Journal of Rural Studies 86 (2021) 633–644

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Implications of alternative farm management patterns to promote resilience in extensive sheep farming. A Spanish case study

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A R T I C L E I N F O

Keywords:
Robustness
Adaptability
Transformability
Resilience attributes
Content analysis
In-depth interviews

A B S T R A C T

The vulnerability of extensive sheep systems in marginal areas, and their capacity to deliver important socio-economic functions and ecosystem services, can be studied through the lens of resilience theory. This research aims to explore how alternative farm management patterns contribute to build resilience in the extensive sheep farming system of Huesca, northeaster Spain. The methodology is based on the content analysis of in-depth interviews to farmers. We follow a specified framework based on the definition of the resilience capacities of robustness, adaptability and transformability, and propose to assess nine case-specific attributes. Results show that sheep farms have undertaken four management patterns to develop over time, namely, extensification, intensification, re-orientation, and conservation. Patterns conservation and extensification appear to promote robustness and adaptability necessary to keep delivering characteristic functions, whereas transformability is much more evident in re-orientation and intensification patterns that re-address the farms' original functions. Matching with natural resources, traditions and perspectives, and farmers' networks are crucial resilience attributes for extensive farming. On the other hand, financial and labour resources, and on-farm diversity favour re-orientation and intensification. The paper casts light on the diverse ways through which farms build their own resilience, and highlights the importance of a balanced development of alternative trajectories for the whole farming system's resilience.

1. Introduction

Extensive sheep farms have been increasingly affected by emerging stressors across the European Union (Ruiz et al., 2020). This paper focuses on the extensive sheep farming system of Huesca (Aragón, Northeast Spain). The system is characterized by family farms, oriented to lamb production, and mostly located in marginal and mountainous areas where other activities would be unviable. Research has shown that important functions and ecosystem services are associated with extensive sheep farming in Huesca, such as the provision of food and farmers' viability, biodiversity and the conservation of soil quality, the reduction of abandonment of marginal areas, and the maintenance of rural population (Rodriguez Ortega et al., 2018; Becking et al., 2019; Spiegel, 2019).

However, in line with European trends, the extensive sheep farming system of Huesca is undergoing a number of economic, social, institutional and environmental challenges. In the last two decades, a significant reduction in lamb meat consumption has seriously affected the sector (MAPA, 2019). This trend adds to the increasing feeding costs and reducing subsidies that, in turn, weaken the farm profitability, the generational renewal and the availability of workers (Bertolozzi-Caredio et al., 2020; Soriano, 2020). Not less importantly, higher competition for land and increasing droughts and wolves attacks threaten the traditional extensive model. To deal with such challenges, extensive farmers have been implementing several farm management strategies during the last decades, which led also to relevant transformations, including diversification to alternative productions (e.g. intensive pig or crop production) and intensification of sheep breeding (Riedel et al., 2007; Sanderson et al., 2013).

In light of these trends, it is of interest to understand whether and how alternative farm management strategies ensure the farms' survival and their capacity to deliver important functions in Huesca. The capacity of extensive sheep farms to keep delivering their functions can be studied through the lens of resilience theory. In this paper, we define the resilience of farms as their capability to ensure the provision of functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses (Meuwissen et al., 2019). To the best of our knowledge, few studies have investigated the

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https://doi.org/10.1016/j.jrurstud.2021.08.007
Received 20 February 2021; Received in revised form 12 June 2021; Accepted 6 August 2021
Available online 12 August 2021

resilience of sheep farms in the EU, none of them in Spain. For instance, Haider et al. (2012) operationalize the resilience in a pasture management system in Asia, whereas Daugstad (2019) explores the resilience of mountainous dairy sheep farms in Norway, and Ashkenazy et al. (2018) investigate the resilience of 11 case studies, among which small ruminant farms in Turkey.

Approaching farm management through resilience is useful to consider the real complexity characterizing farming (Darnhofer, 2014). Nonetheless, the dynamics explaining how farm management builds resilience strategies has not received much attention, although some investigations addressed it (Daugstad, 2019). There is room for advances in understanding how farm management strategies contribute to building resilience. Meuwissen et al. (2019) propose a comprehensive framework to assess the resilience of European farming systems and its interplay with farm management dynamics. This framework, based on the simultaneous assessment of resilience capacities (robustness, adaptability and transformability) and attributes, underpins our assessment. Resilience attributes are those factors belonging to the farm or the surrounding environment enabling the resilience of the farm itself, whereas the concept of robustness, adaptability and transformability describe the capacity to cope with challenges by withstanding or undertaking changes. Both concepts of resilience attributes and capacities have been growingly applied in agricultural resilience literature, yielding promising results (Reidsma, 2019).

