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FoPIA-SURE-Farm 2 Case Study Report Spain

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Carolina San Martín, Isabel Bardají, Alberto Garrido, Bárbara Soriano

(Carolina San Martín; carolina.sanmartin@upm.es)

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D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials E. FoPIA-SURE-Farm 2 Case Study Report Spain

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1 Introduction

1.1 Main indicators, resilience attributes and challenges

The Spanish case study (CS) is referred to the ovine extensive sector located in the north-eastern region of Huesca. The ovine sector was a strong economic motor in the region, but its importance has declined heavily in the last 20 years (Gobierno de Aragón, 2016). A first FoPIA-SURE-Farm workshop (Becking et al., 2019) about current resilience assessment was conducted in the Spanish CS region in January 2019. In this workshop, the stakeholders identified and assessed the challenges, functions and resilience attributes of the farming system. Participants in the focus groups agreed that the most important functions provided by the farming system are to ensure the economic viability of the farm, the provision of affordable and healthy food products, and the provision of a good quality of life. Although these functions are considered important, participants also agreed that they showed a low performance. The indicators (function indicators) selected to measure these farming system functions are the following (Table 1): gross margin (economic viability), sheep census (food products provision) and number of ovine farms, as a proxy of employment generation (quality of life). In a scale ranging from 1 (very bad performance) to 5 (very good performance), the scores of the selected indicators are between 1 and 2.

Table 1. Main indicators and their performance and development. Source: Becking et al. (2019)

Main indicators	Current level (score 1:5)	Current level (explanation)	Current development
Gross margin (Euro/head)	**2**	The gross margins have been very low in the last years	Gross margins are low and tend to be stable
Sheep census (heads/year)	**1**	Sheep census has decreased by 50% in the last 12 years, this is why it is considered very low at the moment	Currently, the sheep census is stable because of the purchase of herds from closed farms by remaining farms
Number of ovine farms (#/year)	**2**	The number of ovine farms has decreased in 30% in the last 12 years, this is why it is considered very low at the moment	Slowly declining

Stakeholders participating in the FoPIA 1 workshop identified two main resilience attributes in the extensive ovine farming system: 'coupled with local and natural capital' and 'diverse policies'. The attribute 'coupled with local and natural capital' was chosen because this farming system is linked to natural resources, especially to pastures. The attribute 'diverse policies' was chosen because, due to the low profitability of the sector, the farming system largely depends on subsides.

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These two resilience attributes were studied by means of two indicators: availability of pastures (ha) and aids received by farmers (Euro/farmer/year), respectively. The performance of these two resilience attributes, as assessed by the first FoPIA-SURE-Farm workshop, is quite low (see Table 2). The availability of pastures has decreased in the last year, not only due to the decrease in the pasture surface in the region (reduction of 67% in the last 14 years) but also because of the limited access to public areas and stubble fields. Regarding the aids received by farmers, they have been stable in the last years, but not high enough to support the sector.

Table 2. Main resilience attributes and their presence in the farming system. Source: Becking et al. (2019)

Main resilience attributes	Current level (score 1:5)	Current level (explanation)	Current development
Coupled with local and natural capital (production)	**2**	This attribute has traditionally been very strong as the ovine farming system is extensive. However, pasture availability has largely decreased in the last years	More recently, due to modernisation and intensification, farmers started to import more resources into the system. This leads to a decoupling of the system with the local natural capital.
Diverse policies	**2**	There is a lack in diverse policies and policies that support the provision of public goods	Coupled aids, although low, seems to be steady. However, aids related to natural public goods seem not to be present

Other resilience attributes emerged from first FoPIA-SURE-Farm workshop are 'socially self-organized' and 'supports rural life'. The proposed indicators for these two attributes are: Farmers' participation in farmers' associations (% of farmers) and regional rural development aids (€/year).

The main farming system challenges identified by the stakeholders in the workshop are the following:

- Lowering meat demand, measured by the indicator lamb meat consumption (kg/inhabitant/year).
- Increasing feeding costs, measured by the indicator feeding costs (Euro/head).
- Increasing wild fauna attacks, measured by the indicator wild fauna attacks (number of attacks/year).
- Lack of workforce in the region, measured by the indicator workforce (AWU/farm).

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1.2 Participation in the workshop

18 people participated in the workshop, of which 7 were farmers (five of the seven farmers belonged to some kind of association). The rest of participants belonged to other sectors: value chain (veterinaries (3), cooperatives (1 farmer) and distributors (1)), and individuals representing the public sector (research institutes and Universities (3), and local public administration (4)).

Participants agreed with the proposed main indicators, resilience attributes and challenges, presented in Section 1.1. Regarding challenges, they indicated that the depopulation of the area is an important and concerning challenge (in fact, this challenge came up in the first FoPIA-SURE-Farm workshop). When preparing the workshop, we considered this challenge but we did not find any reliable indicator to measure it. That led us to consider the workforce (expressed in AWU/farm) as more appropriate to tackle that challenge. The depopulation of the area is mainly explained by the lack of attraction of the sector (low profitability and intense workload), which leads to a continuous depopulation and population ageing. Consequently, there is a lack of sources of employment in the area.

Participants in the workshop highlighted additional challenges such as the lack of skilled labor and generational renewal, the poor quality of life, and the bad image of the livestock sector promoted by social and mass media.

2 Results

2.1 Maintaining the status-quo

2.1.1 Introduction

Participants were invited to provide tipping points levels of functions, resilience attributes and challenges indicators, in order to define the boundaries in which the system is defined in its current configuration and beyond which the system would collapse. They argued that the tipping point levels of sector indicators are already reached: they stated that the sector is on the edge of the collapse.

Therefore, we decided to show the participants the trend and current value of the indicators according to the official statistics. We asked them to discussed if they agree/disagree with the current value of each indicator. In case they diseagree, they were asked to define the current value of the indicator. As a result, the agreed current values are the tipping points of functions, resilience attributes and challenges indicators.

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2.1.2 Indicators

Gross margin

Participants agreed that 25-30 €/head is the current average value of gross margin below which farms will be forced to close. The gross margin varies depending on the area where the farm is located. The participants pointed out that the gross margins of the farms located in the mid-mountain areas are different than that of farms located in the flat area. Participants indicated that 25-30 €/head is the gross margin of the farms in the flat areas, whereas in the mid-mountain areas gross margin threshold is higher, at arounf 40 -45€ (50% more than in the flat areas). This is mainly due to two reasons: first, farmers in the mid-mountain area receive least favoured area (LFA) aids, that contribute to increase the margin; second, the feeding costs of the farms located in the mid-mountain areas are slightly lower than that of in flat areas. Although fodder is also important in the mid-mountain areas (mainly to fed the lambs and the herd in the winter), it is a complement to pastures. The use of pasture as a feeding source decrease the costs in fodders.On the contrary, in the flat areas fodder is the main food resource (although it is complemented with the stubble fields grazing too).

Sheep census

According to participants, the current sheep census has reached the tipping point in the area. There are currently about 530 thousand sheep heads in the region of Huesca, with a reduction of 40% in the last 13 years. The reduction rate has decreased in the last years because the remaining farms are purchasing sheep herds sold by the closing farms. This reduction rate is also experienced in the whole region of Aragón (42% in the last 13 years). The number of sheep is currently of 1.65 million of heads in Aragón.

Number of ovine farms

The number of ovine farms (including goat farms, which are negligible) has decreased by 60% in the period 2005-2015, with a current value of 1,221 in 2015 (Gobierno de Aragón, 2016). An equivalent rate of reduction was found for the same period of time for the entire region of Aragón and La Hoya de Huesca area, with 3,541 and 199 farms in 2015, respectively.

The current number of farms is the tipping point because the abandonment of additional farms would likely cause the end of the sector in the area. The ovine sector is almost the only sector in the region that requires the farmers living close to the farm. Other specializations, such as crops or intensive livestock, do not demand as much time as extensive farming, and therefore, famers may decide to move to urban areas for living. If the ovine sector disappears, it would result in a significant reduction of population in the region.

As aforementioned, the number of ovine farms has been stabilized in the last years (the rate of reduction is lower). It may be explained by the fact that in the last years farmers bought the

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herds of the closed farms to increase their size. This strategy allowed farmers to increase their margins and remain in the sector. However, the purchase of herds from exiting farms is close to reach its maximum point, because shepherds are not able either to manage bigger herds or to hire new shepherds. Currently, farmers are investing a lot of effort and time managing between 500 - 1,000 sheep/shepherd, but the gross margins are not enough to hire new shepherds and increase the herd.

2.1.3 Resilience attributes

Coupled with local and natural capital

This resilience attribute is measured by the total available surface of pastures (ha). In the province of Huesca the total amount of pastures has decreased by 67% in the last 14 years, with a current total of 154,000 ha in the province of Huesca.

Participants concluded that the availability of pastures is adequate to keep the sector, especially now with the decreasing sheep census. However, the problem is the accessibility to those pastures. There are public areas that are not allowed to be grazed. Furthermore, the physical access to pastures is limited because there are crop lands in between that prevent animals from reaching land-locked plots. Participants found difficult to provide a minimum value of pasture surface they need for grazing, but they pointed out that authorities must ease the access to pastures as well as compensate the environmental service of the ovine sector with its activity.

Diverse policies

The indicator to measure the 'diverse policies' is the total aids (coupled and basic payments) the farmers received. According to statistics (European Commission, 2020), the total aids that farmers receive in the region in terms of head is around 24 €/head. Participants explained that this value could not be lower - if it was lower, the gross margin would be null or negative. In fact, they said that this value should increase at least 30%, to obtain suitable gross margins.

Participants in the workshop did not define the thresholds of the 'socially self-organized' and 'supports rural life' resilience attributes, as they found difficult to identify the tipping point of the farmers' participation in associations and the regional rural development aids respectively.

