]	kg CO_2eq/year
Fuel	CO_2	2.664 kg CO_2eq/L-Combustion [e]	kg CO_2eq/year
	CO_2	0.320 kg CO_2eq/L-upstream [e]	kg CO_2eq/year

a (MITECO, 2019); b (MAPA, 2012); c (IPCC, 2006b); d $N_2OeN*44/28$ 14 N_2O; and from: e (Bochu et al., 2013); f (CNMC, 2018).

2.5. Carbon Sequestration in LCA

The carbon sequestration concept refers to the changes in the carbon (C) composition levels of the soil. Such changes take place in the soil due to the addition of manure, crop, and grassland waste. Therefore, the C-level composition of the soil can be impacted by the changes in the use of the land and the various management systems applied to the farm.

In terms of methodology, there are several methods that can be used to estimate carbon sequestration. For example, IPCC (IPCC, 2006a) estimates the changes in soil C levels according to inventories and with a 20-year time horizon. For the purposes of this piece of research, the balance of net carbon flows in the livestock-manure-grassland system proposed by (Petersen et al., 2013) was used with some variants and by adaptation to other systems of similar characteristics to the systems under study (Batalla et al., 2015). The main difference with IPCC (IPCC, 2006a) is the recommendation of using a 100-year perspective in order to analyze the changes taking place in the soil carbon levels in time (Batalla et al., 2015). Therefore, it has been estimated that 10% of the C added to the soil will be sequestrated in a 100-year time horizon (Petersen et al., 2013). Another correction introduced in the method was the consideration of crops in the livestock–manure–grassland systems, separately assessing C sequestration according to land use in the farms. In this regard, the calculation of C sequestration in the production systems under analysis is performed by taking into account carbon fixation in airborne and underground pasture waste, crop airborne and underground waste, and carbon fixation from manure and the soil fertilized by it.

Specifically, in extensive organic farming systems, the pasturelands and crop lands can be considered as a form of carbon sequestration and a way to mitigate the carbon footprint these types of production systems cause (Eldesouky et al., 2018; IPCC, 2006a; Soussana et al., 2010; Stanley et al., 2018; Teague et al., 2016). When we talk about crop lands, we generally mean cultivated meadows or rainfed crops for animal feeding. This is when we consider the residues for the carbon fixation of in the soil.

As some authors have pointed out, when considering carbon sequestration in soil, CF in extensive farms is lower than in intensive farms. In this context, trees play an important role in the carbon cycle and therefore the quantification of the balance between carbon emission and sequestration is one of the main challenges. This way, maximizing carbon sequestration can become a management objective in both agroforestry and rangelands systems (Eldesouky et al., 2018). No information is available on annual sequestration due to trees in these systems, so this aspect has not been considered in this document.

3. Results

In this section of our paper, we describe the results obtained from our CF calculation. The features of the farms under analysis are shown (Table 3) in the first place. And in the second place, the composition of the emissions according to the various greenhouse gases is analyzed (Tables 4 and 5).

The results are broken down by emission type, the livestock species of the farm, and its contribution to the carbon footprint, expressed in kg CO_2eq, kg of CO_2eq per functional unit, and kg of CO_2eq per hectare of total farm area.

3.1. Technical Features of the Farms under Analysis

Table 3 shows the most significant features of the farms under analysis and their technical–financial indexes with the purpose of contextualizing the results of the CF analysis which will be shown at a later stage. The data has been organized by livestock species.

Table III. 3. Technical indicators of the farms included in this research.

System Types Indicators	Beef Cattle (Calves)	Beef Cattle (Yearlings)	Meat Sheep (Lambs 23)	Meat Sheep (Lambs 18.5)	Dairy Goat	Iberian Pig Montanera Fattening	Iberian Pig Closed Herd
Total Area (ha)	140	105	370	500	80	300	230
Average annual temperature (°C)	16.1	15.7	15.6	15.6	15	16	15.5
Pasture area (%) [a]	92.9	97.1	86.5	82	81.2	86.7	97.8
Wooded area (%)	100	97.1	-	-	31.2	100	100
Cultivated area (%)	7.1	2.9	13.5	18	18.8	13.3	2.2
No. of reproductive females (average population)	75	25	900	1700	110	-	22
Total stocking rate (LU [b]/ha)	0.59	0.3	0.44	0.60	0.24	0.18	0.19
No. of weaned animals/reproductive females	0.73	0.68	1.1	1.15	1.7	-	9.2
Inputs purchased by the farm							
Total kg of fodder/reproductive animal	266.7	136	44.4	58.8	72.7	-	-
Total kg of concentrates/reproductive animal	357.3	325.6	103.7	85.9	353.8	-	484.4
Outputs produced by the farm							
No. of animals sold/reproductive animals	0.73	0.68	1	1.1	1.44	-	9
Liters of milk sold/year	-	-	-	-	30,000	-	-
Weight (kg) average of animals sold	220	* 400/500	23	18.5	9	160	**40/170
kg of weaned animals	12,100	-	22,770	36,075	2061	-	4000
kg of fattening animals	-	8500	-	-	-	22,400	17,000
Total live weight (kg) produced (FU [c])	12,100	8500	22,770	36,075	2061	22,400	21,000

a Pasture area (%): includes with and without trees; b LU: Livestock Unit; c FU: Functional Unit (kg of live weight); * 400 kg female and 500 kg male. ** 40 kg for weaner piglets y 150 kg for montanera pigs.

In Table 3, the farms under analysis are seven different farms with four different livestock species and resources that are adapted to their production models. They all (organic) have a common feature (Reglamento (UE) 834/2007, 2007; Reglamento (UE) 2018/848, 2018; Reglamento (UE) 889/2008, 2008): all animals are reared and fed in freedom, with the majority of their time spent grazing in the dehesas or pasturelands of the farms.

In these farms, the land type varies according to the geographical area where they are situated: the beef cattle farms are situated in dehesa areas, that is, they include a variable number of holm oaks or cork oaks, as is the case of pig farms. The latter are also associated to these ecosystems due to the end stage of pig fattening, where pigs feed mainly on acorns from the holm oak or the cork oak.

These two predominant species (Quercus ilex and Quercus suber) make up 60% of the national fruit of the montanera system (Pérez and Del Pozo, 2001). Additionally, these lands are also used by cattle as pasturelands. On the other hand, sheep farms are located in pasturelands, where trees are scarce in the plains and only exist in the mountain areas, where they share habitat with all kinds of endemic bushes. Lastly, dairy goat farms are situated in areas combining mountain and dehesa as well as crop lands.

In relation to the characteristics of the soil (type/conditions of the farms), these dehesas and pasturelands are mostly acidic soils with low organic matter content and a semi-arid Mediterranean climate. Regarding climate conditions, the predominance is the dry climate with low rainfall and extreme temperatures in the winter and summer seasons.

In terms of livestock stocking rate, beef cattle represent 0.59 LU/ha for weaned cattle and 0.3 LU/ha for fattening cattle, which coincide with the findings of Horrillo et al., (2015) and notably less with the research carried out on conventional cattle farms (0.73 LU/ha) by Maroto-Molina et al., (2018).

In terms of sheep, the stocking rate is 0.44 LU/ha for farms selling animals at 23 kg and 0.6 LU/ha for farms selling animals at 18.5 kg, in line with the farms with low stocking rates described in papers such as those of Gaspar et al., (2008). The dairy goat farms have a stocking rate of 0.24 LU/ha and in pig farms, the stocking rate does not exceed 0.2 LU/ha.

With regards of the inputs brought into the farms, there are clear differences between the feeding expenses by hectare in ruminant farms (beef cattle–sheep) dedicated to meat production and those of dairy goat and Iberian pig farms. Energy use (fuel and electricity) reveal similar levels, except for one, the farms selling sheep at 18.5 kg. The use of fuels in these farms is attributable to the use of vehicles for employees to move about and the machinery employed in the farming activities. Goat farms, as Table 3 shows, do not have electricity expenses, as all its premises, milking, and refrigeration units, etc. are supplied with renewable energy (solar panels).

Regarding production indicators or farm outputs, some relevant data are: the calves sold per cow, sale of weaned animals (0.73), and sale of fattened animals (0.68), in line with the research carried out by Escribano, (2016, 2014). Another indicator to be highlighted is the weight of the animals sold in each farm, as this allows to identify the differences amongst the production models for each livestock species. For example, the sale of weaned calves or yearlings, the sale of sheep at 18.5 kg or 23 kg in weight, the sale of kids for the purposes of milking the goats, or the sale of 1-2-year-old pigs and fattening montanera pigs in Iberian pig farms.

3.2. Greenhouse Gas Emissions

Table 4 includes the contribution of the various GHG in the seven systems under analysis expressed in kg CO_2eq/FU. It also includes the percentage contribution of the various production processes.

Table 4 shows the dairy goat farm as having the lowest CF levels per functional unit (FU) (1.19 kg CO_2eq/kg of corrected milk), followed by the Iberian pig dehesa farms (2.9-4.2 kg CO_2eq/kg of live weight at time of slaughter) and lastly, beef cattle (16.27–10.43 kg CO_2eq/kg of live weight), and sheep (11.42-13.24 kg CO_2eq/kg of live weight) with a similar level. When comparing the farms with the same species, the farm that does the fattening of calves within the farm itself reveals lower CF levels than the farm selling weaned claves. The same is the case with sheep farms, the farm selling sheep of heavier weights (23 kg) reveals lower CF levels than the farm selling them at 18.5 kg.

If we analyze the group of GHG, the total emissions can be classified in two according to origin: total emissions deriving from the farm and total emissions deriving from the inputs.

In the organic farms under study, the majority of the emissions originate in the farm itself, although they can vary subject to species. In the beef cattle and sheep farms, which are dedicated to meat production, the farm management itself produces over 90% of the emissions. Therefore, the emissions on account of inputs are lower than 10%. However, in the semi-extensive goat and Iberian pig farms, the sourcing of off-farm fodder implies that GHG emissions originating within the farm are 65%, which is a lower value than those of ruminants farms. Whereas, the proportion of the emissions originated in the purchase of inputs, which include mainly the purchase of animal feed, increase.

Table III. 4. Carbon footprint per functional unit.

	Weaned calves		Beef finishers		Sheep for meat 23 kg l/w		Sheep for meat 18.5 kg l/w		Dairygoat Semi-extensive		Iberian pig “montanera” fattening		Iberian pig close herd	
GHG emissions	kg CO_2eq/kg product	%	kg CO_2eq/kg product	%	kg CO_2eq/kg product	%	kg CO_2eq/kg product	%	kg CO_2eq/kg FPCM	%	kg CO_2eq/kg product	%	kg CO_2eq/kg product	%
Enteric fermentation CH_4	**9.18**	**56.42**	**5.41**	**51.87**	**9.13**	**79.95**	**10.38**	**78.40**	**0.51**	**42.86**	**0.1**	**3.41**	**0.16**	**3.85**
Manure management														
CH_4	1.24	7.62	0.73	7	0.33	2.89	0.38	2.87	0.02	1.68	1.19	40.61	1.46	35.10
Direct N_2O	0.12	0.74	0.14	1.34	0.33	2.89	0.41	3.10	0.0919	7.72	0.07	3.39	0.06	1.44
Indirect N_2O	0.00046	0.00	0.00056	0.01	0.0013	0.01	0.0016	0.01	0.0004	0.03	0.0003	0.01	0.0002	0.00
Total manure management	**1.36**	**8.36**	**0.87**	**8.35**	**0.66**	**5.79**	**0.79**	**5.98**	**0.112**	**9.44**	**1.26**	**43.01**	**1.52**	**36.54**
Soil management														
Direct N_2O soil	4.15	25.51	2.41	23.11	1.11	9.72	1.27	9.59	0.21	17.65	0.34	11.60	0.50	12.02
Indirect N_2O soil	0.58	3.56	0.76	7.29	0.22	1.93	0.25	1.89	0	0.00	0.03	1.02	0.05	1.20
Total soil management	**4.73**	**29.07**	**3.17**	**30.39**	**1.33**	**11.65**	**1.52**	**11.48**	**0.21**	**17.65**	**0.37**	**12.63**	**0.55**	**13.22**
Total On-farm Emissions	**15.27**	**93.86**	**9.45**	**90.61**	**11.12**	**97.38**	**12.69**	**95.86**	**0.83**	**69.94**	**1.73**	**59.05**	**2.07**	**53.61**
Feending														
Concentrate feed cows	0.1	0.61	-		-		-		-		-		-	
Concentrate fattering calves	-		0.16	1.53	-		-		-		-		-	
Concentrate sheeps	-		-		0.20	1.75	0.06	0.45	-		-		-	
Concentrate lambs	-		-		0.05	0.44	0.09	0.68	-		-		-	
Concentrate goats	-		-		-		-		0.25	21.01	-		-	
Concentrate growth pigs	-		-		-		-		-		0.91	31.06	-	
Seeds (wheat, barley, vetch)					-		-		-		-		1.57	37.74
Straw	0.08	0.49	-		-		-		-		-		-	
Hay	-		-		-		-		-		-		-	
Total Feeding	**0.18**	**1.11**	**0.16**	**1.53**	**0.25**	**2.19**	**0.18**	**1.13**	**0.25**	**21.01**	**0.91**	**31.06**	**1.57**	**37.74**
Electricity	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.14**	**4.78**	**0.11**	**2.64**
Fuel														
Production	0.09	0.55	0.09	0.86	0.005	0.04	0.041	0.31	0.012	1.01	0.017	0.58	0.027	0.65
Combustion	0.73	4.49	0.73	7	0.043	0.38	0.36	2.72	0.098	8.24	0.14	4.78	0.23	5.53
Total fuel	**0.82**	**5.04**	**0.82**	**7.86**	**0.048**	**0.42**	**0.403**	**3.03**	**0.11**	**9.24**	**0.16**	**5.36**	**0.25**	**6.01**
Total Off-farm Emissions	**1**	**6.15**	**0.98**	**9.40**	**0.30**	**2.61**	**0.58**	**4.16**	**0.36**	**30.25**	**1.20**	**41.19**	**1.93**	**46.39**
TOTAL CF kg CO_2eq / FU	16.27	100	10.43	100	11.42	100	13.24	100	1.19	100	2.94	100	4.16	100
Total kg de CO_2eq	200857		90454		260314		477724		40635		67267		97153	
Total kg de CO_2eq per ha	1434.7		861.5		717.9		974.9		518.3		224.2		422.4	

Within the total farm emissions, the GHG emissions deriving from enteric fermentation in ruminants farms vary between 79.9% and 42.9% of the total emissions, and it is associated to the extensification of these systems and the diet of the animals based on grazing. On the other hand, when we talk about monogastric animals such as pigs, the emissions from CH_4 enteric fermentation decrease considerably, going down to percentages such as 3.4% and 3.9% for extensive Iberian pig farms.