This paper aims to explain how alternative farm management patterns contribute to build farm resilience in the extensive sheep system of Huesca. In order to do so, three specific objectives are pursued, namely i) to define the farm management patterns undertaken overtime in our case-study; ii) to identify the resilience attributes enabling or constraining those patterns; and iii) to define the resilience capacities promoted by different farm management patterns.

Qualitative and descriptive methods and case studies have shown potential in analysing resilience at farm level (Darnhofer et al., 2010; Vroegindewey and Hodbod, 2018). Having an explorative purpose, this paper proposes a qualitative exploratory approach based on the content analysis of 14 semi-structured interviews to farmers in the case study area (Huesca, Aragón). An exploratory approach is appropriate to study little-know socio-economic dynamics within their context, above all when quantitative information are not available and an in-depth exploration can identify key aspects and areas for further research (Fisher, 2013). Being our research purpose explorative, what we looked for was the understanding of linkages and dynamics, rather than obtaining a general formulation and statistical generalization about what is resilient and what is not. For example, Perrin et al. (2020) succeed in identifying the practices connected to resilience in dairy farming but, as the authors underline, they do not catch the reasons and mechanisms behind that result. Our approach could help covering this gap.

Our methodology is based on a new deductive coding approach to assess the resilience capacities, and nine case-specific resilience attributes. As opposite to our method, previous research attempted to infer the resilience capacities through the direct elicitation of farmers' perception. While such approach facilitates systematic analysis at large scale (e.g. Spiegel, 2019), it incorporates significant cognitive bias by farmers (Herrera, 2017; Perrin et al., 2020), as it requires interviewees' understanding of these concepts (Nera et al., 2020). In contrast, we replaced the perception of resilience by a deductive scheme that, even if does not exclude biases, it anchors results to more concrete definitions of resilience derived from the literature.

2. Conceptual framework

The resilience of agricultural systems has been growingly investigated in the last decades. A strand of literature developed and assessed different sets of resilience attributes (e.g. Biggs et al., 2012; Cabell and Oelofse, 2012; Kerner and Thomas, 2014; Worstell and Green, 2017; Reidsma, 2019), whereas another line of investigation has focused on the concept of robustness, adaptability and transformability (e.g. Darnhofer et al., 2010; Ashkenazy et al., 2018; Daugstad, 2019). In order to provide a comprehensive framework to assess the resilience of European farming systems, Meuwissen et al. (2019) depict an approach based on the assessment of both resilience attributes and capacities. In Meuwissen et al.'s framework, farm management (including agricultural practices and risk management strategies) is an essential dynamic of resilience, and resilience capacities and attributes are the lenses for studying such dynamic. This paper's conceptualization is drawn upon this resilience framework. Assessing how farms build resilience, therefore, requires considering three elements behind the farm management mechanisms. These are the farm management patterns undertaken over time; the resilience attributes enabling or constraining those patterns; and the resilience capacities promoted by different strategies.

As Urruty et al. (2016) pointed out, farmers do not only make decisions to face sudden shocks, but also to deal with challenges on a mid- and long-term perspective. Besides, farmers' investments determine a path dependence, meaning that they influence future farmers' capacity to react and decision-making (Clark and Munroe, 2013). This highlights the need to consider farm resilience as built through combinations of farm management strategies over time, rather than by single strategic choices. This is consistent with the conceptualization of resilience as a process, rather than a property emerging at a precise point in time (Darnhofer, 2014). Within the same farming system, however, combinations of strategies can be diverse, suggesting that similar farms could follow different farm management patterns.

Farm management decision-making and processes are determined by exogenous and endogenous factors (Cabell and Oelofse, 2012; Kristensen et al., 2016), defined as individual/collective competences and enabling/constraining environments enhancing resilience (Meuwissen et al., 2019). They include also policies (Celio et al., 2014), available resources and the capabilities to use them in a (farm) community (Longstaff et al., 2010). As pointed out by Darnhofer (2014), analyses of resilience require exploring not only the processes, but also the conditions enabling them. Thus, the analysis of resilience attributes is relevant to translate evidence into practical indications (Kerner and Thomas, 2014). The resilience attributes, therefore, are those factors, properties or conditions intrinsic to farms (and the farmers), or in the surrounding environment (including policies) which the farms belong to, that can enable or constrain farm management strategies and, therefore, the farm's resilience.

The capacity to deal with challenges while still needs to be delivering functions can emerge through three interdependent capacities of robustness, adaptability and transformability. According to Meuwissen et al. (2019, pp.4), robustness is the capacity to withstand stresses and shocks. Adaptability is the capacity to change the composition of inputs, production, marketing and risk management in response to shocks and stresses, but without changing the structure of the farm. Transformability is the capacity to significantly change the internal structure and identity of the farm in response to either severe shocks or enduring stress that make business as usual impossible.