2.1.4 Challenges

Decreasing meat demand

The lamb consumption cannot decrease more than 1.5 kg/inhabitant/year, corresponding to the current national consumption value. Some participants pointed out the challenges posed by the new vegetarian and veganism trends and the mass and social media in relation to the distorted consumers' perception about livestock farming.

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One participant from the research sector explained that a lamb meat consumption surveys carried out among Spanish consumers revealed that the main threat is not the vegan movement, as the proportion of vegan consumers is still very low. The issue is that meat consumers prefer other type of meats, mainly pork and chicken. Lamb meat is very tasty, very greasy, expensive and difficult to cook. In the case they have to choose an alternative meat, consumers prefer a beefsteak rather than lamb meat.

In any case, the ovine sector is suffering a strong decrease in the demand of lamb that jeopardise the sector survival. The lowering consumption of lamb meat keep prices stable low values (around 7 €/kg).

Although there are some associations emerging that promote lamb meat consumption (e.g., *Ovisalud*), the participants complained about the lack of public support in promoting lamb meat consumption and its health benefits.

Increasing feeding costs

The official statistics show that the current value of the feeding costs in sheep extensive farms in Aragón is 30€/head. Participants agreed with this current value. One participant pointed out that this value, on average, is currently lower: around 20€/head. All participants agreed that the costs of feeding are strongly related to the availability of pastures, which in turn depend on the location area. As mentioned above, farms located in flat areas, where pastures are less abundant, depend more on fodder, and therefore, the cost of feeding is greater. Initially the cost of feeding is lower in the mid-mountain areas, except during droughts when the pasture productivity is affected.

Increase of wild fauna attacks

Participants did not provide any value in relation to the tipping point for wild fauna attacks (mainly by wolves and bears) in the ovine sector. Participants discussed about the importance of this challenge depending on the location of the farm. In the mid-mountain, wild fauna attacks are more frequent than in the flat areas, where those attacks rarely occur. They also mentioned that once the wolves and bears occupy a location, the attacks are continuous. Not only livestock deaths caused by attacks are important in relation to this challenge but also impacts on herds, such as miscarriages and pregnancy problems, which are not covered by insurance instruments.

Lack of workforce

The low level and decreasing trend in the AWU per farm (current value in the region is 1.9 AWU/farm) throughout the years indicate that farms are managed with fewer and fewer workforce. Participants indicate that 1.9 AWU/farm is the tipping point for workforce in this sector. The fact that each farm is running with a decreasing workforce is directly related to the

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depopulation of rural areas, because people are not attracted by the sector any more (profitability and quality of life are low). In addition to the lack of workers in the region, farm margins do not allow farmers to hire personnel, leading to the management of farm as a family business (run by the farmer alone or the farmer with a family member).

The AWU/farm indicator might also measure the quality of life. A decrease in the AWU/farm value indicates a greater workload by the person(s) running the farm due to the extensive ovine sector is very time-consuming.

2.2 System's decline

2.2.1 Introduction

In this activity, each participant analyzed all challenges and identified the interactions with the functions' indicators, resilience attributes and other challenges when thresholds were exceeded. In a plenary session, all interactions were discussed. We present the main interactions that participants were able to draw, indicating the direction and strength of the interactions.

2.2.2 Performance of indicators and resilience attributes

Decreasing lamb meat demand

Participants argued that the decrease in the national lamb demand is a key challenge. It has been decreasing for a long time and currently the consumption remains at very low levels, thus jeopardizing the sectors' future sustainability. Lowering lamb meat consumption has a clear influence on all the functions provided by the system: the economic viability of the farm, the provision of food products, and the provision of quality of life (Table 3). In the short term, this challenge has a negative influence on the number of sheep, whereas, in the long term, it can lead to the closure of the farm. Regarding the gross margin, it will be affected in a large extent because the margins are directly related to the sales incomes: the lesser is the consumption, the lesser are the gross margins.

The influence of social media and mass media came up in the discussion as a determinant challenge to affect the lamb meat demand. All participants agreed that the recent bad perception of meat consumption, influenced by the mass media and social media, is affecting negatively lamb demand. Besides, one participant pointed out that the culinary tradition of cooking and consumption of the lamb are disappearing. The elder people are the ones who mostly cook lamb in the region. These consumers are not replaced by younger ones, so per capita consumption and absolute consumption diminishes also with the depopulation process.

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Table 3. Main interactions of the lamb consumption on the functions and challenges of the farming systems, identified by participants in the workshop. The direction (Dir.) and the strength (Str.) of each interaction are detailed in the table.

	Function			Challenge		
	Str.	Dir.	Indicator	Str.	Dir.	Indicator
Lamb meat consumption	++	→	Sheep census	--	←	Social media and mass media
	+	→	Number of farms	-	←	Ageing of population
	++	→	Gross margin			

Strength of interaction: ++ strong direct relationship, + weak direct relationship, - weak inverse relationship, -- strong inverse relationship. The arrows point from the cause to the effect: if the arrow points right, lamb meat consumption has effect on the indicator/challenge; if the arrows points left, the indicator/challenge has an influence on lamb meat consumption.

Increasing feeding costs

Increasing feeding costs have a strong impact on the functions of the system, ensuring the economic viability of the farm, the provision of affordable and healthy food products, and the provision of quality of life (Table 4). Growing feeding costs lead to a decrease in the gross margin, leading to a reduction in the number of farms and the sheep census.

Regarding the resilience attributes of the system, the attribute 'coupled with local and natural capital', measured as the availability of pasture, has an influence on the feeding costs. Sheep' diet consists mainly of graze, and therefore the lack of pastures will lead to an increase in the use of purchased fodders and the costs of feeding. As aforementioned, the availability of pastures is area-dependent, and so are the feeding costs. In some areas, mainly the flat areas, the access of farmers to pastures is very limited or nil, but also in the mid-mountain areas the access to pastures is limited (Natural Parks and other protected areas). Besides, bureaucracy and regulations hinder the access to the pastures, leading inevitably farmers to depend largely on purchased fodders. In addition, the drought episodes are more and more decisive, as well as the wild fauna attacks, decreasing the pasture availability and accessibility, and therefore, increasing the cost of feeding.

The quality of life was mentioned by participants as a driver explaining the feeding costs. The quality of life came up as one of the main functions of the sector. Participants measured quality of life according to the time invested to manage the farm. So we have two ways to measure the function of quality of life: the number of farms and the required management time (henceforth, named quality of life). The ovine sector is very time consuming, mainly due to the shepherding. Shepherding is conditioned by the availability of pastures. In several occasions, pastures are far away from farms and farmers need to move long distances with the herds, spending a lot of time far from their families. The farther the pastures are, the more time farmers need to invest. Moreover, if farmers want to take some weekend off or some holiday, they need to stable the herds and fed them with fodders, leading to an increase in the feeding costs.

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In addition, one participant pointed out that an increase in the feeding costs might lead to more new associations of farmers (corresponding to the attribute of resilience 'socially self-organized'). Farmers' associations allow farmers to get greater bargaining power and, hence, better prices in the purchase of fodder.

Table 4. Main interactions of the feeding costs on the functions and challenges of the farming systems, identified by participants in the workshop. The direction (Dir.) and the strength (Str.) of each interaction are detailed in the table.

	Functions			Resilience attribute			Challenge		
	Str.	Dir.	Indicator	Str.	Dir.	Indicator	Str.	Dir.	Indicator
Feeding costs	--	→	Sheep census	+	→	Farmers in associations	+	←	Wild fauna attacks
	--	→	Number of farms	-	←	Pastures availability	+	←	Droughts
	--	→	Gross margin						
	+	←	Quality of life						

Strength of interaction: ++ strong direct relationship, + weak direct relationship, - weak inverse relationship, -- strong inverse relationship. The arrows point from the cause to the effect: if the arrow points right, feeding costs have effect on the indicator/challenge; if the arrows points left, the indicator/challenge has an influence on feeding costs.

Increase of wild fauna attacks

The influence of this challenge on the farming system functions and attributes (Table 5) depends on the areas where farms are located. The negative impact of wild fauna attacks on system functions is greater in the mid-mountains than in the flat areas.

The wild fauna attacks affect the resilience attributes. It impacts negatively on the attribute 'coupled with local and natural capital', as an increase of the presence of wolves and bears and their attacks might lead farmers not to take the herds to pastures (mainly located in the mid-mountains). Therefore, this challenge impacts on another challenge: the cost of feeding, which increases when pastures availability and access to them are reduced. The attacks also affect to the quality of life negatively. It means that more time and investments are needed to take care of the herd.

The increase of the attacks shows a positive influence in the 'support rural life' attribute, measured as the aids for rural development. Participants found that an increase in wild fauna attacks will lead to increasing investments in rural areas to protect farmers against those attacks. The increment in the fauna attacks also leads to a greater necessity of workforce to manage this issue. More hired workers (and perhaps their families too) in the region encourages the administration to support the region with economic and social initiatives. Likewise, aids for rural development have a huge positive impact in the availability of workers in the region.

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Table 5. Main interactions of the wild fauna attacks on the functions and challenges of the farming systems, identified by participants in the workshop. The direction (Dir.) and the strength (Str.) of each interaction are detailed in the table.

	Functions			Resilience attribute			Challenge		
	Str.	Dir.	Indicator	Str.	Dir.	Indicator	Str.	Dir.	Indicator
Wild fauna attacks	-	→	Sheep census	-	→	Pastures availability	+	→	Feeding costs
	-	→	Number of farms	+	→	Rural development aids	++	→	Workforce
	-	→	Gross margin						
	--	→	Quality of life						

Strength of interaction: ++ strong direct relationship, + weak direct relationship, - weak inverse relationship, -- strong inverse relationship. The arrows point from the cause to the effect: if the arrow points right, wild fauna attacks have effect on the indicator/challenge; if the arrows points left, the indicator/challenge has an influence on wild fauna attacks.