On the other hand, in pig farms, unlike in ruminants farms, the majority of the emissions derive from manure management, specifically, from manure management direct N_2O, which yields 36.5% and 43%, respectively.

Soil management and the resulting N_2O direct and indirect emissions have also been assessed. For the purposes of this analysis, we must take into account that all farms are organic and the production systems are adapted to each species, even when they have common features. The most important feature to take into account is that all the animals spend 90% of their time grazing and therefore they deposit their dung directly on the ground. The results, i.e., Table 4, reveal certain differences between species and their management types. The estimation of (total) GHG on the soil is between 4.73 kg CO_2eq/FU (30.3%) and 0.21 kg CO_2eq/FU. These GHG emissions deriving from soil management are mostly due to direct N_2O, as the quantities calculated for indirect emissions were minimal because there is no manure accumulation.

In terms of the inputs brought into the farms, Table 4 includes both the fuel generated and the fuel consumed, electricity, purchase of livestock feed for each species, age, and type of animal. The emissions deriving from these inputs create major differences between species, in the same way they did for CH_4 emissions deriving from enteric fermentation. The beef cattle and sheep farms included in this paper reveal values between 2.61 and 9.4 for GHG percentages attributed to off-farm emissions. On the other hand, these acquire importance in the pig and semi-extensive goat farms, especially in terms of the purchase of animal feed (21%–37.7%), thus indicating that farm self-sufficiency based on grazing or self-production of feed is essential and the purchase of feed should be limited. Figure 1 shows the distribution of the carbon footprint components (emissions indicated in kg of CO_2eq/FU) for each type of farm under study and for all the farms.

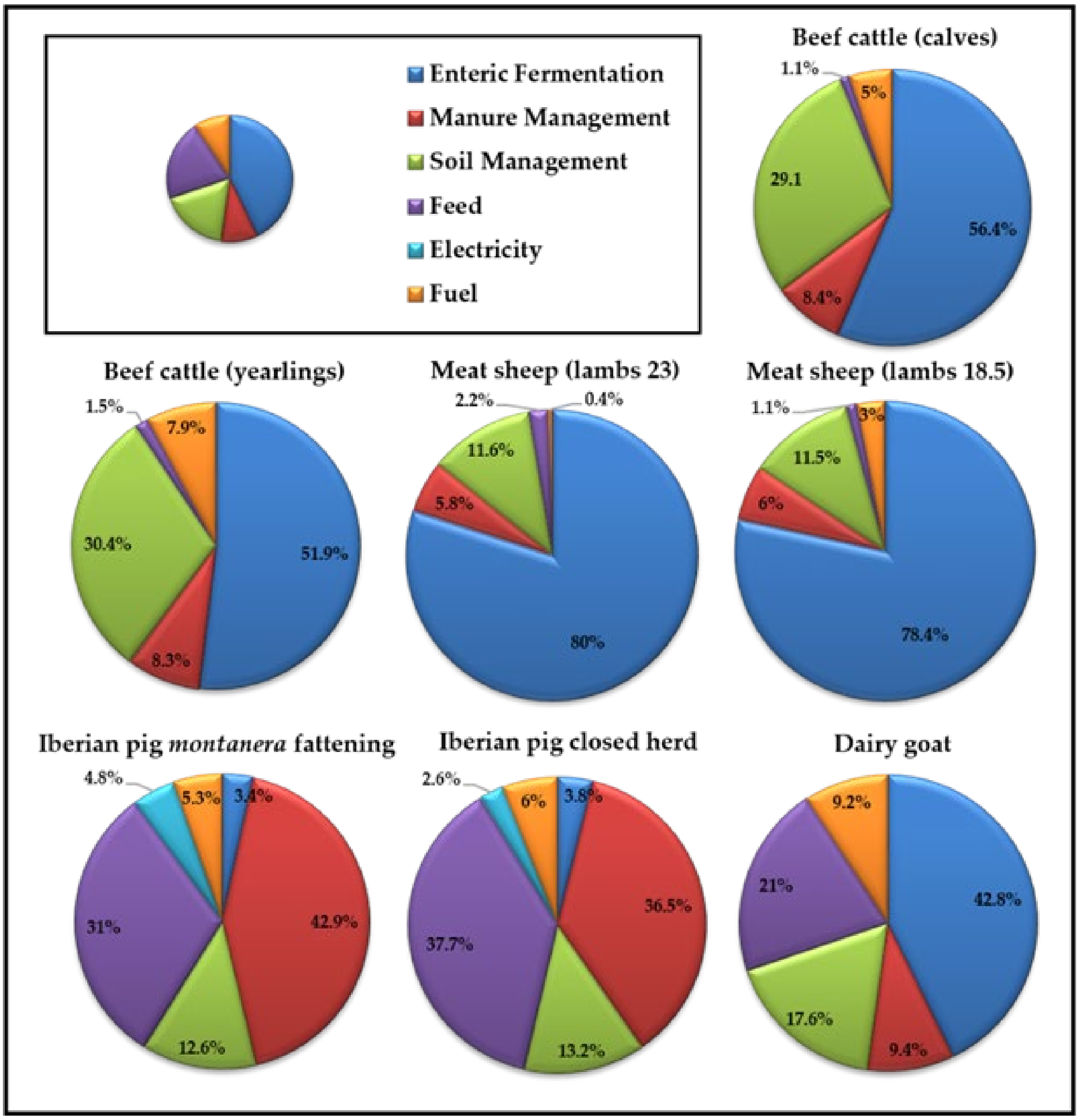

Figure III. 1. Importance of GHG emission levels by type of farm.

3.3. Carbon Sequestration

Table 5 shows the results of carbon sequestration relating to the farms acting as GHG sinks.

Table III. 5. Carbon sequestration.

Sequestered CO_2	Weaned calves	Beef finishers	Sheep for meat 23 kg l/w	Sheep for meat 18.5 kg l/w	Dairy goat Semi-extensive	Iberian pig "montanera fattening	Iberian pig close herd
C from pasture and crops residues							
Pasture residues (kg DM)[a]	**276640**	**217056**	**486400**	**623200**	**153216**	**553280**	**478800**
Above ground kg C	32760	25704	57600	73800	18144	65520	56700
Below ground kg C[b]	91728	71971	161280	206640	50803	183456	158760
Crop residues (kg DM)	**101840**	**30552**	**408880**	**735984**	**71829**	**327104**	**319200**
Above ground kg C	12060	3618	48420	87156	8506	38736	37800
Below ground kg C	33768	10130	135576	244037	23817	241024	235200
Total kg CO_2eq pasture+crops	**624492**	**408553**	**1477212**	**2242653**	**371325**	**1452634**	**1316700**
C from organic N (manure and grazing)							
kg N excreted	5955	2694	8648	16095	2838	3323	3798
kg C from applied manure	3638	2177	10571	20517	5801	216	185
kg C during grazing	15715	6578	17534	31791	4879	1944	2284
Total kg CO_2eq manure-soil[c]	**70962**	**32102**	**103050**	**191796**	**33820**	**7919**	**9052**
Total kg CO_2eq per farm	695454	440655	1580262	2434450	405144	1460553	1325753
Total kg CO_2eq manure-soil/ha	507	306	279	384	517	135	201
Total kg CO_2eq per farm/ha	4968	4197	4271	4869	5064	3646	3712
Kg CO_2 pasture+crops sequestration	**62449**	**40855**	**147721**	**224265**	**37132**	**145263**	**131670**
Kg CO_2 manure+soil sequestration	**7096**	**3210**	**10305**	**19180**	**3382**	**792**	**905**
Total kg CO_2 sequestration	**69545**	**44066**	**158026**	**243445**	**40514**	**146055**	**132575**
Total CO_2 sequestration (kg CO_2eq FU^{-1} $year^{-1}$)[d]	**5.75**	**5.18**	**6.94**	**6.75**	**1.19**	**6.52**	**6.31**
Total CO_2 sequestration (kg CO_2eq ha^{-1} $year^{-1}$)	**497**	**420**	**427**	**487**	**506**	**487**	**576**
Compensated CF							
Compensated CF per functional unit (kg of CO_2eq per FU).	**10.52**	**5.25**	**4.48**	**6.49**	**0**	**-3.58**	**-2.15**
Compensated CF per ha (kg of CO_2eq per ha).	**938**	**442**	**291**	**488**	**12**	**-263**	**-154**

[a] Pasture waste has been estimated to account for 40% of the total production of pasture, with a C content of 45%; [b] According to (IPCC, 2006b) the default expansion factor for below-ground biomass in semi-arid pasturelands is 2.8; [c] The conversion factor for N to C is 13/4 and 44/12 for C to CO_2; [d] Annual C sequestration of 10% is considered.

Carbon sequestration in farm soils has the potential to compensate the emissions deriving from the production systems based on grazing (Crosson et al., 2011). Therefore, the extensive farms or farm businesses under analysis in this paper are situated on lands with the capacity of fixing GHG emissions in the form of vegetable waste and organic nitrogen. Additionally, the biomass waste remaining in the soil and shock-absorbing the CO_2 emissions also contribute to restore the soil and to the production of pasturelands. This capacity to shock-absorb emissions is also due to the N to C transformation process occurring when animals deposit their dung while they are grazing and when manure is added. Additionally, authors such as Byrne et al., (2005) Conant et al., (2001); Jaksic et al., (2006); Soussana et al., (2004) in their papers already suggested that, apart from becoming important carbon sinks, soils with permanent pasturelands can also have a major role in C sequestration, particularly when improved grazing strategies are adopted. Veysset et al., (2010) stated that should carbon sequestration be taken into account, the compensation percentages would become 40%–70% of the total GHG emissions from the grazing-based systems. Soussana et al., (2007) conclude that it is likely for pasturelands in Europe to act as large sinks for the atmospheric CO_2, which would reduce the CF of milk. However, the paper written by Beauchemin et al., (2010) concludes that there is still great uncertainty as to the available estimations, and further research is required before the quantification of the amount attributed to 1 kg of milk can be attained.

Table 5 shows the results of carbon sequestration in the seven farms under study. Such results are expressed as the equivalent total CO_2 fixed by hectare and by functional unit (FU = kg of meat or kg of milk) and result from the addition of the soil C-sequestration value (pastures and crops) and the N deposited by animals (manure and pasture). They include the total kg of fixed CO_2 in the pastures and the crops and the total kg of fixed CO_2 derived from the N deposited through manure and while grazing. The CO_2 equivalent deriving from the pastures and the crops is obtained from the calculation of the kg of dry matter contained in the farm in question. The estimation of the dry matter of pastures for each farm was obtained according to location and the distribution of the farms. Values between 1000 and 1400 kg on average per hectare were calculated for the various farms (Maya et al., 2017; Olea and San Miguel-Ayanz, 2006). N is calculated through the dung depositing of animals, allocating this value between the value that is fixed through the spreading of manure and the accumulated value while grazing. This calculation is performed for each age group in the farm, with the deposited N being different according to age and type of animal. The carbon input to the soil is from above and below ground grazing land and crop residues (assuming a C content of 45% of dry matter). Table 5 shows all major C inputs each year: C inputs from crop residues and manure. The amount of manure and N excreta per animal per year is based on national data (MAPA, 2012; MITECO, 2019). The C:N ratio of the submerged manure was 13.4. However, the current methodology does not allow further adjustments to be made to the soil management as there are no data in the literature on which it can rely.

The final result in terms of sink storage reveals that an amount of between 419.7 and 576.4 kg of CO_2eq/ha is stored, which goes to prove the importance of extensive farming, where pastures and animals (their dung) play a key role in the agricultural systems. For example, Figure 2 shows the sequestration % in pasture-crop and by way of excrements in manure-soil and according to species.

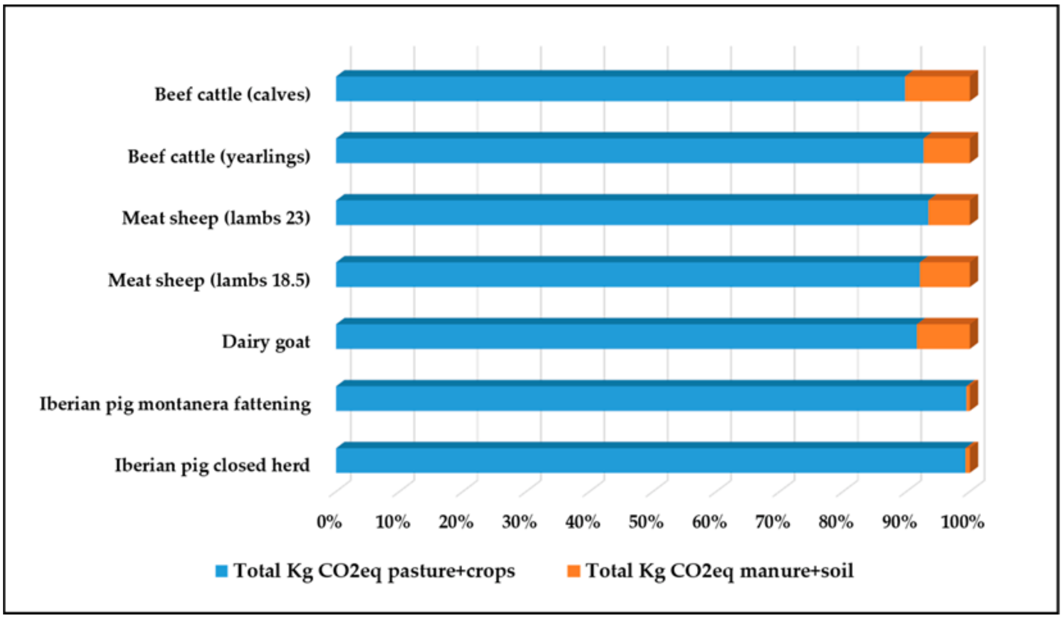

Figure III. 2. Percentage of carbon in the soil deriving from the vegetable waste and from manure and dung depositing.