The difference between robustness and the other capacities is basically due to the absence of structural changes in farms' organization and functions when a farm responds to challenges (Daugstad, 2019; Meuwissen et al., 2019), i.e., the farm remains in the original configuration. Following Darnhofer (2014), adaptability implies marginal changes limited to the farm productive organization to reinforce the existing functions (Olsson et al., 2004), and conserve the original goals and values. In contrast, transformability regards significant, qualitative changes to both the farm organization and functions provided, which imply a transition to a new configuration (Cumming et al., 2005; Daugstad, 2019). According to Darnhofer (2014) and Daugstad (2019), adaptability is functional either to bouncing back to reinforce the original farm configuration (robustness), or to bouncing forward to a new configuration (transformability), likely through a series of incremental adaptations overtime (de Kraker, 2017). The relevance of the analysis of capacities is not limited to a theoretical definition of resilience, but it allows for capturing the changing farming system's dynamics overtime. When putting into perspective the capacity of different farm management patterns to build resilience, it is possible to draw farm trajectories as constant processes of changes (Brédart and Stassart, 2017).

In our conceptualization, therefore, farms build resilience by undertaking manifold farm management strategies overtime, whose implementation depends on the resilience attributes belonging to the farms and the surrounding environment, and which shape diverse resilience capacities and alternative farm trajectories overtime.

3. Methodology

3.1. The case study

The case under study in this research is the extensive sheep farming system of Huesca, Aragón (Northeast Spain). This case study is under investigation within the SURE-Farm project.[1] The extensive sheep system of Huesca is located in a mixed flat and mountainous area in the sub-Pyrenees region of northern Aragón, and is characterized family farms, mostly based on family labour and strongly dependent on not-owned land (Pardos et al., 2008). In this region, sheep farms are oriented to lamb production. Lambs are sold as fresh meet, hence processing basically consists of slaughtering. Traditionally, small local slaughterhouses were the main buyers from farms, but in the last two decades bigger regional slaughterhouses took the floor. The key cycle of this system is the pregnancy and gestation of ewes, with offspring fattened and sold as lambs (Bertolozzi-Caredio et al., 2021). The ewe prolificacy rate can vary between 1 and 2 lambs born per year. The ewes can be fed with varying balance of grazing (planted pastures and natural grassland), forage and concentrates, and with water sources placed in the field. The feeding system determines the type of management, which ranges between (semi)extensive (more grazing based) to (semi)intensive (more stable-based). Traditionally, in this region the sheep farming was mainly extensive and often coupled with olive and almond orchards, and cereal crops, above all in flat lands where crop diversification is more viable. The average farm flock in the region is about 640 heads, but 50 % of farms had a herd size of between 200 and 1000 heads. However, there has been a drop in the total number of heads and the number of farms by 50 % over the last 20 years and 60 % over the last 25 years, respectively (Fau, 2016; Pardos et al., 2008). In 2019, Huesca accounted for about 900 sheep farms. The extensive sheep system of Huesca has undergone remarkable transitions to other production activities and arrangements, such as intensive pig fattening or crop production. In Huesca, there are networks that involve sheep farmers in cooperatives, associations and trade unions. Above all, cooperatives can serve sheep farms for manifold purposes, such as reinforcement of the bargaining power towards retailers, marketing innovations to strengthen consumer guidance and market positioning, experimentation of new technologies and breed selection, and knowledge exchange.

Previous research to this case study identified the main functions provided by extensive sheep farming (Spiegel, 2019; Becking et al., 2019). Basically, the main functions are the generation of farm income, food supply, the animal welfare, and the maintenance of natural resources and biodiversity. Particular attention is paid at the significant ecosystem services delivered, that are highlighted by other investigations in the region, including cultural ecosystem services and heritage (Rodriguez-Ortega et al., 2018). Other functions were also considered, such as good working conditions and attractiveness of rural areas.

There are significant challenges and trends facing the extensive sheep farms of Huesca, to which resilience is required. These challenges were analysed in former investigations (Spiegel, 2019; Soriano, 2020). During the last two decades, declining farm profitability, caused by low sale prices of lamb meat, and increasing production costs (feed, hired work), has been the main challenge. Reduced lamb meat consumption during the last decade has aggravated future perspectives. The food consumption statistics of the Spanish Ministry of Agriculture (MAPA, 2019) shows a continuous decrease of yearly lamb consumption from 2.1 Kg/capita in 2011, to 1.33 Kg/capita in 2019. Traditionally, sheep farms of Huesca have been oriented mainly to the regional market (local slaughterhouses). On the one hand, the sanitary normative introduced in 2007 has drastically reduced the local slaughterhouses due to the strict commitments. On the other hand, the decreasing consumption push farmers toward national retailers and the international market.