Lack of workforce

The workforce is directly related to two functions of the system: the food production (sheep census) and the generation of employment in the region (the number of farms) (Table 6). Furthermore, the workforce is also related with the resilience attribute related to the quality of life. Greater availability of workforce in the region raises the farmers' life quality. However, the quality of life related to the sector, as time-consuming activities and low profitability also limit the number of people attracted to the region, and therefore, the workforce. The lack of workforce in the region leads to the ageing of the sector because there is not generational renewal or the new farmers' entrance.

As mentioned earlier, the workforce is also related to the wild fauna attacks, which leads to a greater workforce. The increase of workforce encourages administration to provide the region with aids to support the rural development that in turn, attract people to the region.

Table 6. Main interactions of the workforce availability on the functions and challenges of the farming systems, identified by participants in the workshop. The direction (Dir.) and the strength (Str.) of each interaction are detailed in the table.

	Functions			Resilience attribute			Challenge		
	Str.	Dir.	Indicator	Str.	Dir.	Indicator	Str.	Dir.	Indicator
Workforce	++	→	Sheep census	++	→ ←	Rural development aids	++	←	Wild fauna attacks
	+	→	Number of farms				++	→	Generational renewal
	++	→ ←	Quality of life						

Strength of interaction: ++ strong direct relationship, + weak direct relationship, - weak inverse relationship, -- strong inverse relationship. The arrows point from the cause to the effect: if the arrow points right, workforce has effect on the indicator/challenge; if the arrows points left, the indicator/challenge has an influence on workforce.

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2.3 Alternative systems

2.3.1 Introduction

The definitions of the alternative system as well as the necessary conditions for these systems to occur were discussed in a plenary session with the entire group. Participants produced some ideas that led to two main alternative systems. A first alternative system, named "**semi-intensive alternative system**", was mainly characterized by a technological development of livestock production and prolificacy. A second system named "**hi-tech extensive alternative system**", was characterized by innovation and technological development oriented towards an efficient management of grazing. The main characteristics of the alternative systems are indicated in the Table 7. The alternative systems shares the common characteristic related to the innovation and improved technology. The innovation and technology follow different directions. In the semi-intensive scenario innovation focuses on improving animal handling, feeding and reproduction. In the high-tech extensive system, innovation focuses on improving pastures management, geo-location and cooperation. In the semi-intensive system, the stabling of animals is the general rule, whereas in the hi-tech extensive system animals are only stabled in specific periods of time (labors, bad weather, etc.). In the hi-tech extensive system the cooperation in the pasture and grazing management is needed.

Table 7. Characteristics of alternative systems.

Semi-intensive alternative system	Hi-tech extensive alternative system
• Technological improvement addressed to prolificacy, feeding, sheep management improvement (fertility, health and welfare)	• Technological improvement addressed to pastures and grazing management, herd geo-location, weather information and wild fauna surveillance
• Minimum shepherding with stabling livestock	• Shepherding with minimum livestock stabling
• Lower workforce necessity	• Workforce necessity
• Lower dedication requirement	• Dedication requirement
• Specialized workforce	• Specialized workforce
• High investment in farm assets and equipment	• Investment in facilities for livestock management in the mountains
	• Cooperative initiatives towards grazing management
	• Activities diversification

In a plenary discussion, the participants discussed the performance of the main functions and resilience attributes in the two alternative farming systems. The results suggest that, in general terms, the main functions of the sector would improve with both alternative systems (Table 8). However, some of the resilience attributes would not improve in the semi-intensive alternative system, and even they would decline, especially the coupled with local and natural resources resilience attribute.

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Table 8. Current perceived performance of main functions and presence of resilience attributes (FoPIA-SURE-Farm 1) and their expected change in future systems.→ implies no change, ↗ implies moderate positive change, ↑ implies strong positive change, ↘ implies moderate negative change, ↓ implies strong negative change, V implies that a boundary condition is relevant for a future system. Arrows and tick marks in bold font are results obtained in the workshop. Arrows and tick marks in normal font are deductions from what has been said in the workshop.

				Future systems	
Indicator	**Current level**	**Status quo**	**System decline**	**Semi-intensive system**	**Hi-tech extensive system**
Gross margin	Low	→	**↘ | ↓**	**↗**	**↗**
Sheep census	Low	↓	**↓**	**↗**	**↑**
Number of farms	Low	↓	**↓**	**↗**	**↗ | →**
Production coupled with local and natural resources	Low	↘	**↘ | ↓**	**↘**	**↑**
Diverse policies	Low	→	**↘ | ↓**	**↘**	**↗**
Socially self-organized	Low	→	**↘ | ↓**	**→**	**↑**
Support rural life	Low	↘	**↘ | ↓**	**→ | ↗**	**↗**
Infrastructure for innovation	Low	↘	↘ | ↓	↗	↗
Reasonably profitable	Low	↘	↘ | ↓	↗	↗
Boundary conditions	**Domain**				
New technology applied to sheep sector farm management	Agronomic			**V**	**V**
Farmers training in new technology	Agronomic			**V**	**V**
Improved sanitary conditions	Agronomic	V		**V**	**V**
Improved animal handling	Agronomic	V		**V**	**V**
Geo-localization technology	Agronomic				**V**
Use of sub-products	Agronomic			**V**	
New financial products	Economic	V		**V**	**V**
New commercialization channels	Economic	V		**V**	**V**
Public aids for public goods provision	Economic	V			**V**
Broader access to pastures and stubble fields	Environmental	V			**V**
Sustainable pastures management	Environmental	V			**V**
Research relationship nature-ovine sector	Environmental			V	**V**
Reduced bureaucracy control	Institutional	V		**V**	**V**
Sector oriented legislation (sanitary, environmental and urban)	Institutional	V		**V**	**V**
Rural development	Institutional	V			**V**
Public awareness of the contribution of sector	Social	V		V	**V**
Improved cooperation among actors	Social	V			**V**

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Several boundary conditions for the performance of the systems coincide in both systems, especially for the agronomic and institutional domains (Table 8). Agronomic conditions, in general terms, are oriented to the improvement of farms efficiency (prolificacy, production and profitability), whereas institutional conditions are oriented mainly to changes in legislation that promote profitability. The number of conditions for the hi-tech extensive system is larger than for the semi-intensive system due to the greater number of conditions in the environmental and social domains. For instance, the hi-tech extensive system is characterized by the provision of ecosystem services, and therefore, there is a necessity of a proper access to pasturelands and their management. Besides, the provision of those services needs to be accompanied by strong relationships among sector actors and a rural development.

2.3.2 Semi-intensive alternative system

System narrative

In the semi-intensive alternative system, the production of meat is improved with an intensification of the production (more labors per year) and the stabling of the livestock. The improvement of production is based on the use of technology and the standards for lamb quality are achieved with a diet based on high quality fodders. The greater production trusts in the national demand, but especially in the openness to international markets, in which the lamb meat prices obey to volatility of markets.

As a consequence of the stabling, the grazing of pastures decreases and the feeding with fodders increases. Grazing is maintained but in a lesser extent and almost exclusively in stubble fields. Therefore, sub-products are necessary as a source of cheap food supply. This alternative system is more likely to be performed in the flat areas of the region. In these areas, pasturelands are less abundant, whereas irrigated lands are more present. The alternative crops (fruits and cereal crops) guarantee the provision of sub-products facing the scarcity of pastures. In these areas, the diversification activities as well as the sub-products supply are easier than in the mid-mountain areas.

Consequences on the indicators

In relation to the function indicators under this alternative system, participants explained that the economic viability of the farm would increase (Table 8). The gross margin would increase as a result of the improved farm management and animal handling. For instance, an improved prolificacy of two-three labors per year, opposite to one labor per year in the extensive system, would decrease the feeding cost by ewe. Increased margins would lead to increasing number of farms (quality of life) and number of heads in the region (food provision). However, in this system, the size of the herds by farms could be smaller than the existing ones. Increasing the

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herd size to increase gross margin would not be needed anymore, because the source of increased gross margin is the improved farm management and the herd prolificacy.

As this system considers stabling and the increased consumption of feed, participants pointed out that the feeding costs would be affected largely by unstable markets of commodities. In turn, market volatility would also affect largely on lamb meat prices. Due to the livestock stabling, breeds adapted to it would be predominant, whereas the maintenance of local breeds adapted to environmental conditions would not be necessary (*Rasa aragonesa* breed).

The stabling could minimize the coupling of the farming system with the local and natural resources. The positive contribution of sheep sector to natural resources (e.g., clearance of mountain area, reduced forest fires occurrence, biodiversity, and improved soil quality) would decrease. Cooperation among farmers would mainly look for increasing bargaining power and prices in feed purchases. The aids perceived from administrations tailored to public (environmental) services provision would decrease due to the intensification of the sector. Initially the intensification of the sector may not necessarily lead to an increase and improvement of the social structure (support of rural life attribute of resilience). However, the better benefits in the sector would attract new farmers to the region and the improvement of the social fabric. The infrastructure for innovation attribute would improve because it was seen by participants as a boundary condition in order to carry out the system.

Boundary conditions

The boundary conditions for this alternative system were mainly related to the agronomic, economic and institutional domains (Table 8). In the agronomic aspect, participants indicated that this system would need to improve the management of the herds in order to increase their control. In order to get acceptable benefits, the production of the livestock has to be high, and therefore sheep prolificacy and productivity have to improve. Consequently, the training of farmers in the new technologies would be necessary.