Lastly, Figure 3 shows the compensated CF by FU. The positive values represent farm emissions in kg of CO_2eq/FU, whereas the negative values represent the carbon sequestration in these systems, also in kg of CO_2eq/FU.

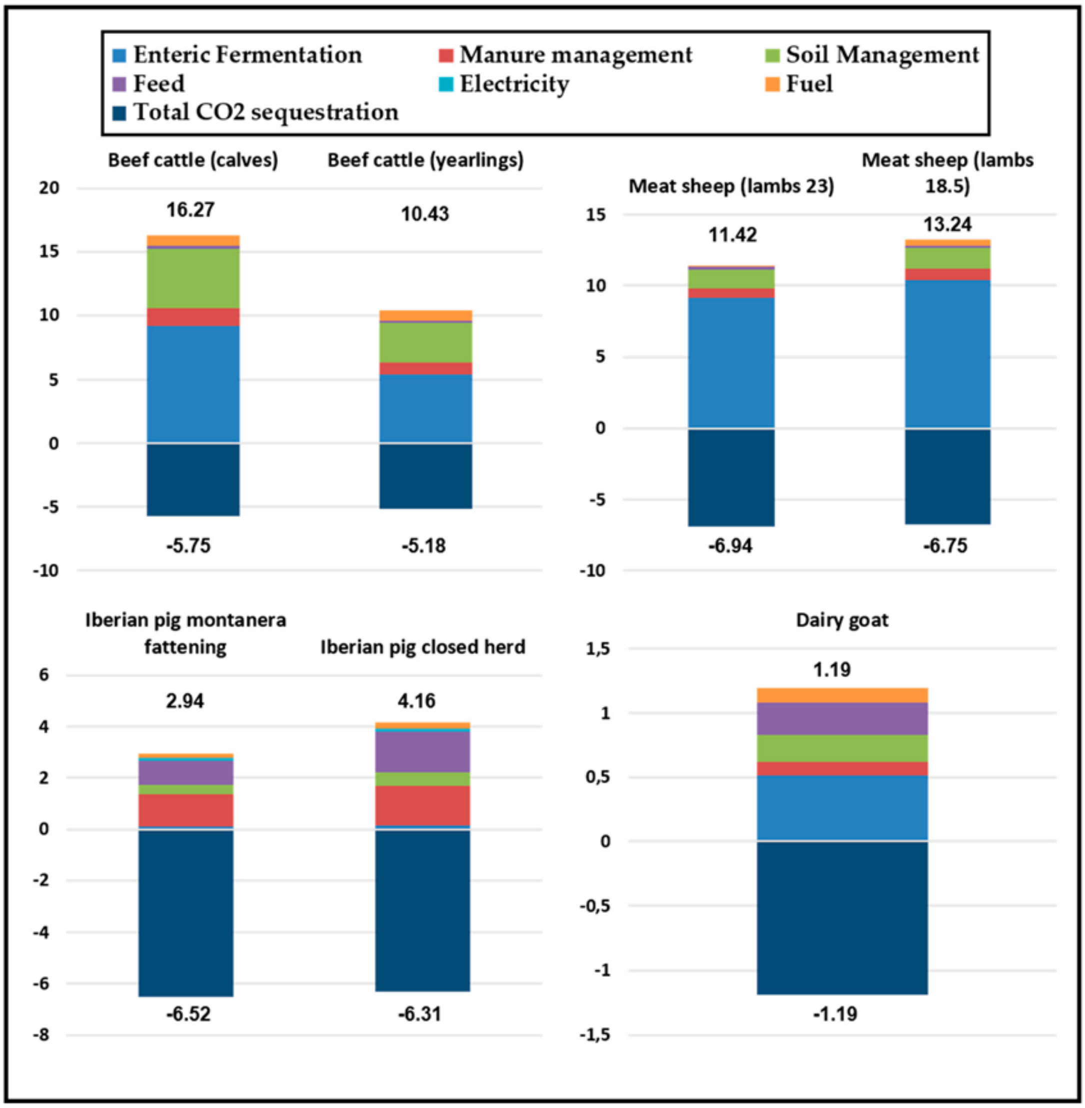

Figure III. 3. Compensated Carbon Footprint (CF)/functional unit (kg of CO_2eq/FU).

4. Discussion

The impact of livestock farm production on the environment is particularly relevant for society. Livestock farming is currently directly associated to climate change, the emission of greenhouse gases, and global warming. However, not all the livestock farming production systems produce and/or compensate to the same extent, as there are extensive livestock farming systems which have a function as carbon sequestration systems and can compensate the amounts of equivalent CO_2 generated by livestock farms (Eldesouky et al., 2018) to a great extent.

The scientific literature has seen the number of livestock farming CF studies increase. However, the majority of these papers focus on the study of intensive farms such as meat sheep and beef cattle farms (Sykes et al., 2019); dairy farms (Hietala et al., 2015; Jayasundara et al., 2019), and intensive pig farms (Arrieta and González, 2019). Other papers have approached the grazing cattle (Alemu et al., 2017; Cardoso et al., 2016; Florindo et al., 2017) and grazing goats (Kanyarushoki et al., 2009; Pardo et al., 2016; Robertson et al., 2015) production systems. However, very few papers deal with organic livestock farming (Buratti et al., 2017; Casey and Holden, 2006; Tsutsumi et al., 2018) that also includes different species and management systems.

The results and conclusions from these papers are hard to compare due to the various production contexts and the methods used, as well as their definition of a functional unit (Bernués et al., 2017; Gutiérrez-Peña et al., 2019). Additionally, there is a limited number of papers on organic farming.

In this study, it has been identified that, organic systems in extensive conditions, the result of CF per unit of product is lower than in other conventional systems. The beef cattle species for the production of organic meat reveals two results: 16.27 kg CO_2eq for farms selling weaned animals weighing 220 kg of live weight and 10.23 kg CO_2eq for farms selling fattening animals weighing 450-550 kg of live weight. As can be seen, in farms where animals are fattened, the final CF decreases, although the cycle might be longer than that of the farms selling animals at weaning age. Other papers such as that of Cardoso et al., (2016) show results that coincide with the results obtained in this paper, registering lower CF values per kg of live calf sold with the more intensive farming systems. In the same way, the debate is open by other papers indicating that there is a direct association between intensification and lower CF per product unit in farms (Batalla et al., 2015; Buratti et al., 2017). In this sense, it would become necessary to standardize the functional unit, the system limits, and the allocation method, as well as incorporating carbon sequestration to these studies.

With regards to organic sheep farms producing meat, the emissions derived from enteric fermentation account for 75% to 97.4% of the total emissions. This result seems reasonable, as thanks to feed management in these farms, which is based on extensification and self-sufficiency, and given that the sheep are not finished here, off-farm GHG emissions contribute to the CF value in a lesser proportion. The results found in this piece of research are lower than those drawn from others in similar conditions with non-organic farms such as those of Ripoll-Bosch et al., (2013) which vary between 19.5 and 25.9 kg CO_2eq/kg of live weight sheep in the north of Spain. Other pieces of research such as that of Dougherty et al., (2019) show results more in consonance with the results of our research, concluding with a CF of 10.9 to 17.9 kg of CO_2eq/kg of sheep in the market (sold). In the same way, the comparison of the various pieces of research on the results of farm CF is very sensitive and depends on the method of analysis being used and the way results are presented, either by weight, financial value, or by area, such as Wiedemann et al., (2015) states in his paper on the sheep production in the United Kingdom, Australia, and New Zealand.

Semi-extensive organic dairy goat farms register lower values in kg of CO_2eq/liter of FPCM than the values reported in the literature. Gutiérrez-Peña et al., (2019) registered a total amount of emissions of 3.17 ± 0.41, 2.22 ± 0.13, 2.29 ± 0.17 kg CO_2eq kg^{-1} FPCM1 for the tree types of farms under analysis or 1.88 ± 0.24, 1.31 ± 0.08, 1.36 ± 0.10 kg CO_2eq kg^{-1} FPCM2, which were more in line with the results found in this paper. These figures do not take into account the total kg CO_2eq/FPCM that the sequestrated carbon values in our study does. Other papers such as that of Patra, (2017) allocate 2.54 kg CO_2eq kg^{-1} to the CF of farms in India. Robertson et al., (2015) reveal the average CF they found was 0.90 kg of CO_2eq/kg of FPCM (without carbon sequestration) lower than that found through our research, but 8.78 t of CO_2eq/ha, which is substantially above 0.518 t of CO_2eq/ha calculated for our organic farm, although they state that the CF of the farms under study decreases as the farms become less intensive, with no CF data being provided for dairy goats in organic farms.

It is hard to compare the results obtained for the Iberian montanera pigs, whose final feed is based on pastures and acorn (ripe fruit of the Quercus spp.). This feature that is so inherent to the dehesa is the one differentiating these systems from those in the research available on pig's CF, which are intensive systems, such as that of Arrieta and González, (2019) who found a CF value of 5.14 and 5.17 ton CO_2eq/ton LW in paddocks and of 6.06 and 6.04 ton CO_2eq/ton LW in confinement. Other papers such as that of Bava et al., (2017) in Italy, found that for traditional ham-producing intensive pig farms, the CF calculated for six farms yielded an average of 4.25 ± 1.03

kg CO_2eq/kg of live weight. The results reported in this paper take into account the GHG emissions attributed to soy and its transport. The protein that soy adds to the pig's diet is essential, but the production of soy is limited in Europe, hence requiring importation from third countries, mainly America and China. In the paper written by Wiedemann et al., (2018, 2016) in Australia, the average calculated was 2.1 to 4.5 kg CO_2eq/kg of LW.

In organic livestock farming, according to the standards (EU) Regulation 834/2007; (EU) Regulation 2018/848, "the livestock shall have permanent access to open air areas, preferably pasture, whenever the weather conditions and the state of the ground allow", with the maximum number of animals per ha being limited (2 LU/ha). Nevertheless, even in compliance with this maximum limit, the degree of extensification of organic farms varies to a great extent subject to the production systems and farm dedication. Not only can this variability be seen at the European level due to its large heterogeneity, but also at a smaller scale (regional or local) such as is the case of dehesas. Organic farms in dehesas are highly extensificated with livestock stocking rates significantly below the limits established by the standard (between 0.18 and 0.6 LU/ha). The maintenance of these stoking rates is considered as a sustainability factor (Gaspar et al., 2009), given that adequate livestock stocking rates contribute to the ecologic stability of the system, as they prevent shrub invasion (as is the case with under grazing; Peco et al., (2006) and the degradation and erosion of the land (as is the case with overgrazing) (Schnabel, 1997).

But the maintenance of these stocking rates also allows for adequate carbon sequestration by the soil, and its quantification is particularly relevant within the current context of fight against climate change. In the farms under study, in the case of ruminants, the emissions are compensated in 35% to 89%, and they are even compensated in 100% of the GHG emissions in the case of dairy goat farms. In the case of the Iberian pigs, the carbon sequestration exceeds the emissions both in farms dealing with the full cycle and fattening montanera farms. These results differ from other papers such as that of Alemu et al., (2017) which included soil C-sequestration but only saw a reduction of the greenhouse gases emission balance in the farm by 12%-25%, with stocking rates ranging 1.2 to 2.5 cow-calf pair/ha.

Maintenance of livestock at stocking rates that are adapted to the productive capacity of the pastures on which they live, reducing the entry of off-farm feed and with capacity to sequestrate carbon, makes organic farms in dehesas a model to follow from the environmental viewpoint, differentiating it from models that pose a threat to the environment. This is the reason why institutions, especially in Europe, must be prepared to discern between the systems that need to be protected and promoted from those that do not have a positive impact.

Currently, the key elements of the post-2020 Common Agricultural Policy (CAP) reform are under debate. The environmental and climate-related aspects are at the center of the debate, as became clear at the Agriculture and Fisheries Council of 15 July 2019 (CAP Progress report 2019), where the delegates highlighted the importance of allowing the member states to have the needs of the locals into account when it comes to applying environmental and climate-related requirements. The debate is focusing on the redefinition of the role of the farmers in climate action and, in particular, in the capture of the soil's carbon for the purposes of improving its structure and quality, which helps agriculture adapt to climate change.

In the currently effective CAP (EU Regulation 1307/2013, EU Delegated Regulation 639/2014, EU Implementing Regulation 641/2014), there is no standard to regulate or propose specific requirements in relation to soil's carbon content. However, in its Greening section, some requirements are indirectly proposed for the protection of soil's carbon, such as the regulations relating to the proportion of the permanent pastures compared to the total declared farming area. We must take into account that the soil's carbon sequestration is a complex issue and that it is necessary to improve the methods of measurement of carbon, increase research, and put it into practice, relying on innovation that allow for the quantification of the extent to which the CAP contributes to increase those amounts of carbon. The post-2020 CAP reform is an opportunity for the member estates to support carbon retention in the soil by developing national and regional supporting measures that can actually contribute to the fight against climate change.

It is clear that in the present context of CAP debate, the discussions are being focused on the environmental pillar of sustainability, but obviously, the final approach proposed for the other two pillars (economic and social) will also be crucial. It has to be considered that, from an economic point of view, the subsidies (first and second pillar of the CAP) received by organic ruminant farms in the dehesa area represent about 45% of their total income (Escribano, 2014). It cannot be ignored that the livestock production model of these extensive systems is based on small and medium-sized farms, often family-run, with traditional and low-input management. These farms contribute to the settlement of the population in rural areas by facing depopulation, but their dependence on public economic resources is very high and therefore their sustainability may be compromised depending on the economic funds they finally may receive.