On the social side, concerns about rural depopulation, low availability of workers, lack of intergenerational renewal, and low quality of life of sheep farmers are widespread. The low quality of life is mainly due to the high work commitments required in extensive sheep farming, and the poor services provided in marginal areas. The main environmental challenges regard more frequent droughts (affecting also feed prices) and conflicts with wild fauna, especially wolves, which threaten the availability of pastures. In fact, due to natural reserves and parks regulations, the wolves' population is growing, resulting in increasing wolves' attack and economic losses. The institutional challenges are relevant too. The policy framework ruling the system originates mainly at European level, and relies on CAP[2] measures consisting of public aids and subsidies. However, national and regional legislation such as sanitary, peri-urban and natural parks regulations, integrate the framework. Since the decoupling of direct payments in 2003, CAP aids to sheep farmers have been reduced and become asymmetric, meaning that farmers who shifted to different productions still receive aids based on past sheep activities. In addition, increasing bureaucracy, commitments from the second pillar CAP measures, and environmental, sanitary and urban regulations have constrained the farmers' capacity to develop the business.

3.2. Data collection and analysis

To collect data, 14 semi-structured interviews were conducted with farmers. The characteristics of our sample are reported in Table 1. The interviews lasted between one, one and half hours. The interviewees were selected purposively to represent diverse farm characteristics and

Table 1
Farms and farmers' information.

ID Interviewee	Gender	Age	Livestock (sheep heads)	Land Rented + owned (ha)
F1	Male	41–65	400	120
F2	Male	41–65	3300	1500
F3	Male	41–65	470	210
F4	Male	18–40	300	50
F5	Male	41–65	700	1300
F6	Male	41–65	1000	340
F7	Male	41–65	370	400
F8	Male	41–65	1000	100
F9	Male	41–65	700	2500
F10	Male	41–65	1000	620
F11	Male	41–65	1200	300
F12	Male	41–65	1200	1120
F13	Male	41–65	800	250
F14	Male	18–40	1200	100

[1] SURE-Farm project: toward SUstainable and REsilient FARMing systems (https://surefarmproject.eu/).

[2] Common Agricultural Policy of the European Union.

management, by the help of the local administration. The agricultural office of the local administration in Huesca indicated a list of potential candidates. These were first contacted by telephone to ask their agreement, and then met in person for the interview. All the 14 candidates accepted. Unfortunately, no female farmers could be interviewed, impeding any gender-based conclusion. In our sample, the farms are led by male farmers, though their wives or daughters could (occasionally) help and participate in the farm's activities. However, the researchers were not able either to interview other household's members (only the male farmers were present for the interview), or to identify female farmers to include in the sample. In a certain sense, this is a representative feature of this sector, in which male gender is predominant. The interviewees were asked to describe farms' characteristics, to share their concerns on challenges they have been facing so far, and their farm management strategies over the last two decades.

Interviews were recorded and transcribed in Spanish, and an analysis was carried out following three steps corresponding to the paper's objectives: 1) a cluster analysis to identify farm management patterns; 2) a coding process to assess the resilience attributes; and 3) a further coding process to assess the resilience capacities. The methodological steps are described below.

3.2.1. *Identification of strategies and farm management patterns*

Firstly, farm management strategies implemented by the 14 farmers were identified across the farmers' interviews. These are the strategies mentioned by the interviewees when describing how they dealt with challenges in the last two decades. As a result, we obtained a list of 20 farm management strategies, as shown in Table 2. Farm management strategies are those operations aimed to (re-)organize the farms' structure and activities in order to meet the productive and economic goals of the farmers. Depending on their goal, strategies can be classified as cooperative when aimed to create collaboration between farmers, as diversification when aimed to open up alternative productive activities, as innovative when aimed to bring new technologies in the production cycle, or livestock management when specifically aimed to the type of productive system. As mentioned in the conceptual framework, resilience is likely to be determined by combinations of strategies rather than by single ones. These combinations of strategies, which we refer to as farm management pattern hereinafter, can differ between farms in the same farming system.

Therefore, based on the 20 identified strategies, alternative management patterns could be identified between the interviewed farms. Though the limited number of observations (14 interviews) would allow to qualitatively group farms based on the interviews' content, a hierarchical agglomerative cluster analysis of the 20 strategies was performed to support the identification of patterns. The cluster analysis is a technique frequently used to group observations (in our case, the interviewed farms) based on one or more indicators (in our case, the 20 strategies). The analysis is based on two principles: achieving the greater similarity within a group, and the greater dissimilarity between groups. A cluster, therefore, contains those farms implementing a similar combination of strategies. In order to cluster the 14 interviewed farms, we applied the following procedure.