In the semi-intensive system, the sanitary conditions would be essential in order to have good benefits, resulting in lesser diseases incidence and deaths of animals. Some participants pointed out that research in ovine sector health is very limited because it is not a profitable sector for the pharmaceutical industry. However, other participants (mostly veterinarians) indicated that in general the use of medicaments and vaccines in the livestock is decreasing due to increasing animal controls and inspection before slaughter and the increasing demand of free-antibiotics meats.

The greater production in this semi-intensive alternative system is expected to be oriented to a broader market due to the scarce national demand. Participants also explained that new

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financial products would be needed because of the greater uncertainty of prices and costs. Entering more globalized market makes lamb prices more volatile. Besides, the larger dependence of purchased fodders and their price variability in the market might make farmers face the danger of decreasing benefits.

Participants presented both institutional and social conditions as necessary for the future alternative system, but they also pointed out that those conditions should occur in the current system too. Farmers indicated that the reduction of bureaucracy and the excessive regulations would be important in order to tackle their work properly with a general improvement in the relationship among farmers and administration. Farmers' participants demand the training of the administration staff according to the area they are working on. They argued that necessities and support for the mid-mountain areas are different to the specific needs in flat areas. On the other hand, participants representing the administration mentioned that farmers' ledgers should improve because they are frequently not good enough to perform a proper control and monitoring of the sector.

In general, all participants pointed out that this system will be not possible if there are not people attracted to the sector and the region. Participants also commented that young people who want to start in the sector continue to find obstacles in their way. Therefore, it would be necessary that institutions ease the access to lands, promote early retirements and help the transfer of farms to their children. Last but not least, the domestic demand of lamb meat would have to increase, as well as the public opinion in relation to meat.

Strategies

Strategies were also identified by participants and classified in the four domains - agronomic, economic, institutional and social (Table 9). Strategies are closely related with the aforementioned conditions, which were also classified in the same domains. Among the agronomic strategies, participants commented that technology would be necessary for the efficient management of livestock, as the use of electric readers, blood tests that indicate which are the best female lambs to rear, etc. They commented that research is an important aspect in order to this alternative system to be successful. Research in this context has to be oriented towards the improvement or introduction of new breeds in the region, whose lambs provide more meat and sheep are more prolific (with at least two or three labors per year). Research was also proposed to be oriented to create sanitary products (medicaments and vaccines) for this sector. The implementation of sanitary measures, such as hygiene, spaced animals, etc., was also a feasible and effective proposed strategy.

Among the economic strategies, participants indicated the opening of the commercialization to foreign countries (meanly to Arabic countries) and the possibility of diversification in on-farm

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activities (e.g., other crops cultivation) would suppose new income sources to farms. Besides, insurance products against the volatility of market commodity prices are necessary to ensure the viability of the sector.

In relation to the strategies in the institutional domain, they mentioned that the harmonization of the worldwide sanitary measures, the reduction of bureaucracy of excessive and specific regulations (especially in sanitary conditions), and the creation of technological tools (e.g., app in the mobile phone) that would allow for the real-time transmission of information to the local administration in order to take measures promptly. The administration staff training in the specific region characteristics would also be necessary. Policies should promote and ease the generational renewal through measures that encourage the early retirement of farmers and the easiness in the access to lands by new young farmers. In addition, institutions should play an important role in counteracting the bad image of meat campaigns, but also farmers and farmers' associations would have to initiate campaigns supporting the benefits of lamb consumption. Moreover, if farmers want to improve their quality of life they should use technology to save time in their tasks.

2.3.3 Hi-tech extensive alternative system

System narrative

The main characteristic of the hi-tech extensive alternative system is the farming system coupling with local and natural resources. The hi-tech extensive alternative system has two main functions: the production of safe and high quality food and the conservation of natural resources and animal welfare. The quality of lamb meat is achieved rearing GPI lambs (*Ternasco de Aragón*), which belong to the local breed (*Rasa aragonesa* breed), adapted to the environmental conditions. The technology is mainly oriented to the shepherding and the management of the pasturelands. The sheep herd mainly grazes extensively on the natural grass pastures available throughout the region for most of the year. It is more likely that this system takes place in the mid-mountain areas than in the flat areas, where the presence of pastures is scarce. Feeding costs would be lower, as the pastures constitute the main diet resource. Those feeding costs would increase in the event of environmental and natural hazards (droughts) resulting in lower quality and quantity of the pastures, and the occasional use of fodders.

Consequences on the indicators

Regarding the indicators of the system functions (Table 8), the gross margin would increase in relation to present because of the increase of the administration aids (related to the environmental service the sector is providing). Differently from the semi-intensive system, the

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size of herds (sheep census) would be greater. The lower prolificacy of sheep (one labor per year) leads to the necessity of increasing the size of the herd in order to maintain the gross margins. Participants also indicated an increase in the number of farms in the region. However, this increase would be possible if the access to the lands increases (and consequently the access to administration aids). If this requirement were not meet, the number of farms would not necessarily increase (available pasture land would reach its limits and there would not accessible to all farmers).

Policies would be very important for the maintenance of the system and should be oriented to the contribution of ovine sector to the conservation of nature, mainly through the management of pastures in the mountains, instead of being production-oriented. Therefore, the attribute coupled with local and natural resources would increase in this system. The management of the pastures requires the system to be socially self-organized in a greater extent, and therefore, collaboration and organization among farmers would be essential. Thus, the social structure would improve (the support of rural life resilience attribute would increase). In order to be efficient, the management of pasture would require more infrastructures in the mountains. As in the semi-intensive alternative system, the infrastructure for innovation was seen as a boundary condition, and therefore, the performance of this attribute would improve.

Boundary conditions

In a certain way, the boundary conditions in the agronomic, economic and institutional domains of this alternative system would be very similar to the semi-intensive alternative system (Table 8). However, the environmental and social conditions would be more present due to the extensive character of system. In this case, the improvement in the management of the herd would also have to occur, and research should be only oriented in the sanitary field. However, research for increasing the production would not be a boundary condition, because the local breed is preferred in this system. Moreover, farmers indicated that an increase in the prolificacy (more than a labor per year) would not be desirable. Labors involve time and extra effort to the farmers, which would cause a decline of their quality of life. Although the sanitary conditions would not be as important as in the semi-intensive system because of the scarce stabling of the herds, participants also considered them important. The most important agronomic aspect in this system would be the necessity of the use of technology in the monitoring of animals, which would spend quite a lot of time in the mountain pastures. This monitoring would be essential in order to know the pastures conditions, presence of wild fauna in the area, etc.

In terms of required economic instruments, it appears that financial products related to weather hazards (mainly droughts and fires that affect the pastures) would be more important than the financial products related to market changes. Although the participants considered the

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international markets for this alternative system, they considered the local approach more important, because the consumption of the *Ternasco de Aragón* lamb is mainly regional. Moreover, financial rewards for services to the nature and society would be essential and the key point this system revolves around. In this sense, the sustainable management of pastures is a requirement and those rewards would be necessary for the benefits margins in the sector.

However, this is not possible if the access to pastures and stubble fields is hindered. Participants indicated that institutions would play an important role leading to changes in the legislation, which would ease this access, as well as the control of grazed areas. Finally, the social component in this system would need to be strong in order to achieve a great coordination among farmers for environmental and livestock activities. Moreover, the public awareness regarding the contribution of the sector to the nature and environment (through the local breed) would be very important.

Strategies

In terms of strategies (Table 9), in the agronomic domain, again the technology for the management of the livestock would be necessary (electric readers, blood tests, etc.), but also the technology for monitoring the animals in the mountains (use of GPS, mobiles phones, satellite images, etc.). Farmers' training in the new technologies and practices would be essential for a good implementation.

On the other hand, economic strategies are not only oriented to the openness to foreign market but also to the local/regional market, encouraging the short channels and the local slaughterhouses reopening. In this sense, besides the support of the sector in the meat consumption, the institutions should innovate in relation to products origin and certification. They pointed out that indicating the origin in the products label, as well as in the sales point, would make the consumers to choose about their consumption. Moreover, according to participants, the current insurance products related to pasture are unfair and badly paid. Therefore, new improved financial products with a correct approach covering droughts would be needed.

In relation to the nature-based character of the system, several strategies are important. On the one hand, the financial rewards to the sector are needed for its contribution to public services, and consequently, technological devices (e.g., GPS) are also needed for the control of grazed pastures. On the other hand, changes in legislation related to the land access, forest management, and protection measures in relation to wild fauna attacks are essential. . An interesting point the participants mentioned was the necessity of a new urban legislation (in relation to location of farms, restaurant business near farms, etc.). As in the semi-intensive system, the promotion of the generational renewal would be necessary. In relation to the

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generational renewal, creation of shepherds' schools by the administration institutions would be desirable in order to incorporate trained people to the sector. Besides, the activities' coordination among farmers and the use of technology would be important to have a good quality of life.

2.4 Strategies towards the future

2.4.1 Strategies implementation and performance

The strategies differ between alternative systems (semi-intensive and hi-tech extensive). For the hi-tech extensive system, strategies have a strong environmental component due to its nature-based character, whereas for the semi-intensive system environmental strategies would have less importance. However, in the agronomic domain both future systems share the necessity of the implementation of technology and innovation, although their orientation is not the same. For instance, in the semi-intensive system the technology is oriented to the provision of private goods through the increase of production and prolificacy, whereas in the hi-tech extensive is mainly oriented to the public goods through the pastures management.

Present strategies were not discussed in the workshop because of time constrain, but we have interpreted them according comments received during the workshop. Several current strategies could be implemented in the alternative systems but they are still not very well developed. Therefore, investments (mainly in innovation and research) would be needed for their implementation. Some current strategies that were not addressed in this workshop (in italics in the table 9) are compatible with the alternative farming systems. These strategies are mainly oriented to the economic domain, specifically related to the on-farm economic administration (investments in farm, savings, sales contracts, etc.).