In the past, the different models of public policies derived from the implementation of the CAP have had a significant environmental impact on the dehesas. In the period between 1992 and 2000, the model was oriented towards the compensation of income from commercial production activities, resulting in an increase of stocking rates at farm level, intensifying the systems in order to obtain higher levels of income. The intensification led to environmental problems such as lack of tree regeneration and soil degradation and erosion. During the period between 2000 and 2013, the support system known as "decoupling" was established, which had an unequal effect on livestock farming: while cattle maintained their censuses, in the case of sheep and especially goats, the censuses dropped and many farms abandoned their activity, leading to an invasion of scrub, significant changes in the pasture species and landscape alterations (Langa Gonzalo, 2010).

More recently, the CAP 2014–2020 has focused on promoting the development of territories, the efficient use of resources with a view to a sustainable and diverse agricultural sector, paying even more attention to rural areas (Escribano, 2014; Franco et al., 2012). This approach has led to the maintenance of livestock censuses in dehesa systems and in particular it can be also said that it has been from that moment on that the development of organic farming in Spain has been most notable, with an increase in the number of farms of more than 50% between 2014 and 2018 (MAPA, 2019).

The post-2020 CAP that finally takes effect will undoubtedly affect the long-term sustainability of organic livestock farming in dehesas. It is therefore crucial at this time that, specific measures might be included to guarantee the agro-ecological balance of the system, enhancing and compensating economically its environmental functions in order to increase the low income and margins that these farms obtain whilst promoting practices that maintain their ecological stability.

In view of the above, it seems appropriate to consider that the balance of GHG emissions is a good indicator of the environmental sustainability of livestock farming, although not the only one, since in order to quantify the overall sustainability of the dehesa agroecosystem, there are many other environmental, social, and economic indicators to be considered. In this sense, there is research that globally evaluates the sustainability of extensive and organic livestock farms based on a set of indicators of different nature (environmental, economic, and social) (Escribano, 2016; Gaspar et al., 2009, 2007). In a future climate change scenario, the carbon footprint and carbon sequestration are indicators that should be incorporated into a global framework of sustainability and used in a combined way to measure the vulnerabilities of extensive systems to possible effects such as droughts, temperature increase, forest fires, and other extreme weather events that may affect this highly sensitive agroecosystem.

5. Conclusions

This paper analyzes the CF of organic livestock farming in seven farms using a life cycle assessment approach, which allowed for the quantification of the GHG balance in the productive process, differentiating it by origin (enteric fermentation, manure management, soil management, feed inputs, and energy use).

On analyzing the origin of the greenhouse gas emissions, our research reveals that enteric fermentation is the major one in ruminants farms. In the case of pigs, however, emissions deriving from manure management are the highest. On the other hand, feed inputs in organic farms are not so relevant as in conventional farms. Organic systems maximize pasture exploitation which in turn contributes to the lesser consumption of off-farm feeds and at the same time, the grazing technique improves the quality of the pasture by increasing soil's carbon sequestration.

The high capacity of carbon sequestration of the soil in these farming systems of dehesas derives from the large areas of land, which to a great extent compensates for the livestock emissions. In the case of ruminants farms, the emissions are compensated in 35% to 89%, and even in 100% in the case of dairy goats; in the case of Iberian pigs, carbon sequestration levels exceed the emissions. Given these results, particularly highlighting the extensive livestock management system of these ecosystems, we can conclude that the model used by organic livestock farming in the dehesas is a feasible strategy for reducing GHGs from livestock farming.

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Chapter IV: A scenario-based analysis of the effect of carbon pricing on organic livestock farm performance: a case study of Spanish dehesas and rangelands

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A scenario-based analysis of the effect of carbon pricing on organic livestock farm performance: a case study of Spanish dehesas and rangelands.

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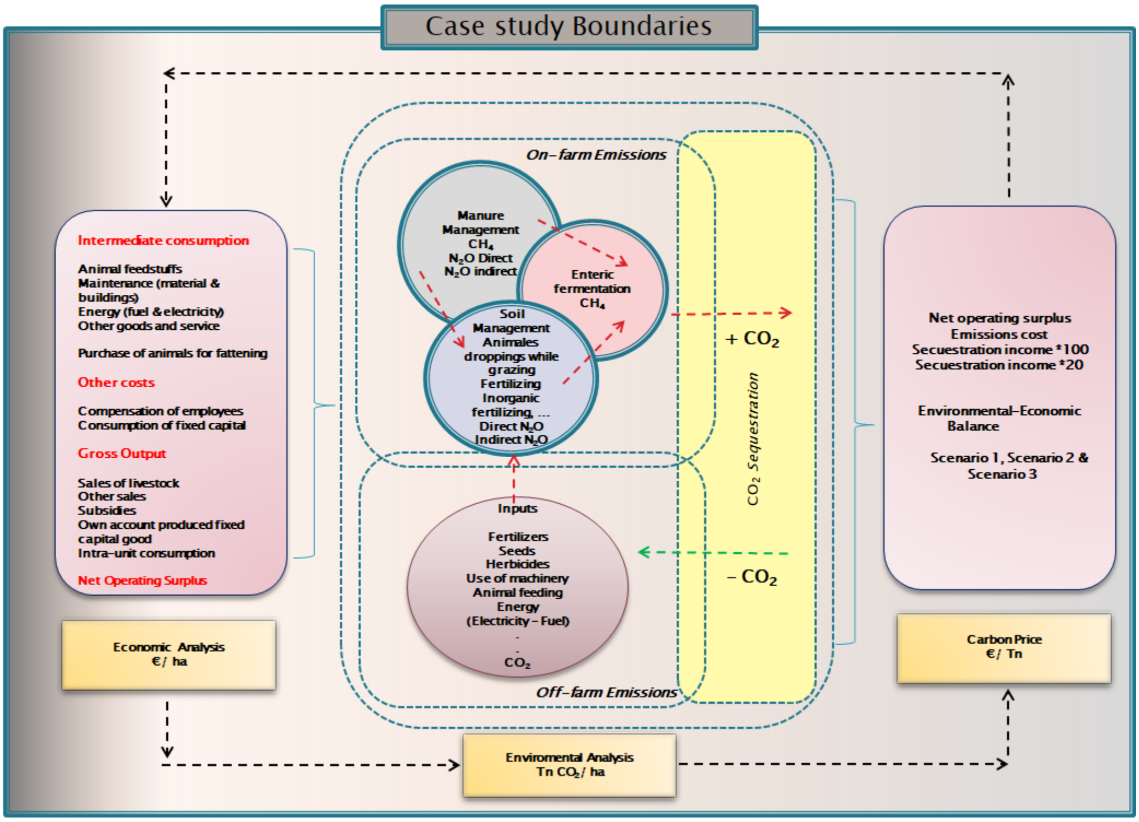
Abstract:

The current livestock farm production model is being questioned due to its excessive use of resources and impacts on the environment, and it has played a major role in climate change due to the excessive level of greenhouse gas (GHG) emissions. A valid tool in the reduction of such emissions is the imposition of a tax on CO_2 emissions that can act as an economic and financial instrument. Additionally, livestock production based on grazing animals is proposed as a more sustainable model that involves improved environmental practices and provides society with various ecosystem services, including carbon sequestration. The main purpose of this paper is to estimate the maximum price per tonne of CO_2 equivalent (eq) that could be borne by the various models of organic livestock farms in the dehesas and rangelands of southwestern Spain. With this purpose in mind, we have made a scenario-based estimation of the environmental-economic balance in three different scenarios considering farm emissions and CO_2 sequestration levels. The results show that the maximum price that farms can bear is within a range of € 0.20 to € 792/tn of CO_2 eq depending on the scenario analysed and the production model. In the cases in which carbon sequestration balances GHG emissions, the implementation of carbon pricing implies additional economic income for farm accounts.

Keywords: Organic livestock, GHG emissions, grazing system, carbon sequestration, carbon price, economic analysis.

Graphical Abstract



1. Introduction

Agriculture, food production and processing systems are currently being questioned since they have been considered to be unsustainable on account of their excessive resource use, their fossil fuel use and their heavy environmental impacts on water, soil, air and biodiversity (Eldesouky et al., 2020). Many of these impacts are associated with greenhouse gas emissions (GHGs) and their effects on climate change.

The fight against climate change has certainly become a major challenge in our society, and this has caused social pressure to be put on political leaders to promote and boost the implementation of agreements such as the Paris Agreement (UNFCCC, 2019). Thus, the need to achieve economic advances while attaining sustainable development was proposed in the recent Convention on Climate Change in Madrid on December 2019 (COP25), with a focus on the discussion around the Alliance for Climate Action and the reduction of net CO_2 emissions to zero emissions by 2050.

Livestock farming occupies 83% of the soil used for food production and generates 60% of the GHG emissions of the world's farming industry (Poore and Nemecek, 2018). In fact, Life Cycle Assessment (LCA) calculates that in the world's livestock farming industry, the percentage of GHG emissions derived from deforestation and animal feed production reaches 68%, 27% is attributed to enteric fermentation and manure management and only 5% is attributed to grazing (Leip et al., 2010). Specifically, in Spain, nearly half of the emissions derived from the farming sector are generated by the use of fertilisers and soil management whereas the other half is caused by livestock farming, enteric fermentation and manure management (MITECO, 2019).

Nevertheless, not all the animal production systems generate GHG emissions with the same intensity. In this sense, when we analyse these systems in terms of territories, we arrive at the conclusion that extensive systems have lower impacts per area unit (Batalla et al., 2015; Eldesouky et al., 2018; Gutiérrez-Peña et al., 2019; Stanley et al., 2018) compared to the other more intensive models. To this, we can add the capacity these farming systems have to fix the CO_2 in the soil, pastures and bushes.

In this context, rangelands are estimated to contain 343 thousand million tonnes of carbon worldwide, nearly 50% more than the amount stored in the world's forests (FAO, 2017). The extensive livestock production system with livestock grazing over large areas of land seems in principle to a more sustainable production model with the potential to generate greater added value in economic and environmental terms compared to other more intensive systems associated with major inputs and environmental impacts (Eldesouky et al., 2018).

At a time when public intervention mechanisms are being sought to force different productive sectors to reduce their GHG emissions, the implementation of a mechanism such as carbon pricing can have relevant effects on the agricultural and livestock sector. Specifically, our research shows that this carbon pricing tool can have very different effects depending on how it is implemented and the type of enterprise, as is the case with livestock companies using organic production schemes.

Likewise, certain economic and financial instruments can constitute valid tools to reduce CO_2 emissions, minimise the environmental impact and reward farms that are environmentally more efficient with regards to this external factor. Amongst them, the carbon markets propose establishing a price on CO_2 emissions, which is promoted in numerous countries with initiatives such as the EU Emissions Trading System (EU ETS). The EU ETS operates according to the "cap and trade" principle and has proven that establishing a price on carbon emissions can be an important tool in the fight against climate change and the reduction of contamination (Bakhtyar et al., 2017; European Commissions, 2018). In this context, the price of CO_2 equivalent (eq) would be governed by the provisions of emissions trading. Currently, there is a European market for CO_2 contamination duties created in 2005, which applies only to certain companies such as electricity companies, cement factories, paper factories, etc. This market pays in the area of €4 to €30/tn and is expected to increase prices to €36/tn in 2020 (IETA, 2019).

In terms of the potential options, one of the proposals that has gained the most acceptance is a policy that establishes a fee payable by the contaminating parties

(Pigou and Aslanbeigui, 2017), which was subsequently extended with the Coase Theorem (Coase, 1960) proposing the internalisation of the generated externalisations. The European regulations based their regulations on these models (UE, 2004). Nevertheless, the issue remains in the assessment and determination of the fee payable for the CO_2 eq emissions generated by the various economic agents. Given the above scenario, the purpose of this paper is to estimate the maximum CO_2 eq price that can be borne by organic extensive livestock farms in dehesas and rangelands by adapting the break-even point concept (Caulfield and Teeter, 1988; Yamamoto and Takeuchi, 2012). For this purpose, the following were analysed: the economic balance, the carbon footprint and the carbon sequestration of the farms under study. Based on the above information, the maximum carbon price has been estimated as an indicator that can increase the value of these farms and determine the CO_2 eq prices in agricultural markets.

2. Background

The scientific literature on GHGs and their impacts on the environment and society is constantly increasing. Several studies perform carbon footprint analysis and farm life cycle analysis, but in most cases, it is not common to incorporate carbon sequestration and its implications for climate change mitigation in these analyses. In addition, in the literature, we can also find studies that have previously studied the current situation and evolution of CO_2 prices, as well as the CO_2 tax, in the business sector in different countries.

2.1. Life cycle analysis and carbon footprint in livestock

The analysis of livestock production systems under grazing conditions in the Iberian Peninsula has been conducted by Batalla et al., (2015) in the case of sheep for meat and by Gutiérrez-Peña et al., (2019) in the case of goats in protected areas such as the Grazalema mountain area, where the importance of the land factor in agroforestry areas and the animal-crop interaction is highlighted.

In line with these papers, measuring the impacts of agricultural and livestock farming activities would be a major objective that can be met through an LCA of these systems, the calculation of their carbon footprints (CFs) and the estimation of their carbon sequestration, as shown in the papers of Buratti et al., (2017), Eldesouky et al., (2018), Horrillo et al., (2020), Stanley et al., (2018) and Vagnoni and Franca, (2018).

More recently, in the scientific literature, we can find several studies that analyze GHG emissions in different productive systems, both intensive and extensive, and analyze their productions with varied methodological approaches, which sometimes make it difficult to compare the results. Thus, Ruviaro et al., (2020) analyze the intensification of dairy cattle production in Brazil in the last decade and how that intensification has put great pressure on the environment. This work points out the importance of finding a balance between economic, social and environmental objectives by assessing the economic costs of different production systems, including the costs of GHG emissions.