The cluster analysis consists of three choices: the type of similarity matrix, the fusion algorithm, and the number of clusters to be selected. According to Weltin et al. (2017), our cluster analysis was based on a Gower dissimilarity matrix (reported in Appendix), due to its flexibility in handling binary data (such as our data on the 20 implemented strategies). Next, we applied a complete linkage fusion algorithm, as it was found to be successful in a wide variety of applications (Groβwendt and Röglin, 2017). Various indexes have been designed to select the proper number of clusters in a cluster analysis. Following Charrad et al. (2015), rather than using just one of them, we assessed a list of 30 indexes and we chose the number of clusters indicated by the majority of indexes. In our case, eight indexes[3] out of 30 suggested four clusters as the most proper number of clusters. The resulted clusters represent four different combinations of strategies, i.e., four management patterns, as reported in Table 3. A dendrogram of the cluster analysis is reported in Appendix.

Based on the different combination of implemented strategies, the four management patterns were defined as follows: extensification (more reliance on pasture-based), intensification (more stable-based), re-orientation (reduction of sheep and diversification), and conservation (farms' structure maintenance based on quality production).

3.2.2. *Analysis of resilience attributes*

The framework by Meuwissen et al. (2019) does not provide a specific list of resilience attributes to be assessed. In fact, the definition of the attributes to be evaluated depends strictly on the context and purpose of the study. For example, the Resilience Alliance proposes five attributes that, however, are not tailored to farm-level analysis and serve for assessments at broader scale (e.g. community, regions). Other research in agricultural contexts propose very different sets of attributes depending on the context of study (e.g. Cabell and Oelofse, 2012; Kerner and Thomas, 2014; Worstell and Green, 2017). Hence, we needed to develop resilience attributes adapted to our study's scope and purpose.

In order to identify the proper attributes, we applied the following procedure. First, we selected literature proposing resilience attributes in an agricultural context. This literature is reported in Table 4. Once a list of suitable attributes was defined, this paper's researchers compared the attributes against the farmers' interviews in order to: 1) eliminate those attributes for which no information could be gathered (out of scope), 2) merge those attributes that, in our case study, are strictly interconnected one another, 3) propose new attributes. For example, 'socially self-organized' (Cabell and Oelofse, 2012) and 'locally self-organized' (Worstell and Green, 2017) were merged into a single attribute (Farmers' network). Merging attributes allowed for avoiding overlaps between similar attributes that would focus on the same case study's aspects. The attribute 'Subsidies buffer 'was proposed by the authors due to the relevance of these economic resources in the case study (Soriano, 2020). As shown by the EU Farm Economics Overview (2018), in fact, extensive sheep farming strongly relies on public aids, which might imply a specific influence on farms' resilience. The attribute 'Alignment to legislation', instead, focuses on the regulatory framework. As a result, we identified and defined nine case-specific attributes, as shown in Table .4. This Table also shows the attributes gathered in the literature from which our nine case-specific attributes were derived.

In the following step, the nine resilience attributes were coded. Coding consists of the qualitative analysis of interviews to select fragments of text (quotes) and group them into meaningful labels named codes (Hsieh and Shannon, 2005; Glaser and Laudel, 2013). Each code contains information on a specific topic (e.g. a resilience attribute) from multiple sources of data (the transcribed interviews). The quotes were coded into the nine attributes. The content analysis, therefore, can be referred to as deductive since codes were identified prior to the coding analysis. The attributes were then divided as whether they enable or constrain a given management pattern, based on the farmers' description on what factors impede their strategic choice, or induce them to make one. For example, available labour force may enhance a pattern (e.g. intensification), while weakening another (e.g. extensification) due to scarce availability of workers in the latter pattern.

The results of the coding are reported by means of a bar chart indicating the number of selected quotes for each attribute, by management pattern. To mark the difference between enabling and constraining impacts, constraining attributes are signed by minus (−) instead of plus. According to Bertolozzi-Caredio et al. (2020), the measurement of quotes in a qualitative content analysis of a limited sample of farms does

[3] Hartigan, cindex, db, beale, sdindex, sdbw, gplus, ratkowsky.

Table 2
The 20 identified strategies across the 14 farms. The X indicates whether a farm (in the top row) has implemented the corresponding strategy (left column).

Type of strategy	Coded strategies	INTERVIEWED FARMERS													
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
COOPERATE for	*Learning & experimentation*								X	X			X		
	Input sharing								X					X	
	Trade & marketing						X		X	X		X	X		
	Technical support & advice	X		X								X	X	X	
DIVERSIFICATION to	*Intensive pig*	X	X												
	Perennials (Almonds/Olive trees/ Vine)	X		X		X	X	X			X			X	
	Agricultural crops	X	X	X	X	X		X		X	X				
	Calf fattening									X			X	X	
	Agritourism													X	X
	Off-farm job	X	X							X					
INNOVATION by	*Insemination & breed selection*					X	X	X	X		X	X			X
	Virtual or drone shepherd	X			X	X				X		X			
	GPS & video control					X			X						X
	Forage selection										X	X			
	Unifeed[a] *and new structures*			X		X							X		
LIVESTOCK PRODUCTION MANAGEMENT	*Reduce livestock*	X		X		X						X		X	
	Quality products	X			X	X	X		X			X			
	Intensification		X			X		X			X				
	Extensification								X	X					X
	Reserves and self-feeding		X									X	X	X	X

X = the coded strategy is implemented in the relative farm, otherwise it is not.
[a] Unifeed is a feeding technique based on a mechanical system to ensure balance feed.

not aim to provide quantitative evaluation, but to highlight the main directions in farmers' opinions, and which aspects are more emphasized. Quantitative interpretations should be accompanied by the qualitative content in the analysis of findings, but exclusive quantitative conclusions should be avoided.