Otherwise, there are several strategies addressed in this workshop that match with current strategies (underlined in the table 9). Most of these strategies are economic strategies such as opening new marketing channels, developing new financial products and find alternative of-farms income sources. Furthermore, institutional strategies coincide with the current ones, for example by conducting public awareness campaigns about the positive contribution of the extensive sheep sector to nature conservation and health. Besides, most of the strategies proposed for alternative systems could also be implemented in the present.

2.4.2 Strategies' impact on the system resilience attributes

In general, the implementation of strategies lead to the resilience attributes improvement, although that occurs in the hi-tech extensive system in a greater extent (see table 8). In relation

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to the performance of the resilience attributes in the alternative systems, a transformation of the systems occurs, mainly due to the way in which animals are managed. In the semi-intensive system the contribution of the sector to the environment is lost in a greater extent, with a transformation to a better production; in the hi-tech extensive the provision of public goods is maximized with the adoption of technical innovations.

Non-regret and experimental strategies

As aforementioned the strategies of agronomic, economic and institutional are, in general, more common to both alternative systems. However, the environmental and social strategies are specific to the hi-tech extensive alternative system, due to its more environmental-based and social nature. In any case, strategies regarding innovation and cooperation among system actors would be necessary, no matter what future system unfolds (non-regret strategies).

The room for experimentation is going to depend on the economic investment the strategy demands. In both alternative systems, several strategies are oriented to technology implementation. The implementation of technology generally does not allow for experimentation because of its great investment, which farmers are not willing to assume. For instance, in the hi-tech extensive system the use of satellite images or the GPS per ewe is expensive. In the semi-intensive, the replacement of more prolific ewes requires high investments. However, other non-costly strategies can be performed by the sector without large investments. For instance, strategies related to the sanitary prevention, which lend robustness to the sector (healthier animals that respond better to diseases), or the coordination among actors.

Probability and desirability of alternative systems

The probability of unfolding the hi-tech extensive alternative system would be larger than that of the semi-intensive system. The semi-intensive alternative system is going to compete with other intensive sectors (e.g., pork) that are more profitable. Nevertheless, the hi-tech extensive system might highlight its importance in the contribution to the public goods and the conservation of the local breed *Rasa aragonesa*. Participants in the workshop indicated that the probability of occurrence of each alternative system depends on where the farms are located too. Because of the greater availability of pastures, the hi-tech extensive system is more suitable to mid-mountain areas. Farmers mentioned the latest system as the preferable option in the future but also the most complicated to accomplish. In contrast, the lower presence (or absence) of pastures in flat areas of the region make the semi-intensive systems more appropriate in those areas. Besides, the presence of irrigated lands supports the activity diversification. Participants pointed out that both alternative systems could be interesting to educate and trained young people, and therefore, could be an interesting way to attract them to

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the region. Riedel et al. (2007) have related young farmers with a greater dynamism and technologies adoption in the ovine production system and the reduction of shepherding.

Table 9. Current strategies and future strategies for different future systems. Current strategies are based on FoPIA-SURE-Farm 1. Strategies statements proposed for future systems that are currently been implementing in the present are underline. Current strategies statements (not indicated in the workshop for future systems) are indicated in italics. Bold font checks indicate that these strategies were mentioned during the workshop for a specific system. Normal font checks indicate that, based on the discussions during the workshop, it seems likely that strategies will be applied in certain systems.

				Future systems	
Strategy	**Domain**	**Current system**	**Status quo**	**Semi-intensive system**	**Hi-tech extensive system**
Use of technology for management efficiency improvement (electronic readers, blood test, etc.)	Agronomic			**V**	**V**
Research in more prolific and productive breeds.	Agronomic	V	V	**V**	
Research for sanitary conditions of the ovine sector (new vaccines, medicaments, etc.)	Agronomic			**V**	**V**
Implementation of sanitary conditions (hygiene, spaced animals, etc.)	Agronomic	V	V	**V**	**V**
Use of technology for animal positioning (GPS, mobile phone, etc.)	Agronomic				**V**
Farmers training in new technology	Agronomic			**V**	**V**
Financial products to cover market volatile prices	Economic	V	V	**V**	
Financial products to cover droughts	Economic	V	V		**V**
Opening up a foreign market	Economic	V	V	**V**	**V**
Short channel boost	Economic	V	V		**V**
Openness of local slaughterhouses	Economic				**V**
Diversification (on-farm)	Economic	V	V	**V**	
Alternative income sources (off-farm)	Economic	V	V		**V**
Investment in the farm assets	Economic	V	V	V	V
Costs reduction and flexibility	Economic	V	V	V	V
Sales contracts	Economic	V	V	V	V
Access to market information	Economic	V	V	V	V
Improvement of the access to pastures and stubble fields	Environmental	V	V		**V**
Use of technology for control of grazed pastures	Environmental				**V**
Research in methane emissions from ovine sector	Environmental			**V**	**V**
Use of technology for real-time communication with administration	Institutional			**V**	**V**

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Strategy	Domain	Current system	Status quo	Future systems	
				Semi-intensive system	Hi-tech extensive system
Trained administration staff in region specificities	Institutional			**V**	**V**
Reduce bureaucracy and excessive and specific regulations	Institutional			**V**	**V**
Tailored legislation in environmental management	Institutional				**V**
Tailored legislation in sanitary conditions	Institutional			**V**	**V**
New urban legislation					**V**
Remuneration to the sector for contribution to public goods	Institutional				**V**
Improve legislation in relation to wild fauna	Institutional	V	V		**V**
Innovation of laws for products origin and certification	Institutional			V	**V**
Promote generational renewal (early retirements, access to land, etc.)	Institut./Social			**V**	**V**
Creation of shepherd schools	Institut./Social				**V**
Promotion of lamb meat consumption	Institut./Social	V	V	**V**	**V**
Promotion of local breeds outside the region	Institut./Social				**V**
Improvement awareness of sector contribution to public goods	Institut./Social	V	V	V	**V**
Associations and cooperatives	Social	V	V	V	V
Improvement of quality of live (work intensity reduction with technology)	Social	V	V	**V**	**V**

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3 Interpretation

3.1 Tipping points

The farming system's main indicators (functions, attributes and challenges) are close to the tipping point indicating the system is about the collapse. However, participants indicated in the workshop that the ovine sector in the region has already reached the collapse, mainly because the profitability is not high enough.

Gross margins: Participants in the workshop indicated that average gross margins (25-30 €/head) correspond to the limit of margin they can assume. Pardos et al. (2008), in a study of 56 sheep farms in the entire region of Aragón, indicated a gross margin value of 26.66 ± 16.1 €/head, where the average value is in concordance with workshop value. However, the study encompasses a variety of farm types, from intensive to extensive farms. If we dig deeply in this work, margins are different between types of farms. Corresponding to more extensive farms, the margins are between 26.54 and 14.11 €/head. According to MAPA (2020), gross margins have increased in the last 10 years with an increase of 100% with values in 2017 of 47 €/head in the region of Aragon, which agree with the margin participants indicated for the mid-mountain areas. Incomes depend on aids, variable costs and size of herds, and seem to determine the gross margins (Milán et al., 2003; Pardos et al., 2008). The great diversity of farming practices that defining the ovine sector in the region, make difficult defining an average value for gross incomes. García Martínez et al. (2008) found for the bovine sector of the region that gross margins differed according the size of herds and farms, but they do not differ if aids are not considered. Therefore, it seems that aids make the difference in the economic results. In any case, participants commented that margins are very low and that the robustness of the system is rooted in the emotional ties to the sector that goes beyond the economic aspect.

Lamb meat consumption: This indicator has declined strongly in the last 15 years (40% of reduction), with a current value of 1.5 kg/inhabitant/year (MAPA, 2018). The urban trends in relation to meat consumption seems to condition the lamb meat market (Martin-Collado et al., 2019). The consumption of sheep cheese has increased, whereas consumers of meat have decreased. Consumers do not care about its origin and consider the lamb meat as fatty, preferred in only two cuts (leg and chops), and only consumed in celebrations or special occasions. Corcoran (2003) also pointed out the negative trend of the meat consumption in Europe due to factors as the competence with other meats, population and familiar structure, location and frequency of purchases, changes in the perception of food and health, consumption habits, and meat industry distrust. However, consumers consider that the quality of meats is conditioned by external factors such as the way animals are fed, animal welfare and

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environmental friendly production. These factors might be taken as a commercial advantage (trusted quality products) by the extensive sector (Bernués et al., 2006). The quality of these products need also to be informed and proved through advertising, certification and appropriate labels (Bernués and Olaizola, 2012). The low lamb meat demand is keeping locked prices at low levels, around 7 €/head (MAPA, 2020b).

Depopulation: The rural depopulation is an important challenge that this sector has been facing since the last century (Ayuda and Pinilla, 2002). The depopulation seems to do more with the general socio-economic context of the region (lack of workforce, migration to urban centres, etc.), than with the sector itself (Bernués and Olaizola, 2012). The current population in the region of Aragón is about 1.3 million, 219,000 people in the Huesca province, and about 68,000 people in the La Hoya de Huesca area. The number of farms has decreased around 30% in the last 15 years in Aragón (European Commission, 2020), a phenomenon related to the abandonment of the activity in the region. This trend has also been reported by Bernués and Olaizola (2012). However, the decrease in the number of farms is higher (60%) in the regional government statistics (Gobierno de Aragón, 2016). The closure of farms usually involves a reduction in the sheep census, although in the last 10 years this census has been stable (between 500 and 600 thousand heads in Huesca province) (MAPA, 2020c), because herds of closed farms have been acquired by the surviving farms. Pardos et al. (2007) found an average increment of 85 sheep per farm from the period 1996-2001 to period 2002-2005. However, at some point, surviving farms will not be able to assume new cattle incorporation and the sheep census will drastically decrease. For the extensive bovine sector in the same region, García Martínez et al. (2008) indicated the retirement, the lack of replacement by the next generation, and the substitution of livestock for other activities as the causes of farm abandonment.