Other papers such as Liang et al., (2020) show the effect of cattle production on the organic carbon storage in the soil and suggest how grazing cattle on natural and cultivated pastures can be a strategy for reducing GHG emissions and mitigating climate change. Kamilaris et al. (2020) model different alternative management scenarios for the economic and environmental sustainability of the beef finishing systems. These authors conclude that the systems with more intensive and shorter durations are the systems these have less environmental impact, but they also demonstrate that medium-duration pasture-based beef production systems in Scotland achieve a balance between financial returns and environmental efficiency. Similarly, Escribano et al., (2020) address the dilemma between intensification and land use. These authors observed that more extensive systems with low GHG emissions and high levels of carbon sequestration could maintain their productivity by improving their positive effects on the environment while revitalizing rural areas.

Finally, other studies that can be found in the recent literature that perform Life Cycle Assessment (LCA) comparing management options are Zucali et al., (2020) on dairy goat farms in Lombardy and Tallaksen et al., (2020) on the pig sector. This last study performs a life cycle analysis of fossil energy together with GHGs emissions for the pig production systems in the Midwest United States. There are however few studies that analyse Iberian pigs and the environmental impacts of these farms on the dehesa ecosystem (García-Gudiño et al., 2020).

2.2. The price of CO_2 and carbon tax

In the scientific literature, there are several studies that analyze the price of CO_2 in the context of emissions trading systems. A number of studies analyze China and its energy sector is the main focus of emissions, especially the relationship between the carbon price and the abatement costs in the energy sector in Asian countries (Tang et al., 2020; Wang and Wei, 2014; Zhou et al., 2015). Other studies apply methods that estimate the maximum carbon prices, use auctions as allocation methods or implement general equilibrium models (Li and Jia, 2016; Lin and Jia, 2019, 2017; Tran et al., 2019).

In the agricultural sector, where emissions reduction is not only a technical challenge but also a socio-economic issue (Rehman et al., 2020), there are several studies that address the problem from different perspectives. Specifically, there are several studies that have showed the consequences of imposing a tax on CO_2 eq emissions in the livestock sector (Key and Tallard, 2012; Slade, 2018; Wirsenius et al., 2011), as well as the effects this has on the per capita income of a country (Lin and Li, 2011) or on the costs of CO_2 eq abatement in farming (Vermont and De Cara, 2010). For example, for the wood sector Lauri et al., (2012) estimate different CO_2 price scenarios from 20 to 110 euros/tCO_2 for the use of wood as an energy resource. An analysis of the European agricultural market is addressed by De Cara and Jayet, (2011), which obtains a balance price of between 32-42 euros/tCO_2 eq as necessary for carbon reduction. De Cara et al., (2005), using a farm-type, supply-side oriented, linear-programming model (farm level approach), show how carbon abatement costs may vary depending on the farm system and technology adoption level. Similarly, Hediger, (2006) modelled GHG emissions and mitigation costs from an agricultural system perspective – including for plains, hills and mountain areas- in Switzerland to develop an analytical tool for assessment purposes. Finally, the application of general equilibrium models to the American market (McCarl, 2001; Schneider et al., 2007), to the European market (Pérez Domínguez et al., 2009) or at the global level (Golub et al., 2009) can also be found.

Most of these studies do not analyse the livestock holdings and their different problems and practices in detail, and so it is considered appropriate to analyse how the possible pricing of CO_2 can influence extensive livestock farms operating under organic conditions.

3. Materials and Methods

Six of the most common organic production farms in the dehesas and rangelands of the southwest of Spain were selected with the aim to perform a case study analysis. These farms produce meat obtained from various zoological species (cattle, sheep and pigs). These dehesa and rangeland areas are characterized as having a Continental-Mediterranean climate, with average annual temperatures ranging from 16 to 17 °C. Summers are long, hot and dry with the average temperatures typically exceeding 26 °C and the highest temperatures usually exceeding 40 °C. Winters are mild with an average temperature of 7.5 °C and a low temperature of 2 °C on average. Rainfall is distributed irregularly and varies from 300 to 800 mm per year, with significant variations from one year to another. In terms of the soil structure of the area, these dehesas and rangelands are primarily characterised as having acidic soils with little organic content (Gaspar et al., 2008, 2007).

3.1. Case Study and Data Collection

The case study is a tool that allows an in-depth analysis of an object of study or a unit (Yin, 2009, 1984). According to (Chetty, 1996), this technique is useful to provide answers to phenomena, to describe them and to find the reasons why they take place. Additionally, it can also be used to describe actual situations and is applicable, for example, to issues relating to enterprise management, with the enterprise being the unit of study.

In other words, a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident (Yin, 1984). The case studies in this research are organic livestock farms selected for their distinctive characteristics, which represent production models in southwestern Spain. Moreover, the case study as a research strategy comprises an all-encompassing method with a design logic incorporating specific approaches to data collection and to data analysis. In this sense, the case study is not a data collection tactic or merely a design feature alone

(Stoecker, 1991) but is a comprehensive research strategy. Therefore, this methodology is fully adapted to conduct the proposed comprehensive analysis (economic and environmental) of the mentioned livestock farms in which it is pertinent to deepen the knowledge of their environmental impacts and their relationships with economic profitability in the current context.

Nevertheless, the study case methodology makes it impossible to extrapolate the findings statistically; however, if the cases are adequately selected, it is possible to extrapolate the findings, discover the basic principles and contribute to scientific development (Flyvbjerg, 2006). The recent literature includes numerous papers that use case studies to analyse livestock farm management from socioeconomic and environmental viewpoints (Asai et al., 2018; Bernués et al., 2017; López-Sánchez et al., 2016; Mapiye et al., 2018; Martin-Collado et al., 2014; Neira et al., 2014; Regan et al., 2017; Vellenga et al., 2018).

The cases (farm holdings in this study) included four ruminant farms: two cattle production-oriented ones, with the first producing beef cattle calves (BCC) and the second producing beef cattle yearlings (BCY); and two meat sheep production-oriented ones, with the first one producing meat sheep lambs weighting 23 kg (MSL23) and the second producing meat sheep lambs weighting 18.5 kg (MLS18.5). In addition, there were two pig farms: one Iberian pig farm using the Montanera fattening system (IPMF) where piglets are purchased off-farm and finished during the Montanera period; and the other one was an Iberian pig closed herd (IPCH) farm keeping breeding sows and boars, raising piglets and finishing them in the Montanera period.

As indicated, the farms under study can be classified into ruminants and pig farms, being all of them are representative production models in the study area, i.e., dehesas and rangelands of the southwest of Spain. The data were collected in 2017 by means of an in-depth survey including information on land use, agricultural and fodder production, work structure, flock composition, reproductive indicators, production yields, energy, machinery and facilities, and economic data on costs, sales and subsidies. These data were used both to describe the farms, through a set of technical indicators selected from the papers written by (Escribano et al., 2002, 2001b, 2001a, Gaspar et al., 2008, 2007; Martín et al., 2001), and for economic and LCA analysis.

Table 1 shows the main technical indicators for the cases under study. These indicators contribute to a better understanding of this research since they provide a description of the farms analysed by summarising aspects such as the farm size and land use, describing the livestock species exploited, etc. Some of these indicators also are used directly or indirectly to calculate the carbon footprint and carbon sequestration through the LCA analysis.

Table IV. 1. Technical indicators of the cases under study.

Indicators	BCC	BCY	MSL23	MSL18.5	IPMF	IPCH
Total Area (ha)	140	105	370	500	300	230
Wooded area (ha)	140	102	-	-	300	230
Pasture area (ha)[a]	130	102	320	410	260	225
Cultivated area (ha)	10	3	50	90	40	5
Total LSU[b]	83	32	162	302.1	56	40.5
Total stocking rate (LSU/ha)	0.59	0.3	0.44	0.6	0.18	0.19
No. of reproductive females (average population)	75	25	900	1700	-	22
No. of reproductive males (average population)	2	1	30	55	-	3
Annual Work Units (AWU)	1.17	2.33	2	3.13	2	2.17
Permanent (AW)	1	1	1	2	1	1
Family (AW)	0	1	1	1	1	1
Temporary (AW)	0.17	0.33	0	0.13	0	0.17
Female/male rate %	37.5	25	30	31	0	7.3
Replacement rate %	13	40	16.7	11.8	0	0
Number of offspring born per female breeder %	0.8	0.8	1.2	1.3	0	9.8
Number of fattening animals per female breeder %	0	0.68	1.1	1	0	9.1

[a] includes areas with and without trees; [b] Livestock Stocking Unit. BCC: Beef Cattle Calves; BCY: Beef Cattle Yearlings; MSL23: Meat Sheep Lambs 23 kg; MSL18.5: Meat Sheep Lambs 18.5 kg; IPMF: Iberian Pig Montanera Fattening; IPCH: Iberian Pig Closed Herd.

The BCC study case is based on a small extensive cattle farm, which is situated in a dehesa with holm and cork oak trees at 30-40 feet/ha. The land is owned by the farmer and the end product is the sale of weaned calves with 200-250 kg live weights.

The second case study, i.e., BCY, is also a small farm only dedicated to rearing cattle through an extensive system in a dehesa with holm oak trees at 35-45 feet/ha. Unlike the previous case, the end product is the sale of fattened yearlings with 500 kg live weights for males and 400 kg live weights for females.

The two remaining ruminant cases are sheep farms, one of which, i.e., MSL23, is an extensive meat sheep farm situated in a rangeland farming area. The farmer is under a rental agreement, and the products sold are finished lambs with 23 kg live weights. This farm is part of a cooperative business; therefore, the lambs are brought to the cooperative business' classification centre for their final commercialisation.

The MSL18.5 case study is also part of a sheep cooperative business. This farm has a total area of 500 ha, and the land is owned by the farmer. The farm is divided into two areas that are well differentiated: one of them is an area of rangeland (80%) and the other is dedicated to annual winter and fodder legume crops (18%). This is a family business where the products sold are lambs with 18.5 kg live weights, which are then finished in the cooperative facilities.

The IPMF case study is a pig farm in a dehesa area with an average tree density of 35 feet per ha (40% is holm oaks and 60% is cork oaks). The farmer has a rental agreement of 67%, and it is a family business managed by the proprietor. This farm's livestock system is based on the purchase and fattening of pigs from farms where piglets are reared. The products sold are pigs with 160 kg live weights finished in the Montanera system.

The last case study, i.e. IPCH, is an extensive full cycle pig farm in a dehesa area. This dehesa consists of a mixture of holm oak (+) and cork oak trees accounting for over 50 feet per ha. The farm is rented, and the lessee is the manager of the farm. The products sold are both piglets with 40 kg live weights and finished pigs in the Montanera system with 170 kg live weights.

3.2. Economic Indicators

The economic indicators were developed on the basis of the System of Integrated Environmental and Economic Accounting, applied to the economic accounting for Agriculture and Forestry (Communities European, 2002) and the EC Regulation no. 549/2013 relating to the European System of National and Regional Accounts in the

European Union, and adapted to the microeconomic level with the following indicators:

Specifically, the Net Operating Surplus ("NOS") of farm i is calculated as follows:

$$NOS_i = \sum_n^j GO_i - \sum_l^k C_i \qquad [1]$$

Where $\sum_n^j GO_i$ is the sum of the gross output obtained by farm *i* from income *n* to *j*, and $\sum_l^k C_i$ is the sum of the costs of farm *i* from cost l to cost k. $\sum_n^j GO_i$ is the gross output calculated as follows:

$$\sum GO_i = SL_i + OS_i + S_i + OCCG_i + IUC_i \qquad [2]$$

Where SL_i are the livestock sales of each farm *i*, OS are the other sales, S is the subsidies received by the farm, OCCG is the own account produced fixed capital good (animals produced in livestock units and transferred to their fixed capital) and IUC is the intra-unit consumption (agricultural products produced within the livestock unit and used by the unit as inputs into the production process within the same accounting period).

In addition, costs $\sum C_i$ equal the following:

$$\sum C_i = IC_i + CFC_i + CE_i \qquad [3]$$

IC is the sum of the intermediate consumption of farm *i* and is calculated as follows:

$$IC_i = AF_i + M_i + E_i + OGS_i + PAF_i \qquad [4]$$

Where AF is the cost of animal feedstuffs, M is maintenance, E is energy, OGS is other goods and services and PAF is the purchase of animals for fattening.

Lastly, CFC_i is the consumption of fixed capital and CE_i is the compensation of employees (employee salaries).

3.3. Calculation of GHG Emissions based on LCA

The LCA is one of the most commonly used methods to measure environmental impacts and develop the framework for the calculation of the balance of GHG emissions in livestock farms since it is an internationally-accepted standard method to efficiently quantify the environmental impact of a product. Although it is not frequent, it can also include the analysis of carbon sequestration (Buratti et al., 2017; Eldesouky et al., 2018; Horrillo et al., 2020; Stanley et al., 2018; Vagnoni and Franca, 2018).

Among the variety of methodologies available to estimate GHG emissions, Life Cycle Assessment (LCA) is used to identify and quantify the environmental impact of a product (Buratti et al., 2017). Throughout the entire life cycle of a product, LCA accounts for resource consumption, energy, pollutant emissions, etc. (Goldstein et al., 2016). In this study, LCA has been performed following UNE-EN-ISO 2006 (ISO, 2006a, 2006b) standards and IPCC (IPCC, 2007, 2006) guidelines for the calculation of the carbon footprint. These guidelines have been adapted to national inventories of GHG emissions in Spain, such as in (MAPA, 2012) and (MITECO, 2019), as well as various emission factors (Bochu et al., 2013; CNMC, 2018).

The scope of this paper is the entire production cycle of extensive farms, concluding when the animal leaves the farm. The analysis includes on and off-farm emissions. The system boundaries cover all emissions that occur within the farm (enteric fermentation, manure management, soil management ...). It also comprises emissions from manufacturing and transport for each input being used in the system (feed, fuel and electricity consumption, etc.).

The functional unit (FU) employed in this study for the emissions was 1 hectare of the total farm area. LCA uses the concept of an FU to compare several food products. The FU aims to provide a common basis of comparison between different means to achieve the same end (Owsianiak et al., 2014). In the case of pasture-based systems, the land (surface) is fundamental to adequately express the emissions from livestock (Gutierrez-Peña, 2019).