3.2.3. Analysis of the resilience capacities

In the third step, the three resilience capacities were analysed through further coding. During the interviews, farmers described the impact of implemented strategies on their own farms' structure, organization and delivered functions. We analysed such description to learn about the impact of strategies in each management pattern, by coding explicative and meaningful quotes into three codes of robustness, adaptability and transformability. Thus, a quote contains a description of a strategy's impact (or an aspect of it) on the farm, which needs to be referred to a resilience capacity. As described in the conceptual framework, robustness is the capacity to withstand stresses without changing structure or configuration; adaptability is the capacity to cope with challenges by implementing minor changes, but without relevant change in structure and identity; and transformability is the capacity to cope with challenges by moving to another configuration through relevant change in farm structure and identity.

Importantly, farmers do not explicitly refer to robustness, adaptability and transformability in their narratives, these being mainly academic concepts. Therefore, to infer information on which resilience capacities emerged behind the quotes, we developed a deductive scheme based on three questions to be answered while coding, as reported in Fig. 1. These questions were answered for each quote explaining an aspect of the strategy's impact on the farm. Each quote, therefore, relates to one capacity. This implies that a strategy, which can be described by many quotes, could relate to all capacities (although likely to different extents).

To infer whether a particular quote was referred to robustness we wondered: "Does the quote indicate that the strategy allows for assimilating change without altering farms' structure and functions?". If yes, the quote had to be coded as robustness, otherwise the following question had to be answered: "Does the quote indicate that the strategy permits to adjust or re-organize the farms' configuration and productive combination without significantly change functions and identity?". If yes, the quote had to be coded as adaptability, otherwise the last question had to be answered: "Does the quote indicate that the strategy leads to radical changes in farms' trajectory, while still delivering important functions?". If yes, the quote has to be coded as transformability, otherwise we considered the strategy not able to deliver the essential functions of the system, i.e., non-resilient. As a result, the quotes were grouped across three codes of robustness, adaptability and transformability. The three capacities were studied by management pattern. The coded quotes have been reported through a frequency table, where frequency was measured as the percentage share of quotes referred to a capacity on the total quotes selected within a management pattern.

4. Results

The cluster analysis revealed four alternative farm management patterns based on different combinations of strategies, namely extensification, intensification, re-orientation, and conservation. Fig. 2 shows the quotes coded in the nine resilience attributes, by management pattern. The figure shows a divide between patterns. In extensification and conservation patterns, farmers put emphasis in attributes like '*Farmers' networks*', '*Match with natural resources*', '*Subsidies buffer*', '*Farmers' tradition & perspectives*', and '*Learning capacity*'. Instead, regarding intensification and conservation patterns farmers emphasized the role of '*Available labour force*', '*Financial resources*', '*Alignment to legislation*', and '*On-farm diversity*'.

Fig. 3 shows the quotes coded in the three resilience capacities. Adaptability is emphasized in all patterns, especially extensification and re-orientation. However, the patterns intensification and re-orientation seem to emphasize mainly transformability, whereas the patterns conservation and, to a lower degree, extensification stress robustness.

Nonetheless, the emphasis put by farmers in diverse aspects of resilience cannot explain the interdependences between farm management, attributes and capacities, which follow different dynamics depending on the pattern. In the four subsections below, therefore, we describe the rationale behind the four management patterns and their corresponding interplays with resilience attributes and capacities. The analysis is supported by selected quotes underlying specific aspects discussed in the section: these quotes have been translated from Spanish to English.

Table 3
Resulted clusters and strategic combinations. The column on the left shows the identified clusters with the corresponding interviewed farms. The top row reports the identified strategies used in the cluster analysis. The numbers in the table (0,1,2,3) indicate how many of the farms included in a cluster have implemented the corresponding strategy. The right column shows the average livestock and land size in each cluster.