Land availability: In the sector, the availability of lands is essential in order to run the extensive farming system. Farmers usually use different lands to feed the herd: not only pastures, but also stubble fields and uncultivated lands. Although the area with main pasture use (including uncultivated lands) has decreased in 67% in the last 15 years in the Huesca province (currently there are 150,000 ha) (MAPA, 2020d), the low sheep census does offset the decline of available land. The key point in this sense is the difficulty to know the total amount of available pastures in the region, which is difficult if a tipping point for this indicator (corresponding to the coupling with local and natural resources resilience attribute) is reached. Administrative institutions mostly determine the access to pasturelands. In this study, communal mountain lands access is limited in the mid-mountain areas because of the proximity (or inclusion) to a protected area (*Sierra y Cañones de Guara* Natural Park), where grazing is restricted, although it is necessary for modulating the vegetation dynamics (Bernués et al., 2005). In the flat areas of the region, the increasing intensification of the agriculture is increasing the area of irrigated crops and limiting

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the area of grazing lands. In this context, it should be kept in mind that the greening aids are incompatible with grazing in the stubble fields, limiting the areas for this activity. The intensification of the sector has led to the abandonment of lands, mainly in the mid-mountain areas. This abandonment causes a simplification and homogenization of the landscape due to the increase of the tree and shrub stratums, which lead to decrease in biodiversity and increase of fires (Lasanta-Martínez et al., 2005; Vicente-Serrano et al., 2000). Grazing activities ease the existence of open forest areas, which prevent fires but also provide recreational areas demanded by society (Bernués and Olaizola, 2012).

Draughts: Droughts have been increasing in the last years (Turner, 2005). Droughts are an important challenge, especially for the future, because of the dependence of extensive systems for feeding. In fact, in other drier regions of Spain, the lack of available pastures because of the droughts, prompted the European Commission to allow grazing in stubble field considered as ecological focus areas (EFA) (Commission implementing decision (EU) 2019/1389, of 4 September 2019).

Feeding costs: Participants indicated that the average value of feeding cost is 20-30 €/head. These values seem to be higher than those reported by Pardos et al. (2008). Whereas values of costs for lamb feeding are similar whatever the degree of farm intensification (lambs are usually fed with fodder), the value for sheep feeding varies among farms. Thus, the (semi) extensive systems considered in their study indicated a value of 14-17 €/head, whereas the more intensified system spent 33.5 €/head. Those values are referred only for feed purchase (no feeding trough, auto-consumption or rent of grazing land). When rest of variable costs were included, Pardos et al. reported costs values of 42-45 €/head for (semi) extensive systems, which are greater than the values provided by participants (we do not know if all feeding costs are included in the provided values by participants).

3.2 Thresholds' exceedance

Participants indicated that the **gross margin** is the decisive variable that determines if the sector is in the edge of collapse. Income and costs will determine the gross margin per head. The farmers' incomes are dependent on aids (Bernués and Olaizola, 2012; De Rancourt et al., 2006) (Figure 1). The aids perceived by farmers are not coupled with production anymore, and they are currently related to the land ("basic aids"). However, participants indicated that they do not agree with payments coupled with hectares because they do not have lands in property, and therefore, they do not perceive those aids. According to Casasús et al. (2007) and Riedel (007), the sector needs new agro-environmental instruments to foster the shepherding and maintain the mountain agro-ecosystem.

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Regarding the **sales incomes**, the lamb meat consumption has been decreasing throughout the last decades (MAPA, 2018), having a negative effect on the farms' margins, which might conduce to the closure of several farms in the region.

The **feeding costs** are a key element in the gross margin per head. They depend on the type of farm (Pardos et al., 2008). Farms where intensification is implemented have greater feeding costs (50%), compared to other farms where extensification is performed in some way. Feeding costs are also negatively influenced when the availability of the grazing lands are limited by weather conditions and the appearance of wild fauna.

Another important challenge identified by participants is the **decrease in the population**, which is linked with a decrease in the amount of farms dedicated to the ovine sector. The high time-demanding and low profitability (Gil et al., 2003) makes the sector no attractive any more. The lack of workforce can be explained by the diversification of activities and incomes that are needed in the families (Olaizola and Manrique, 1992). The socio-economic context of the farm (the location and distance to job centres), and the familiar factors condition the permanence of the sector in the LFA (García-Martínez et al., 2009).

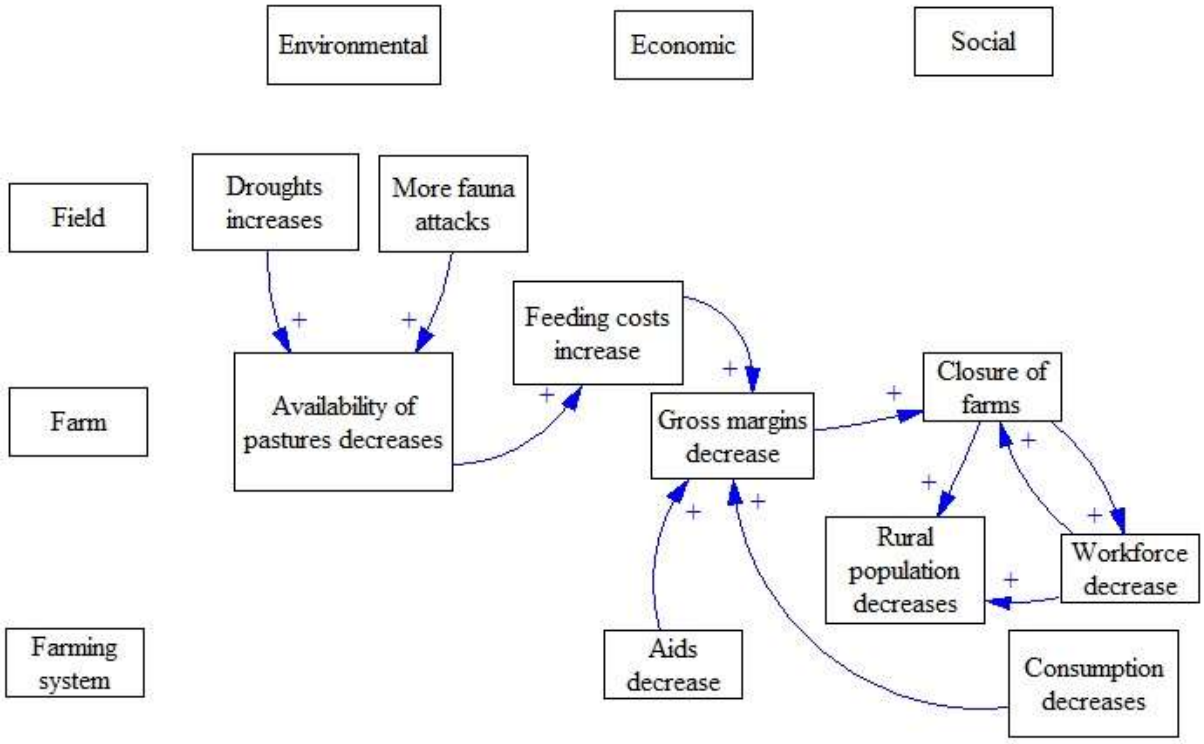

Figure 1. Interacting thresholds in the farming system.

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3.3 Alternative systems

In the alternative systems all the main **functions** are expected to increase in a moderate way. The gross margins would increase in both systems, although margins seem to differ depending on the degree of intensification or extensification of the farms, as well as the areas where the farms are established. The location of the farm determines the agro-ecological potential and the access to markets (Geoghegan et al., 1997). Thus, the semi-intensive alternative system is related to lead to more production but also the locations of farms in the irrigated areas (flat areas) makes them not eligible to receive aids for the less favourable areas (Pardos et al., 2008). In the hi-tech extensive alternative system, the production is not expected to change, and therefore, the incomes in this aspect would not change. However, their performance in less favoured areas (mid-mountains) and the provisions of public goods services (as the intention of CAP to promote the extensification as an environmental tool, instead of consider it as a productive sector) is supported by subsidies that increase the current margins. Despite of the extensification measures of the CAP, it seems that intensification of the Spanish ovine sector is the trend (Oregui and Falagan, 2006; Pardos et al., 2007), which is linked to a decrease in the time of grazing and the increase of feeding inputs (Riedel, 2007).

Greater gross margins would lead to a greater number of farms in the region, although this increase would be limited by the availability of lands in the hi-tech extensive system. The increase of the sheep census is expected in both alternative systems, although this increment would be greater in the hi-tech extensive alternative system: the lower production in this system would be compensated with greater herd sizes.

In relation to the **resilience attributes**, the improvement of all attributes indicated in table 3 is only expected in the hi-tech extensive alternative system, whereas the attributes regarding the semi-intensive alternative system decrease their performance. The decline in the semi-intensive system is mainly related to the decoupling of natural capital and the loss of the aids from institutions due to the intensification. Whereas the self-organization of the system increases because of the more cooperation needed in the hi-tech extensive system for the management of pastures, this attribute moderately decreases in the semi-intensive system. However, self-organization would increase in relation to get better process in the purchases of fodders. The increment of the diverse policies and socially self organized attributes in the hi-tech extensive alternative system increase the robustness of the current system, by improving the margins in the sector (with policies) and the management of pastures (cooperation between farmers).

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In both systems, other resilience attributes not discussed in the workshop, such as the investment in technology, lead to more robust and adapted systems. In this sense, the robustness is especially seen in the semi-intensive alternative system, where infrastructure regarding sanitary conditions improvement makes animals more resistant to diseases. In addition, the incorporation of technology for livestock management in the hi-tech extensive system makes farmers to adapt this management depending on the conditions. For instance, the employment of satellite images or GPS allows farmers to head for best pastures or to know the location of wolves and bears. The support of the rural life increases in both alternative systems because of the new people incorporation to the region.