All the emissions are expressed in tn of CO_2 eq, depending on their potential effect on global warming as proposed by the IPCC (IPCC, 2007), with the values being 1 for CO_2, 25 for CH_4, and 298 for N_2O. The emissions factors used to quantify GHG emissions are shown in Table A1 of the Appendix.

3.4. Carbon sequestration

Carbon sequestration (Petersen et al., 2013) has been estimated during the LCA of the farms under study and adapted to the systems under analysis based on the studies of other similar farms (Batalla et al., 2015; Horrillo et al., 2020). Carbon sequestration has been estimated for a time horizon of 20 and 100 years. These two estimates allow for the construction of different scenarios for the subsequent economic analysis. The more conservative scenario, that is, 100 years, is analysed following the method used in the papers of Horrillo et al., (2020) and Eldesouky et al., (2018). Subsequently, the same methodology was adapted for a time scenario of 20 years (Petersen et al., 2013).

Carbon sequestration is calculated from the estimation of the dry matter in pastures and crops, soil and manure management, and it takes into account the good practices exercised on these soils that increase the C sequestration in these farms (rotational grazing, permanent crops, stubble burning, and manuring).

3.5. Maximum tn/CO_2 eq price and the Break-Even Point

To calculate the maximum CO_2 eq price that the various farms can bear, we have adapted the concept of the Break-Even Point, which has been applied in other environmental policy measures in order to assess the consequences of the decisions made following natural disasters (Caulfield and Teeter, 1988) or to establish the lowest price to prevent deforestation in Indonesia (Yamamoto and Takeuchi, 2012). In order to do this, we use the definition of the Net Operating Surplus NOS_i, which was calculated following the steps described in section 2.2.

In addition, the environmental balance EB_i is calculated as follows:

$$EB_i = \sum TCO2E_i \text{ x } PCO2 - \sum TCO2S_i \text{ x } PCO2 \qquad [5]$$

Where $\sum TCO2E_i$ is the sum of the total CO_2 emissions (tn CO_2eq/ha), $\sum TCO2S_i$ is the total CO_2 sequestration and PCO2 is the price per tn/CO_2.

Expressions [1] and [5] enable us to obtain the environmental-economic balance (EEB_i) of farm *i*, provided that PCO2 is known.

$$EEB_i = NOS_i - EB_i \qquad [6]$$

By way of replacement of [6] in this equation, [7] is obtained as follows:

$$EEB_i = NOS_i - \left(\sum TCO2E_i \text{ x } PCO2 - \sum TCO2S_i \text{ x } PCO2\right) \quad [7]$$

Specifically, PCO2 has been calculated as the quotient of NOS_i and $\sum TCO2E_i$ - $\sum TCO2S_i$. Thus, $PCO2^*$ is defined as the maximum price of tn/CO_2 and thus the equation looks as follows:

$$PCO2^* = \frac{NOS_i}{\sum TCO2E_i - \sum TCO2S_i} \quad [8]$$

This method was applied to three potential different scenarios (Scenarios 1-3) by applying a common P_CO_2 equal to € 24,81 per tonne of CO_2 eq (SEDENCO2, 2019). In the first scenario (Scenario 1), the systems were considered only as GHG emissions agents and therefore the carbon sequestration potential was not taken into account. In the second scenario (Scenario 2), carbon sequestration was included in the livestock systems with a 100-year horizon. Lastly, in the third scenario (Scenario 3), the carbon sequestration horizon was 20 years.

4. Results

4.1. Results of the economic analysis of the farms under study

Table 2 shows the results of the economic analysis including the costs (intermediate consumption and other costs), gross output (sales and subsidies) and net operating surplus per farm analysed.

Table IV. 2. Economic indicators.

Indicators	BCC	BCY	MSL23	MSL18.5	IPMF	IPCH
Intermediate consumption (IC)						
Animal feedstuffs (€/ha) (AF)	34	13.6	22.7	5	150	213.3
Maintenance (materials & buildings) (€/ha) (M)	64.3	39.5	29.5	89.5	8.2	46.9
Energy (fuel and electricity) (€/ha) (E)	20.6	19.4	1.3	10.1	13.2	11.2
Other goods and services (€/ha) (OGS)	41.7	14.3	21.9	42.8	14.8	20.8
Purchase of piglets for fattening (€/ha) (PPF)	-	-	-	-	60	-
Other Costs (OC)						
Compensation of employees (€/ha) (CE)	91.4	64.6	51.1	110.4	52.6	80.3
Consumption of fixed capital (€/ha) (CFC)	46.3	120.9	25.2	73.1	53	47.9
Gross output (GC)						
Sales of livestock (€/ha) (SL)	157.1	117.1	196.6	212.2	239.6	280.2
Other sales (€/ha) (OS)	0	14.29	15.2	15.3	40	26.1
Subsidies (€/ha) (S)	107.1	85.7	96.2	142	26.7	13.1
Own account produced fixed capital good (€/ha) (OCCG)	71.4	95.2	25.8	24.6	-	-
Intra-unit consumption (€/ha) (IUC)	43.3	17.8	79.1	103.9	89.5	84.8
Net operating surplus (NOS) (€/ha)	**80.7**	**88.2**	**216.1**	**106.7**	**50**	**0.1**

The ruminant farms (BCC, BCY, MSL23 and MSL18.5) reveal that for intermediate consumption, the main costs are broken down between maintenance and other expenses, which include subcontracting external services and the maintenance of the facilities and machinery. In these farms, animal feedstuffs do not represent a major cost since the animals graze throughout the year and the farms are self-sufficient. The annual cereal crops and their own production of straw and hay serve as food sources for the animals in times of scarce pastures. The occasional purchase of feedstuffs and fodder is used at the initial stage of fattening the calves and lambs, as well as for the maintenance of breeders at times with poor weather conditions, scarce food, etc. In terms of the other costs, salaries are the main expenditure in these farms, and this item varies from farm to farm. In terms of farm income, the sale of animals is the main source of income. Additionally, subsidies are another significant source of income, which represent 30% to 40% of the total income.

In the case of pig farms (IPMF and IPCH), regarding intermediate consumption, the largest difference compared to ruminant farms is the cost of feeding, which are the highest costs in both pig farms. This is due to the production model itself, where animals are fed concentrates all year round, except for the latest fattening stage, where they are fed in the Montanera system. Additionally, in these intermediate consumption stages, there are two particularities, one in each farm. In the first case, the cost of purchasing animals for fattening (piglets in this case) is an indicator in this case only because of the productive system in use. In the second case, it is the maintenance costs, energy costs and other costs that increase in comparison to the previous pig case on account of the availability of facilities dedicated to the breeding and rearing of piglets. In other costs, in both cases, salaries represent the main expense for the farm. In terms of income, the sale of the animals is the main source of income in both farms. In the case of the pig farms, in terms of subsidies, they only receive the aid derived from the Rural Development Program since they are certified as organic.

The accounts of the farms reveal profits (NOS) for the cattle farms (BCC and BCY) of approximately €80/ha. Higher profits are seen in the sheep farms at €106.7/ha and €216.1/ha in MSL18.5 and MSL23, respectively. However, pig farms yielded the lowest profit, with the IPCH having a very low profit.

4.2. Environmental and GHG Emissions Analysis

The balance of the GHG emissions is shown in table 3, including the contribution of the various GHG emissions in the systems under analysis expressed as tn CO_2 eq/ha, as well as the results of carbon sequestration concerning the role of farms as carbon sinks.

Table IV. 3. GHG emissions and carbon sequestration.

	BCC	BCY	MSL23	MSL18.5	IPMF	IPCH
GHG emissions	Tn CO_2eq/ ha	Tn CO_2eq/ ha	Tn CO_2eq/ ha	Tn CO_2eq/ ha	Tn CO_2eq/ ha	Tn CO_2eq/ ha
Enteric fermentation	0.809	0.447	0.573	0.764	0.007	0.015
Total manure management	0.119	0.072	0.042	0.049	0.096	0.142
Total soil management	0.417	0.262	0.084	0.112	0.028	0.051
Total On-farm emissions	**1.347**	**0.781**	**0.698**	**0.934**	**0.132**	**0.193**
Total Feeding	0.016	0.013	0.016	0.013	0.069	0.146
Electricity	-	-	-	-	0.011	0.010
Total fuel	0.072	0.068	0.003	0.029	0.012	0.023
Total Off-farm Emissions	**0.088**	**0.081**	**0.019**	**0.043**	**0.091**	**0.179**
Total tn de CO_2eq	200.9	90.5	260.3	477.7	67.3	97.2
Total CO_2 emission (tn CO_2eq/ ha) (TCO2E)	**1.434**	**0.862**	**0.718**	**0.975**	**0.224**	**0.422**
Sequestered CO_2						
Total tn CO_2eq pasture-crops	624.5	408.6	1477.2	2242.7	1452.6	1316.7
Total tn CO_2eq manure-soil	70.9	32.1	103.1	191.8	7.9	9.1
Total tn CO_2eq/ farm	**695.5**	**440.7**	**1580.3**	**2434.5**	**1460.6**	**1325.6**
tn CO_2 pasture+crops sequestration *100	62.5	40.9	147.7	224.3	145.3	131.7
tn CO_2 manure+soil sequestration *100	7.1	3.2	10.3	19.2	0.792	0.905
Total tn CO_2 sequestration*100	**69.6**	**44.1**	**158**	**243.5**	**146.1**	**132.6**
Total CO_2 sequestration *100 (tn CO_2eq /ha/year) (TCO2S100)[a]	0.497	0.42	0.427	0.487	0.487	0.576
tn CO_2 pasture+crops sequestration *20	131.1	85.8	310.2	470.9	305.1	276.5
tn CO_2 manure+soil sequestration *20	14.9	6.7	21.6	40.3	1.7	1.9
Total tn CO_2 sequestration*20	**146.1**	**92.5**	**331.9**	**511.2**	**305.8**	**277.3**
Total CO_2 sequestration *20 (tn CO_2eq /ha/year) (TCOS20)[b]	**1.04**	**0.88**	**0.89**	**1.02**	**1.02**	**1.21**
Compensated CF						
Compensated CF/ ha (tn of CO_2eq/ ha)*100	**0.938**	**0.442**	**0.291**	**0.488**	**-0.263**	**-0.154**
Compensated CF/ ha (tn of CO_2eq/ ha)*20	**0.392**	**-0.02**	**-0.179**	**-0.048**	**-0.795**	**-0.783**

[a] TCO2S100 calculated for a 100-year period; [b] TCO2S20 total CO_2 sequestration calculated for a 20-year period.

The ruminant farms (BCC, BCY, MSL23 and MSL18.5) show that the highest contribution to the total emissions is represented by enteric fermentation, followed by manure and soil management. In particular, cattle farms selling weaned calves (BCC) had the highest carbon footprint (TCO2E 1.434 tn of CO_2 eq/ha). The lack of fertilisers and the minor use of fossil energies, such as fuel and electricity, mean that in these cases, the animals themselves and their management are responsible for the highest percentages of emissions. Additionally, the table shows that the results obtained for carbon sequestration that have already been mentioned. This value was calculated in two scenarios: the first one with a 100-year horizon and the second one with a more reduced 20-year horizon. Logically, the results for carbon sequestration in these extensive farms over a 20-year time horizon is more beneficial since the majority are seen to have a favourable balance, this is, they reduce more CO_2 eq than they emit.

In the pig farms (IPMF and IPCH), the main indicator that is responsible for on-farm emissions is manure management, whereas the inputs derived from the purchase of feedstuffs are the most significant off-farm

emissions. Differently from the ruminant farms, the environmental balance is favourable in both scenarios simulated, the 20-year and 100-year scenarios.

4.3. Economic-environmental balance of the farms under study

Table 4 shows, in addition to the NOS [EQ 1], the cost attributed to emissions according to the CO_2 price and the estimated income from carbon sequestration over 100 and 20 years. Taking into account these parameters, we can see that the environmental economic balance (EEB) [EQ 7] expressed in €/ha can vary depending on the case study and the scenarios in use. Generally speaking, the economic-environmental balance of these organic farms implies an improvement in comparison with NOS when sequestration is considered for the 20-year interval.

Table IV. 4. Economic-environmental results for the farms under study.

	BCC	BCY	MSL23	MSL18.5	IPMF	IPCH
Net operating surplus (NOS) (€/ha)	80.7	88.2	216.1	106.7	50	0.1
Emissions cost (EC) (€/ha)	35.6	21.4	17.8	24.2	5.6	10.5
Sequestration income *100 (SI100) (€/ha)	12.3	10.4	10.6	12.1	12.1	14.3
Sequestration income *20 (SI20) (€/ha)	25.8	21.8	22.1	25.3	25.3	30.1
Environmental-Economic Balance (€/ha)						
Scenario 1	45.1	66.8	198.3	82.5	44.4	-10.4
Scenario 2	57.4	77.2	208.9	94.6	56.5	3.9
Scenario 3	71.0	88.7	220.5	107.9	69.7	19.5

Specifically, in the case of the pig farms, in spite of NOS being low, the negative value of the environmental balance (emissions minus sequestration) is favourable for these two farms, that is, the extensive production models of organic pigs reduce more CO_2 eq than they emit. In this sense, out of the three hypothetical scenarios proposed with the results, only the case where emissions are accounted for (Scenario 1) yields reduced NOS. In the other two scenarios, the NOS is increased, becoming approximately €20/ha over the 20-year sequestration horizon.

4.4. Estimation of the Maximum CO_2 price

Table 5 shows the results obtained for the maximum CO_2 price after adapting the break-even point that the various farms are able to afford and having developed it for the three hypothetical scenarios mentioned above.

Table IV. 5. Maximum CO_2 price.

	BCC	**BCY**	**MSL23**	**MSL18.5**	**IPMF**	**IPCH**
Scenario 1 (€/tn)	56.2	102.4	301	109.4	223	0.2
Scenario 2 (€/tn)	86	199.5	742.6	218.6	*	*
Scenario 3 (€/tn)	205.9	*	*	*	*	*

*Infinite.