Clusters	Strategies									
	Learning & experimentation	Input sharing	Trade & marketing	Technical support & advice	Intensive pig	Perennials	Agriculture	Calf fattening	Off-farm job	Agritourism
Intensification (F2,F7,F10,F13)	0	1	0	1	1	3	3	1	1	1
Extensification (F8,F9,F12,F14)	3	1	3	1	0	0	1	2	1	1
Re-orientation (F1,F3,F5)	0	0	0	2	1	3	3	0	1	0
Conservation (F4,F6,F11)	0	0	2	1	0	1	1	0	0	0

4.1. *Extensification pattern*

Farmers belonging to the pattern extensification indicate strategies leading to more extensive and self-feeding systems, which does not regard a shift from 'non-extensive' to extensive, but from 'already extensive' to 'more pastures-based'. This strategy relies on the advantages of using available natural resources instead of external feed input, which is crucial for costs management and self-sufficiency. Such pattern is characterized by many innovations (e.g. insemination, GPS/video control and virtual shepherds), and by cooperation for learning & experimentation.

The opportunity to extensify further the farm depends on the availability to and accessibility of pastures. In fact, farms in the extensification pattern show the highest average land size (see Table .3). The '*Match with natural resources*', therefore, is a crucial attribute to develop along this path. Otherwise, other management patterns are likely to be undertaken. The effect of '*Match with natural resources*' can be well explained by the following quote, which underlines the role played by this attribute in farm management:

> "Regarding the capacity to increase the activity, sometimes you need to stop, mainly in extensive farming. Because the natural resources are limited and located in certain areas, and you cannot overcome this boundary, but you can find other ways". [F12, 1200 heads, 1120 ha]

Extensive management is very time demanding and requires hard work, above all in light of the increasing wolves attacks from which flocks must be protected. This is the main reason behind the several innovations that are applied in this pattern. Consequently, '*Learning capacity*' seems crucial in the extensification pattern. This capacity is enhanced by the farmers' willingness to engage in learning networks for exchanging knowledge and experiences, relying on consultants and collaborating with research centres for experimentations (e.g. breed selection, virtual shepherd). These learning networks often follow farmers' cooperatives initiatives, such as learning group meetings, or learning trips to visit innovative systems in other regions. For example, this farmer explains:

> "We (the farmers) have training trips, to visit and learn from different management systems. This is important, above all for younger farmers, to learn different ways to improve the extensive management without necessarily following the 'conventional' strategy, that is, to grow, grow and grow". [F12, 1200 heads, 1120 ha]

Farms belonging to the extensive management patterns rely also on the traditions linked to lamb production in this region. The will to carry on the business following "the traditional way" is a determinant of this pattern. Likewise, the farmer's perception of continuity in the farm contributes to the decision to pursue the necessary adaptations to enlarge the farms. This farmer explains decision-making based on future perspective:

> "Obviously, I make investment decisions by thinking that my son will take over the farm. However, if my son does not go on, I should rent or sell my farm. Even in this case, investments may add value, for example through new infrastructures and mechanization." [F12, 1200 heads, 1120 ha]

The extensification pattern contribute to robustness and adaptability because it seems to preserve and improve original functions such as the quality of life (by innovating pasture management), the ecosystem services provided (by extending pastures) and, to some extent, the farm income (by exploiting added values and reducing feeding costs), while adjusting farms' structure and assets. An evidence of adaptability in extensification patterns is shown in this quote:

> I have friends who adapted the farm by pursuing extensification and enlarging the livestock (…) I can see that this kind of family farming (extensive farming) is resisting, because it has adapted." [F1, 400 heads, 120 ha]

In fact, to improve and innovate the pastures management the cluster extensification shows much more adaptability. The original structure is somewhat reinforced. For example, grazing livestock is a very time demanding activity and requires hard work commitments by the farmer. Consequently, farmers agreed that extensive livestock might decrease significantly the quality of life as there is no time left for personal needs. This farmer explains how innovations (e.g. the use of virtual shepherd and electric fences on pastures) can improve the quality of life by reducing work commitments, and the need of workforce:

> "To improve the quality of life is one of the priorities of this sector. Much is changed by the use of, for example, virtual shepherds and mobile, electric fences. My father went to work on pastures every day, but now it's not necessary anymore." [F11, 1200 heads, 300 ha]

4.2. *Conservation pattern*

Farmers belonging to the pattern conservation did not express any evident intention to intensify/extensify, or to diversify (there is the lowest degree of diversification), but farmers are more oriented to quality production. These farms opted for the exploitation of the intrinsic added value of extensive farming, which is materialized by the Protected Geographical Identification (PGI) label 'Ternasco de Aragón[4]', in order to combat low sale prices. To do so, affiliation to cooperatives is fundamental. They also implemented some innovations for pasture management and breed selection. These farms also show the lowest extension of land on average.

[4] The *Ternasco de Aragón* PGI is a quality label set in 1996, and delivered by the Ternasco de Aragón ruling council to those farms following a specified production protocol to ensure a typical, quality production. http://www.ternascodearagon.es/consejo-regulador-ternasco-de-aragon/.