As we have been mentioning throughout the document, the location of farms is important. In the areas where the hi-tech extensive systems are more likely to occur, the adaptation of the system is going to happen. This system supposes an adaptation regarding the current system, where farmers need to adapt to policies changes related to environment. Whereas the main function of the extensive system is maintained in the hi-tech extensive alternative system, the loss of this function makes the semi-intensive alternative system a transformation of the current system. In this system the function of the provision of meat is maintained but the production needs to be adapted to the new standards, especially sanitary standards.

3.4 Causal loop diagram

In the ovine extensive farming system in the Huesca province, there are multiple loops (Figure 2). In turn, some of them are interconnected and small loops are included into big ones.

We can find the **balancing feedback loop (B1: "Gross margin")** that shows that the gross margin is related (increases) to the sheep census, that increases the number of farms, and the workforce and the quality of life. The increasing workforce, considered as a fixed cost, may lead to a decrease in the gross margins. In relation to **B1**, we can find the **balancing feedback loop (B2: "Feeding costs")**. These feedback loops are linked through the farmers' quality of life. Improving life quality implies increasing feeding costs. One way to reduce the hard workload of the extensive farming is changing the way the animal is managed and by housing the herd. It supposes an increase in the feeding costs that leads to lower gross margins. A new relationship between variables steams from this loop. The increased feeding costs encourage farmers to associate to get better prices.

The low profitability and the intense workload lead to the current low attractiveness of the sector and the depopulation of the region. Extensive farming is the main source of rural

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population as farmers need to live close to the farm (Bernués and Olaizola, 2012). Related to this issue, it can be seen a **reinforcing feedback loop (R1: "Rural development")**. The rural development programmes enhance the attractiveness to the region by new people which could be interested in remaining in the rural areas. This situation benefits the workforce availability and hence the farmers' quality of life. In turn, the improvement of the farmers' quality of life eases the generational renewal living in the rural areas that turns to encouraging the initiatives and programmes of rural development.

The good perception by the general public of the sector is essential for lamb meat consumption. A new feedback loop appears called **balancing feedback loop (B3: "Lamb meat consumption")**. The coupling of the sector with the natural resources leads to an improved sector image perceived by social media. If the social media perception improves, social media will pursue campaigns that foster the public awareness about the sector and its positive contribution to nature and health. A better image might result in increased lamb consumption that in turn leads to an increase in the ovine census. The increasing census has a limit as the sector is coupled with local and natural capital. Pastures cannot withstand a continuous increasing sheep census. The increase in the lamb consumption is also going to lead to an increased gross margin, which is directly related to increasing the number of farms and sheep census. On the other hand, the favourable campaigns might come from other actors, such as the associations of farmers (shown in the figure 2 as 'socially self-organization').

The ovine sector is strongly linked to the natural resources, specifically to the pastures. An additional **reinforcing feedback loop** is identified called **R2: "Natural capital of the sector"**. Changes in the regulations might improve the definitions of measures and incentives adapted to the specificities of the extensive livestock. These incentives enhance the sustainable pastures management (coupled with local and natural capital of the system), which leads to a better perception of the extensive sector by the media and consumers. The positive public perception also encourages institutions and legislators to change the laws and regulations favouring the extensive farming. The measures to incentivise the pastures sustainable management can be monetary (subsidies) and non-monetary measures by facilitating the access to current locked pastures. This loop is related to the B2-Feeding costs. Increasing access to pastures leads to lowering feeding costs and greater gross margins.

The causal loop diagram also shows that there are challenges that affect negatively the pasture availability such as the wild fauna attacks and the impact of droughts. Consequently, it appears a new **balancing feedback loop, B4: "Wild fauna attacks and droughts".** On the one hand, the presence of wild fauna attacks limits the access to the pastures, whereas the increasing droughts lower the pastures productivity. Changes in the pasture access and availability trigger

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the definition of specific institutional measures tailored to cover the negative impacts. If new farmers' economic incentives arise to deal with wild fauna cohabitation and droughts the farms' gross margin will increase. Greater profitability will encourage the financial institutions to develop and offer new financial products tailored to lessen the impact of wild fauna attacks and droughts.

Finally, a new loop appears in the causal loop **(balancing feedback loop, B5: "I+D and knowledge transfer")**. The transfer of shepherding knowledge among farmers and other actors in the sector guides the research and innovation according to the sector necessities, which in turn reinforces the farmers training. The training of farmers might promote the creation and strength of farmers associations, which leads, among other things to reduce the feeding costs. Lower feeding costs result in increased gross margins. Therefore, new farms will be opened, and the workforce and generational renewal will increase. The greater number of farmers and workload in the sector will in turn contribute to the transfer of knowledge.

Although there are several relationships among the selected indicators of the functions, attributes and challenges of the sector (Figure 2), it is observed that all reinforcing and balancing feedbacks in the system revolve around three four pillars. 1) The profitability of the sector mainly defined by the lamb consumption (and prices) and feeding costs. Public awareness of the functions and quality of products may raise the consumption of the lamb meat. (2) The attractiveness of the sector mainly influenced by the profitability and the farmers' quality of life; the low attractiveness results in low levels of workforce availability and new entrants. (3) The coupling of the extensive sector with the natural capital. Favoring the access to pastures and providing incentives to farmers for the sustainable management of pastures would lead to greater margins. The increased profitability will trigger the rest of the identified loops. And (4), the research and innovation and the need of attract the private sector might increase productivity, jointly with the public-private collaboration in RD and innovation projects focused in the extensive livestock farming and its contribution to nature and heath, the cohabitation with wild fauna and health and new forms of public services provision cooperation.

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Supplementary Materials E. FoPIA-SURE-Farm 2 Case Study Report Spain

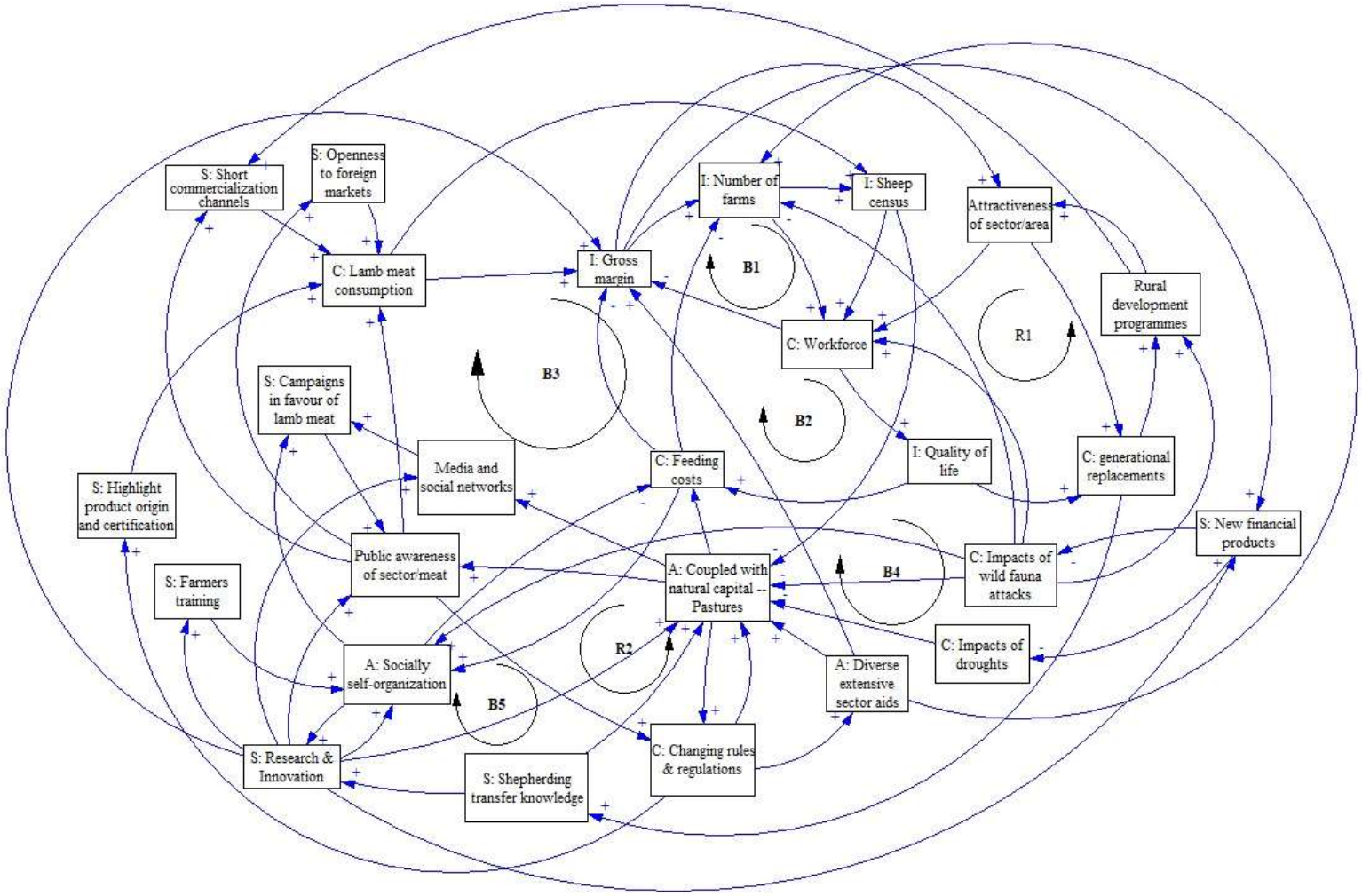

Figure 2. Causal loop diagram of the farming system in Huesca province (Spain). A + implies a positive cause-effect relationship and a - implies a negative cause-effect relationship. B stands for a balancing feedback loop and R stands for a reinforcing feedback loop. I indicates an important system indicator related to the system's functions. C indicates a system challenge. A indicates an indicator related to a resilience attribute. S indicates a strategy applied to maintain current functionality of the system.