The results show the maximum price of a tonne of CO_2 eq in the market that each farm could afford without incurring losses. At this maximum price, the farms would have an economic-environmental balance equalling zero.

In scenario 1, which only takes into account CO_2 eq emissions in the economic-environmental balance, the farms are sensitive to CO_2 eq prices to a higher or lesser degree except in the case of IPCH.

In scenario 2, which accounts for the environmental balance including carbon sequestration over a 100-year interval, the ruminant farms are seen to be able to afford maximum CO_2 eq prices that are above those of the previous scenario since they offset the emissions costs with the income derived from carbon sequestration. In these organic livestock farms, the economic-environmental balance is reduced if sequestration is not included, and the farms cannot afford CO_2 eq prices above those in Table 5 for each farm.

However, in this second scenario, pig farms have been seen to operate in a differentiated way since there is no maximum value for the price of a tn of CO_2 eq. This means that these farms could afford any carbon price since their emissions balance is always a negative value (emissions minus sequestration) and, consequently, the economic-environmental balance outcome will increase as the carbon price increases.

Lastly, in the third scenario, there is also no maximum value for the price of a tn of CO_2 eq for five of the six cases under study. This is because with a 20-year sequestration horizon, these organic farms reduce more carbon than they emit, and so an increase in the price of CO_2 eq will always mean an increase in the economic-environmental balance of the farm.

Figure 1 represents the price line of the CO_2 eq for each farm and for each of the three proposed potential scenarios. As shown, the effect of establishing a price on CO_2 eq is significantly different subject to the type of farm, which is represented by a more or less steep slope of the lines in the graphics. Thus, the cattle farms (Figs.1. a - b) represent the maximum price sensitivity since they have a negative slope in all scenarios, except in the second case in scenario three with a 20-year sequestration timeframe. Additionally, the maximum price point for this farm represents the lowest value amongst the six farms, that is, both cattle farms are the most sensitive to the implementation of a fee on CO_2 eq.

In the second place, sheep farms (Figs.1. c - d) are situated amongst the cattle and pig farms in terms of their price sensitivity and break-even points. Thus, these farms are relatively less sensitive than the cattle farms. Additionally, both farms have a much less steep slope; and in the case of scenario three, the trend is positive, which indicates that a price on CO_2 eq would mean a clear benefit for such farms.

Finally, the pig farms (Figs.1. e - f) behave in a different way than the ruminants farms since the non-sequestration scenario has a very different impact in the two farms. Nevertheless, the sequestration consideration has a very favourable effect in both farms, showing a steep slope in the lines of these scenarios compared to the other two types of farms.

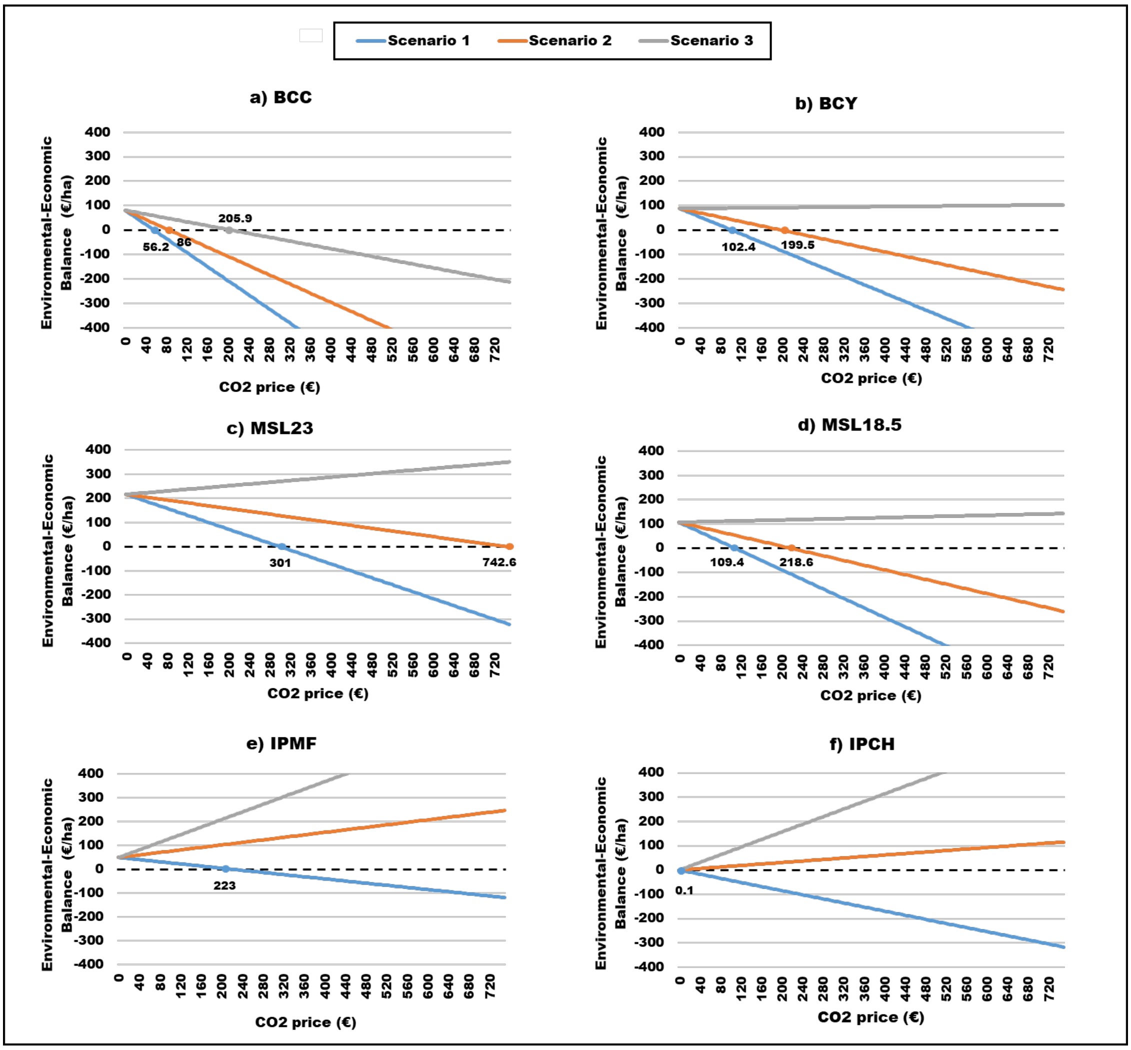


Figure IV. 1. Economic-environmental balance results in the farms under study with different CO_2 eq prices.

5. Discussion

In the analysis of extensive livestock systems, we must take into account that the animal production systems based on pastures are complex and involve numerous factors that are interrelated and affect their sustainability (Bernués et al., 2011; Ripoll-Bosch et al., 2012). Pastures in these systems are estimated to represent around 50% of the animal feed. On occasion, these rangelands are not properly used due to poor management, and sometimes they may even be underused. Nevertheless, such ecosystems require adequate management since they are important for the protection and regulation of the main ecosystem services (carbon sequestration, preservation of biodiversity, and water resources) (Alexandratos and Bruinsma, 2012; Herrero et al., 2013a, 2013b; Steinfeld et al., 2006).

Several studies argue that the carbon footprint of the meat produced in extensive livestock systems could decrease from 9% to 43% if the carbon sequestration of pasturelands was taken into account (Halberg et al., 2010; Nguyen et al., 2012; Pelletier et al., 2010; Veysset et al., 2011).

Furthermore, the intrinsic nature of these livestock systems as CO_2 originators is associated with the presence of animals and, specially, ruminants due to their enteric fermentation. Even then, in such ecosystems, the presence of these ruminants is as natural as it is necessary since their absence would cause the existence of others, which would generate the same or higher levels of CO_2 eq emissions, as is the case of wild ruminant populations or the emissions derived from microfauna breathing (microorganisms) due to the putrefaction of the pastures that are not used.

In this sense, the maintenance of this livestock herds creates positive externalities or public assets. These are defined as cultural ecosystem services (Millennium Ecosystem Assessment, 2005) or environmental services since they can perform major roles in landscape preservation (Casasús et al., 2007; Plieninger et al., 2006), biodiversity improvement (Benton et al., 2003; Henle et al., 2008), woodland fire prevention (Kramer et al., 2003) and carbon sequestration in their soils (Horrillo et al., 2020), amongst others. Nevertheless, these public services do not have a market price (Swinton et al., 2007) and they are hard to dissociate since they are very interrelated in a dynamic and complex way (Bennett et al., 2009) and, therefore, they are hard to measure.

The extensive livestock farms in dehesas and rangelands provide numerous ecosystem services. Amongst them all, carbon sequestration is the most significant in the fight against climate change (Gaspar et al., 2016; Kay et al., 2019). On this account, the CO_2 emissions of livestock farms is an issue that must be considered by the public sector with an emissions market based on charging the cost of pollution to those who contaminate so that as the cost increases, the agents causing pollution can be incentivised to refrain from doing so.

In this context, this study reveals that the livestock farms under analysis would not be negatively impacted by an increase in the CO_2 price, but instead they would benefit from it, provided there was a rewards market for CO_2 emissions.

The proposed analysis allows us to obtain a view on the maximum price that the extensive livestock farms could bear, which is in line with the papers that analyse the implementation of a tax on the CO_2 emissions of livestock farms of 30 USD/tn (Key and Tallard, 2012), how these farms could bear a similar price/tax to that established in Canada for livestock farms (Slade, 2018), or the case of the tax established on animal origin products in countries of the European Union (Wirsenius et al., 2011).

Establishing a price on CO_2 can result in diverse effects according to the type of farm and whether sequestration is considered or not, as well as the number of estimated years. Although when the price is established taking into account only the emissions, this can cause a marked negative effect on the economic-environmental outcome. This result is in line with the effects of establishing a tax on CO_2 in countries such as Denmark, Sweden, Finland or Holland contributing to emissions reductions (Lin and Li, 2011).

In this respect, there are currently an increasing number of scientific documents using CF and LCA that have been published in the last few years. In the last decade, LCA (ISO, 2006a, 2006b) has received increasingly more attention as a tool to determine and compare the environmental impact (Gava et al., 2020) and to support the actions aimed at reducing the impacts on the farming, livestock and food systems (Hellweg and Canals, 2014; Notarnicola et al., 2017; Weidema et al., 2008). Nevertheless, the flexibility of the standards when it comes to preparing an LCA model has caused concern in terms of the credibility, transparency, complexity and capacity of communication of these studies (Gava et al., 2018) since certain aspects are not specified such as how the functional units and the system's limits should be defined, how to establish the environmentally-relevant impact categories, or how to select the standards to quantify such impacts. This wide scope of action has been controversial since the derived outcomes could be different and often non-comparable (Boons et al., 2012).

In order to overcome these issues, more detailed definitions and stricter rules should be included in order to allow greater uniformity between the structure of the various studies using LCA (Jeswani et al., 2010). Examples include the definition of a hectare as a functional unit for the systems that are more associated with the territory or establishing adequate management as a tool to maximize carbon sequestration and influence the GHG balance. In summary, in order to guarantee homogeneity in terms of measuring the carbon that is emitted and sequestrated, it is key that the methodology be accepted, agreed and regulated at an international level. This is the basis of establishing a carbon price that may guarantee transparent market rules. In this sense, some papers show how the existence of a rewards market incentivises more sustainable environmental practices in farming (Galinato et al., 2011) or the need to consider carbon sequestration as a tool clearly decreases the potential effects of climate change and not only the emissions (van Vuuren et al., 2013).

6. Conclusions

Animal production systems based on grazing are sustainable since the level of their GHG emissions is lower than those of other more conventional and/or intensive models. In the same way, the paper shows that by including carbon sequestration, the emissions balance can be a negative one, particularly when the time scenario is 20 years. In this context, establishing a CO_2 price would reward the incomes obtained in the farms in a favourable manner.

In this sense, including carbon sequestration in the national inventories of dehesas and rangelands can have an impact in terms of applying a price to the carbon markets, but it can also have implications in the development of green policies within the Common Agricultural Policy framework, highlighting that these systems are sustainable and providers of a great number of ecosystem services, where their environmental impact is limited and even favourable emissions balances can be achieved.

The time horizon that is considered when calculating sequestration becomes a key aspect for discussion, together with the need to establish a clear framework for the allocation of a CO_2 eq price and the creation of the necessary tools to contribute to the development of a regulated rewards market.

In this scenario, the managers of livestock farms have room to make decisions to help reduce emissions and maximize sequestration. Amongst these decisions, selecting an organic production model may contribute to reducing livestock stocking rates and the promotion of fodder crops for self-consumption. In fact, our findings show that the farms that manage these models efficiently also obtain additional profits on account of their low emissions.

The effect of carbon pricing on organic farms is complex. Deductively, it seems that it can be somewhat unfavourable for ruminant farms (the most common type of livestock kept in organic conditions) since ruminants are major GHG emitters and C sequestration at the farm level is not always sufficient to compensate for these emissions. However, given that on organic farms the objective of food self-sufficiency is one of the main goals of these systems, with specific agri-environmental practices and the proper management of grazing, it is possible to achieve the goal of self-sufficiency and, collaterally, to maximize C sequestration by compensating for emissions. The strategy of associating these practices with monetary income can provide an additional incentive to achieve the goal of carbon balance, at least by equalizing it to zero.

In addition, in the case of pig farms, it must be taken into account that the number of these farms is still very limited and increasing this number is a challenge since it would be very positive for the region due to the economic importance of the extensive Iberian pig sector. Producing high quality Iberian products certified as organic adds significant value to pork products and improves their profitability, especially if the marketing channels are reinforced. This would require increasing the volume of production and thus also increasing its competitiveness in larger markets. Therefore, the implementation of carbon pricing for these farms that perform as "carbon sequestrators" would be very favourable and would be an incentive for their conversion to organic.

Appendix:

Table A 1. Emission factors used to quantify greenhouse gas emissions (GHG).

Emission and Source	Type of GHG	Emission Factors	Unit
On-farm			
Enteric fermentation	CH_4	51.06 kg CH_4/cow a year [a]	kg CH_4/year
	CH_4	7.64 kg CH_4/sheep a year [a]	kg CH_4/year
	CH_4	5 kg CH_4/goat a year [a]	kg CH_4/year
	CH_4	2.75 kg CH_4/breeding pig a year [a]	kg CH_4/year
	CH_4	0.62 kg CH_4/growing-finishing pig a year [a]	kg CH_4/year
Manure management			
Manure management CH_4	CH_4	6.91 kg CH_4/cow a year [b]	kg CH_4/year
	CH_4	0.28 kg CH_4/sheep a year [b]	kg CH_4/year
	CH_4	0.21 kg CH_4/goat a year [b]	kg CH_4/year
	CH_4	18.76 kg CH_4/breeding pig a year [b]	kg CH_4/year
	CH_4	7.59 kg CH_4/growing-finishing pig a year [b]	kg CH_4/year
Manure management direct N_2O	N_2O	0.005 kg N_2O eN/kg N solid storage system [c]	kg N_2O/year [d]
Manure management indirect N_2O	N_2O	0.01 kg N_2O eN/volatilized [c]	kg N_2O/year [d]
Soil management			
N from urine and dung inputs to grazed soils in Cow (Iberian swine)	N_2O	0.02 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
N from urine and dung inputs to grazed soils in Sheep	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
N from urine and dung inputs to grazed soils in Goat	N_2O	0.01 kg N_2O eN (kg N input)$^{-1}$ [c]	kg N_2O/year [d]
Indirect emissions soil management	N_2O	0.01 kg N_2O eN (kg % N volatilized/leaching)$^{-1}$ [c]	kg N_2O/year [d]
Off-farm			
Concentrates Meat Cow	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat Calf	CO_2	0.445 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat sheep	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Meat Lamb	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Dairy Goat	CO_2	0.410 kg CO_2eq/kg [e]	kg CO_2eq/year
Concentrates Piglet, 2nd stage feed	CO_2	0.227 kg CO_2eq/kg [e]	kg CO_2eq/year
Straw	CO_2	0.100 kg CO_2eq/kg [e]	kg CO_2eq/year
Hay	CO_2	0.170 kg CO_2eq/kg [e]	kg CO_2eq/year
Wheat	CO_2	0.335 kg CO_2eq/kg [e]	kg CO_2eq/year
Barley	CO_2	0.305 kg CO_2eq/kg [e]	kg CO_2eq/year
Pea	CO_2	0.116 kg CO_2eq/kg [e]	kg CO_2eq/year
Electricity	CO_2	0.410 kg CO_2eq/kWh [f]	kg CO_2eq/year
Fuel	CO_2	2.664 kg CO_2eq/L-Combustion [e]	kg CO_2eq/year
	CO_2	0.320 kg CO_2eq/L-upstream [e]	kg CO_2eq/year

[a] (MITECO, 2019); [b] (MAPA, 2012); [c] (IPCC, 2006); [d] $N_2OeN*44/28$ ¼ N_2O; and from: [e] (Bochu et al., 2013) ; [f] (CNMC, 2018).

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CONCLUSIONS

<u>Key aspects for the transition from the traditional model to the organic production model in *dehesa* cattle farms</u>

According to the opinions shared by the panel of experts, one of the main findings of the research is that the number of *dehesa* organic cattle farms will increase, although only slightly. Nevertheless, this will not imply increased sales of beef cattle, which is the end product. This factor, together with the lack of self-sufficiency of food supplements (need of organic concentrates) and the scarcity of certified organic slaughterhouses, will hinder the implementation and/ or transition of traditional farms to organic production farms.

Additionally, it was concluded that it would be advisable for certain specific lines of support to be activated, as they would stimulate production in *dehesa* organic cattle farms. Such measures, together with the improvement of commercialisation strategies and the increase of market prices, would guarantee the continuity of these farms.

<u>Limitations and potential for improvement for the conversion from traditional livestock farming to organic farming in *dehesas*</u>

The conversion of *dehesa* livestock farms to organic farms could improve the economic expectations of these production systems at a time in which the agrifood production traditional methods are the object of debate in the EU due to their environmental impact.

According to the results of the focus group, although at the beginning there seems to be a close relationship between the *dehesa* systems and the organic systems, in practice major barriers or limitations have been found, which go beyond the production models and hinder the expansion of the latter. In the organic production model: high market prices of organic fodder, the scarce development of the agrifood industry and the lack of slaughterhouses and cutting plants are key factors that prevent the implementation of this production model.

In this sense, self-sufficiency and the improvement of certain infrastructures could attempt to improve stability and competition in the organic agricultural production. Other additional barriers can be classical elements that are intrinsic to the organic or sustainable products, such as the need of a differentiated commercialisation and a higher price in comparison to conventional products. At the same time, the lack of structure in the sector and insufficient commercialisation are negative influences for the promotion and development of organic livestock production. Equally, it seems necessary to create farmer associations and implement public measures that ensure the commercialisation of organic products at an adequate price.

And lastly, the development of an adequate organic production model would imply the need to implement actions to promote training and conscience awareness both in consumers and the livestock industry players, as the lack of knowledge of the products traits would make it difficult to guarantee demand and the consumption of these organic products. In this sense and at the same time, trust of the organic products and the promotion of their brand image should be reinforced. For such purpose, advertising campaigns with Government support would be transcendental.

Carbon footprint in *dehesa* and rangeland organic livestock farms of the southwest of Spain

An analysis of the origin of the greenhouse gas effect emissions of *dehesa* and rangeland organic livestock farms in the southwest of Spain reveals that in ruminant farms the main cause of GHG emissions is enteric fermentation. In the case of pigs, however, the emissions deriving from manure management account for the highest figures. On the other hand, feeding inputs in the organic livestock farms are not as relevant as in conventional farms, since organic systems maximise the use of rangeland which, in turn, contributes to a lesser consumption of fodder outside the farm, and, at the same time, grazing improves the quality of the pasture as soil carbon sequestration increases.

The high capacity of carbon retention of the soil in *dehesa* agricultural systems derives from large areas of land, which to a great extent offset the cattle emissions. In the case of ruminants farms, the emissions are offset by 35% to 89%, and even by 100% in the case of milk goat farms. In the case of Iberian pig farms, the levels of carbon sequestration exceed the level of emissions. In view of these results and specially highlighting the extensive livestock management system of these ecosystems, we may conclude that the model used by organic livestock farms in *dehesas* is a feasible strategy to reduce the GHG emissions deriving from livestock farming.

Estimation of the maximum price per tonne of CO_2eq that the various organic livestock farm models would bear in the *dehesas* and rangelands in the southwest of Spain

The animal production systems based on grazing are sustainable since their greenhouse gas emission levels are lower than those of other more conventional and/ or intensive models. In the same way, the study points out that on including carbon sequestration, the emissions' balance can be negative, especially when the time scenario is 20 years ahead. In this context, the establishment of a price for CO_2 would positively off-set the profits in these farms.

In this sense, including carbon sequestration in the national inventories of rain-fed *dehesas* and rangelands can have an impact not only on the application of a price in the carbon markets, but can also have implications on the development of green policies within the PAC framework, which would classify these systems as sustainable and capable of providing a large number of ecosystem services, with a limited and even positive environmental impact.

The time horizon for the calculation of carbon sequestration is considered a key aspect for debate, together with the need to establish a clear framework for the allocation of a CO_2eq price and the creation of the tools necessary to contribute to the development of a standardised offset market.

In this scenario livestock farm managers still have room to make decisions in order to minimise emissions and maximise sequestration. Such decisions must take into account that choosing an organic production model contributes to reduce livestock stocking density, promote self-production of food and fodder cereals crops. In fact, the results reveal that those farms that best manage these models, obtain economic benefits that supplement the benefits obtained on account of their low emissions.

CONCLUSIONES

Aspectos clave para la transición del modelo tradicional a la producción ecológica en explotaciones de vacuno en dehesas.

De acuerdo con las opiniones expresadas por el panel de expertos, uno de los principales resultados obtenidos es que aumentará el número de explotaciones de ganado vacuno ecológico en las dehesas, aunque este incremento será ligero. Sin embargo, esto no implicará mayores ventas de carne de vacuno de cebo, que es en definitiva el producto final. Este factor, junto con la falta de autoabastecimiento en la suplementación de alimentos (necesidad de concentrado ecológico) y la escasez de mataderos ecológicos certificados dificultará la implementación y/o la transición de las explotaciones tradicionales al modelo de producción ecológica.

Además, se concluyo que sería aconsejable que se pusieran en marcha líneas de ayuda específicas, ya que estas estimularían la producción en las explotaciones de vacuno ecológicas de dehesa. Estas medidas, junto con la mejora de las estrategias de comercialización y el aumento de los precios de mercado, garantizarían la continuidad de estas explotaciones.

Limitaciones y posibilidades de mejora para la conversión de la ganadería tradicional a la ganadería ecológica en dehesas.

La transformación de las explotaciones ganaderas de dehesa en ecológicas, podrían mejorar las expectativas económicas de estos sistemas de producción en un momento en que los métodos tradicionales de producción agroalimentaria son objeto de debate en la UE por su impacto ambiental.

De acuerdo con los resultados del Focus Group, aunque en principio se puede observar una estrecha relación entre los sistemas de dehesas y los sistemas ecológicos, en la práctica se han encontrado importantes barreras o limitaciones que van más allá de los modelos de producción y que dificultan la expansión de estos últimos. En el modelo de producción ecológica: los elevados precios de mercado de los piensos ecológicos, el escaso desarrollo de la industria agroalimentaria y la falta de mataderos y salas de despiece son factores clave que frenan la implantación de este modelo de producción.

En este sentido, el autoabastecimiento y la mejora de ciertas infraestructuras podrían intentar mejorar la estabilidad y la competitividad de la producción agrícola ecológica. Además, como factores limitantes se suman otros elementos clásicos que se encuentran intrínsecos en productos ecológicos o sostenibles, como la necesidad de una comercialización diferenciada y el precio más alto en comparación con los productos convencionales. Al mismo tiempo, la falta de vertebración del sector y la comercialización deficiente repercuten negativamente en la promoción y el desarrollo de la producción ganadera ecológica. Igualmente, se ha observado que es necesario crear asociaciones de agricultores e implementar medidas públicas que aseguren la comercialización de los productos ecológicos a un precio adecuado.

Por ultimo, el desarrollo de un modelo de producción ecológica adecuado implicaría la necesidad de implantación de acciones para promover la educación y la formación tanto de los consumidores como del sector ganadero, ya que sin un conocimiento de las características del producto es difícil asegurar la demanda y el consumo de estos productos ecológicos. En este sentido y de manera paralela, debería reforzarse la confianza en el producto ecológico y una promoción de la imagen de marca de estos productos. Para ello, las campañas publicitarias con un apoyo gubernamental tendrían un papel trascendental.

Huella de carbono en explotaciones ganaderas ecológicas en dehesas y pastizales del suroeste de España

Al analizar el origen de las emisiones de gases de efecto invernadero en las explotaciones ganaderas ecológicas de dehesas y pastizales del suroeste de España, revela que en explotaciones de rumiantes es la fermentación entérica la principal causa de emisiones de GEI. En el caso del porcino, sin embargo, serian las emisiones derivadas de la gestión del estiércol las más altas. Por otro lado, los inputs por alimentación en explotaciones ecológicas no son tan relevantes como en las explotaciones convencionales. Debido, a que los sistemas ecológicos maximizan la explotación de los pastos, lo que a su vez contribuye a un menor consumo de piensos de fuera de la explotación y, al mismo tiempo, las técnicas de pastoreo mejoran la calidad de los pastos al aumentar la retención de carbono del suelo.

La alta capacidad de retención de carbono del suelo en estos sistemas agrícolas de dehesas se deriva de las grandes superficies de tierra, que compensan en gran medida las emisiones del ganado. En el caso de las explotaciones de rumiantes, las emisiones se compensan en un 35% a 89%, e incluso en un 100% en el caso de las cabras lecheras; en el caso de los cerdos ibéricos, los niveles de secuestro de carbono superan al de las emisiones. A la vista de estos resultados, y destacando especialmente el sistema de gestión ganadera extensiva de estos ecosistemas, podemos concluir que el modelo utilizado por la ganadería ecológica en las dehesas es una estrategia viable para reducir los GEI procedentes de la ganadería.

Estimación del precio máximo por tonelada de CO_2 eq que podrían soportar los distintos modelos de explotaciones ganaderas ecológicas en las dehesas y pastizales del suroeste de España.

Los sistemas de producción animal basados en pastoreo son sostenibles ya que su nivel de emisiones de gases de efectos invernadero son inferiores frente a otros modelos mas convencionales y/o intensivos. Igualmente, se observa, en el estudio que al incluir el secuestro de carbono el balance de las emisiones puede ser negativo, máximo cuando el escenario temporal es a 20 años. En este contexto, el establecimiento de un precio del CO_2 compensaría de manera positiva las rentas de estas explotaciones.

En este sentido, la inclusión del secuestro de carbono en los inventarios nacionales de dehesas y pastizales de secano puede tener un impacto a la hora no solo de aplicar un precio en los mercados del Carbono, sino que pude tener implicaciones en el desarrollo de políticas verdes en el marco de la CAP destacando estos sistemas como sostenibles y portadores de un gran número de servicios ecosistémicos donde sus impactos ambientales son limitados e incluso positivos.

El horizonte temporal a considerar para el cálculo del secuestro se sitúa como un aspecto clave de debate, junto con la necesidad de establecer un marco claro de asignación en el precio del CO_2 eq y crear las herramientas necesarias que favorezcan el desarrollo de un mercado de compensación normalizado.

En este escenario, los gestores de las explotaciones ganaderas tienen margen para la toma de decisiones de cara a minimizar las emisiones y maximizar el secuestro. Entre estas decisiones optar por un modelo de producción ecológico contribuye a reducir cargas ganaderas, la autoproducción de alimentos y el fomento del cultivo forrajeros. De hecho, los resultados muestran que las explotaciones que mejor gestionan estos modelos obtienen beneficios económicos complementarios por sus bajas emisiones.

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