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3.5 Linking alternative systems to scenarios

As presented in the section 2.3, in both alternative systems, the functions of the sector (provision of food, profitability of the sector and provision of quality of life) are the same as in the maintenance of the status quo. In the semi-intensive alternative system the resilience attribute coupled with natural capital is decreased although is still important due to the ovine sector needs that link. In the hi-tech extensive alternative system the attribute coupled with natural capital is improved in a greater extent. Public aids are essential in the hi-tech extensive alternative system, as in the current state in order to maintain the status quo. However, in the semi-intensive system, because of an intensification of the production, subsidies are not available for the sector any more. Challenges, like the reduced consumption of lamb meat by consumers, the lack of workforce and the feeding costs, are still important in the future alternatives. The feeding costs are more important in the semi-intensive alternative system due to a greater dependency of feed inputs (fodders) and more independency of pastures. On the other hand, wild fauna attacks will only suppose a challenge in the hi-tech extensive alternative system. In the semi-intensive system, the greater stabling of the livestock and the location in flatter areas will render attacks less relevant in this alternative system.

For both alternative systems, research and technology are necessary for the improvement in the production (especially in the semi-intensive system) and the quality of life. Besides, in the hi-tech extensive system technology it is very necessary for the management and control of the pastures, grazing and wild fauna. Changes in regulations are important for maintaining the current system and for the alternative systems. The openness to bigger markets is mainly a focus in the semi-intensive system, whereas the hi-tech extensive system is more centered in the short channels of commercialization and the regional market.

Compatibility between the different Eur-Agri-SSPs scenarios and the current and alternative systems was assessed. The scores in the compatibility assessment were provided by the research team. Results of the assessments are presented in the Table 10. The maintenance of the current system as well as the alternative systems has a strong compatibility with SSP1 scenario (sustainability path), which stands as the most probable Eur-Agri-SSP by the stakeholders. The compatibility with this scenario is very similar for the three systems, although it is greater for the hi-tech extensive alternative system. SSP1 is oriented to a progressive decrease in the demand of livestock-based products, which is in conflict with the provision of lamb meat in the sector. However, the development of short supply channels (SSC), the provision of environmental services, and the implementation of technology oriented towards environmental friendly processes and cooperation make the hi-tech extensive alternative system quite adequate to the SSP1 scenario. In the semi-intensive alternative system, the

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openness to broader and international markets (outside the European Union) and intensification of production are counteracted with the technological efficiency and support to the rural development in the region, making this alternative system moderately compatible with SSP1 scenario.

Table 10. Compatibility of alternative systems with different Eur-Agri-SSPs. Where values -1 to -0.66: strong incompatibility, -0.66 to -0.33: moderate incompatibility, -0.33 – 0: weak incompatibility, 0-0.33 weak compatibility, 0.33-0.66: moderate compatibility, and 0.66-1: strong compatibility.

	Scenarios				
Systems	**SSP1**	**SSP2**	**SSP3**	**SSP4**	**SSP5**
Maintaining status quo	0.51	0.32	-0.83	0.14	0.21
Semi-intensive alternative system	0.63	0.66	-0.62	0.35	0.38
Hi-tech extensive alternative system	0.73	0.44	-0.67	0.07	0.17

The continuity with the established pathway (SSP2 scenario) presents low compatibility with the current state of the sector. a moderate compatibility with the hi-tech alternative system. and a stronger compatibility with the semi-intensive alternative system. The lower compatibility regarding SSP1 for the hi-tech alternative system is due to the necessity of the improvement in the existing legislations in relation to the environment. and the application of new technologies. However. the high demand of meat. the possibility of commercialization in Europe and the increasing interest for high standard products make this scenario moderately sustainable in the future according the two proposed alternative systems. The support for efficiency and productivity by European policies matches with the higher compatibility of the semi-intensive alternative system with SSP2.

The SSP3 scenario (regional rivalry) is strongly incompatible with the current and alternatives systems. The lack of institutional support for environmental services of agriculture and livestock is incompatible with the ovine sector. which needs to complement incomes with the direct payments. The low investment in technology is also an inconvenient for the alternative systems. which are based on the adoption of technologies by the sector. The reinforcement of national markets in SSP3 at the expense of the internationalization of markets would not be favorable with the Spanish ovine sector. where demand of lamb meat seems to continue decreasing in the future. unless national consumption is encouraged. In this sense. this scenario is negative for the semi-intensive alternative systems. which trusts in new international commercial channels. The hi-tech extensive alternative system is based on the valorization of the local product and the short channels of commercialization. and therefore. this alternative system would be compatible with SSP3. However. the low profitability of the sector. the null recognition of its contribution to

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the environment services. and the deficiencies in the rural development and workforce make the hi-tech extensive system very incompatible with SSP3 too.

The SSP4 scenario (inequality path) presents weak compatibility with the current and the hi-tech extensive systems. In SSP4 exists a high disconnection between urban (institutions) and rural populations. which leads to the decrease of the environmental standards and the support of the sector by the people and the institutions. The environmental standards and the support by institutions are essential in the hi-tech extensive alternative system. which make it incompatible with SSP4. However. SSP4 is more compatible with the semi-intensive system. In SSP4. public institutions promote international markets and production with new technology implementation. The stimulation of the production and industrialized farms make the semi-intensive system the most compatible system with the SSP4 scenario.

Similarly to SSP4. the semi-intensive system is the most compatible system with the SSP5 scenario (technology path). whereas the current and hi-tech extensive systems are mainly incompatible. In this path the technology is encouraged with private investments in technology. which is oriented to production and the trade libration and globalization. In this scenario. the public support is reduced and the environmental standards are put aside.

We can conclude that the extensive ovine sector in the region of Huesca is prepared for SSP1. especially the hi-tech extensive alternative system. SSP1 is the best option because of the increment of support for environmental services. However. the system is very close to collapse. and therefore. the accommodation of SSP2 to the current state is not possible. The establishment of the semi-intensive alternative system according to SSP2 is more compatible due to the current trend to productivity support. The semi-intensification of the sector is the only alternative system moderately compatible with scenarios SSP4 and SSP5. However. SSP3 is strongly incompatible with the current system or the alternatives systems. This is explained by two facts: the lack of internationalization of markets is incompatible with the semi-intensive alternative system; and the lack of environmental services valorization is incompatible with the hi-tech extensive system by this scenario.

3.6 Strategies

Strategies were clearly oriented to the extensive sector valorization and the improvement of its contribution to the environment (management of natural capital). Those strategies are mainly based on the technology development. the support to rural development and the quality of life. and the improvement of farm economic margins.

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In general. all strategies implemented in the present are compatible with the alternative systems. Besides. most of the strategies implemented might be implemented in both alternative systems. The improvement of research and technology can be implemented in both alternative systems. although the specific priorities of the research and innovation would be different for each strategy. For instance. the technology implemented in the hi-tech extensive system is related to the management of pastures. geo-localization of livestock and wild fauna. Although this technology has started to be implemented in the last years. there is still a large room for improvement. In contrast. in the semi-intensive system. the technology is implemented for the improvement of production and management of livestock (sanitary conditions). and which might also be implemented in the hi-tech extensive system to some extent.

Strategies oriented to the valorization of the extensive system and the improvement of the environmental services are compatible with the hi-tech extensive alternative system. Strategies oriented to the increase of the lamb consumption would improve the profitability in both alternative systems. although their performance would be better in the hi-tech extensive system. perhaps due to the better perception of the sector by consumers because of its contribution to environment.

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4 Conclusion

Currently the extensive ovine sector is in the edge of the collapse. Indicators for farming system functions and resilience attributes are close to the tipping points. which make them very vulnerable to increasing challenges. It seems that adaptations and strategies carried out up to day. such as the improvement of breeds. profitability. opening of new commercial channels and products (cuts). have not contribute enough to the resilience capacities of the system.

The negative trend of the system indicators suggests the necessity of a change in the sector. Two different alternative systems are proposed: a semi-intensive alternative system and an extensive system endorsed by technology (hi-tech alternative system). In the proposed alternative systems the function of providing safe and quality food remains. However. there is a difference in the provision of public goods between the systems. The provision of public goods would decrease or even disappear in the semi-intensive system. In the hi-tech extensive alternative system the contribution to environment is strengthened.

Most of the challenges affecting the current system will also be affecting the future alternative systems. Nevertheless. the alternative scenarios will be more prepared to cope with the low profitability and the low attractiveness of the sector by implementing strategies based on innovation. As the main difference between the alternative systems is based on the feeding livestock regime. we can find some differences in the challenges' impacts. The semi-intensive alternative system will be dealing with feed prices volatility as this system is dependent on purchased off farm feed. Droughts will greatly impact on the high-tech extensive system as pastures are the main source of feed.

Between the two scenarios the most resilient one is the high-tech extensive. The semi-intensive systems look for increasing profitability via increasing productivity. However. improvements in productivity are not still promising in the ovine sector. The intensification in the ovine sector is far from guarantee the same intensive production as the provided by other intensive sectors such as pig. beef of chicken sectors.

The sheep extensive sector needs to underpin and boost its function of provision of public goods. such as its contribution to main natural resources. local breeds and animal welfare. The hi-tech extensive alternative system consists of a transformation of the system. based on innovation towards more sustainable and efficient management of the pastures. and new information and collaborative tools that facilitate actors' cooperation in the pastures and time management that improve their quality of life. Besides. the development and implementation of new technologies need to be supported by the investment of private and public institutions in research programs.

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