Strategies										Characteristics	
Insemination & breed selection	Virtual or drone shepherd	GPS & video control	Forage selection & CRISPR	Unifeed and new structures	Reduce livestock	Quality products	Intensification	Extensification	Reserves and self-feeding	Average livestock (no. of heads)	Average land (hectares)
2	0	0	1	0	1	0	3	0	2	1368	693
2	1	2	0	1	0	1	0	3	2	1025	955
1	2	1	0	2	3	2	1	0	0	523	543
2	2	0	1	0	1	3	0	0	0	833	230

Farmers' networks are particularly relevant for farms in the conservation pattern to deal with increasing competitiveness in the market and decreasing lamb meat consumption. The core of farmers' networks in the area are the cooperatives. A relevant role played by cooperatives in Huesca regards the farmers' marketing capacity. In fact, through the cooperatives, farmers can produce lamb under a PGI label and increase their bargaining power towards retailers.

In general, sheep farms depend on a large amount of subsides (EU Farm Economics Overview, 2018). Accordingly, in the case under study, subsidies are particularly important for extensive farms that are less efficient and less competitive in the market. The attribute '*Subsidies buffer*' enable especially the patterns conservation and extensification. The CAP direct payments represent a very important resource to compensate low profitability, as described by this farmer as following:

> "I have ensured a basic payment at the end of the year, who has the same right (out of agriculture)? Who, in my generation, gain a payment like this? In practice, no sectors out of agriculture. Then, you can decide to use this resource to survive, or to grow."[F14, 1200 heads, 100 ha]

The management pattern conservation appears to promote mainly robustness due to its capacity to maintain the original farms' organization through quality production despite price drops and decreasing consumption. In previous investigations (Ashkenazy et al., 2018), the strategy of quality production could be related to transformability. Instead, our evidence suggest that this strategy does not imply drastic changes to the farm configuration and, therefore, it does not appear as a transformation. Such interpretative difference could be due to different scale of analysis (farm level versus regional scale), or farms' original structure. For instance, consistent with Sans et al. (1999), this farmer explains that the choice to sell under a quality label does not imply any change in the production cycle, because the basic requirements (e.g. breeds, maximum weight of lambs to be sold) are already part of the traditional production methods:

> "My production must be certificated by a cooperative to be sold as 'Ternasco de Aragón', but it does not imply particular changes on-farm. When a buyer comes to my farm, if I'm into the cooperative I sell as Ternasco de Aragón, otherwise as normal lamb meat. The breed (and the farm production method) is the same." [F7, 370 heads, 400 ha]

4.3. Re-orientation pattern

Farms belonging to the reorientation pattern depict a gradual transition from extensive lamb production to other activities. The pattern is characterized by a reduction of the livestock size on the one hand, and a high diversification on the other hand. In fact, these farms show the lowest average livestock size. Formerly, the process of livestock reduction has occurred gradually over the last 15 years as a reaction to the reduction in the CAP payments scheme and lamb meat consumption. Later on, these farms re-oriented to diverse activities (e.g. cereal crops, almonds, intensive pig) to compensate for the low profitability of lamb production. Importantly, the sheep extensive farming has continued in any case.

A common characteristics of this farms is that they were already diversified to some extent before the re-orientation, suggesting that '*On-farm diversity*' makes farms more flexible and suited for further diversification. When the economic pressure of decreasing lamb consumption and profitability have started becoming unsustainable, other agricultural activities carried on the farm has gained greater importance. The re-orientation process requires financial resources, but it is also promoted by the availability of workers willing to enter the sector, which can be either local or migrant. In fact, it is hard for a farmer to carry on both extensive livestock and, for example, extensive almonds and crop production, even with the familial support. This farmer, for instance, highlights the different availability of workers between alternative patterns:

> "At the moment that you need to hire workers for handling almonds or olive trees, it is not hard to find them. But, if I had a thousand sheep to bring on pastures, it would be hard to find a shepherd. Besides, it would not be profitable". [F3, 470 heads, 210 ha]

The attribute '*Farmers' tradition & perspective*' appears relevant for any farmers maintaining extensive sheep farming, but becomes particularly evident in the re-orientation pattern in which the flock is reduced consistently, but not eliminated, as explained by this farmer:

> "No, we did not want to stop sheep farming although this activity is very time demanding, so we decided to reduce livestock (...) About stopping sheep farming? No, no, no. I don't contemplate this option, even if sheep is time demanding". [F1, 400 heads, 120 ha]

Farms re-orienting production adjust the livestock size to cope with the reduction of lamb meat consumption and the low sale price, which appears to fit with adaptability. At the same time, these farms address new productions and reverse the relative importance of sheep farming into the farm business, which makes the overall process more related to transformability, because the original functions somewhat change. The following quote describes the re-orientation:

> "I believed that we could deal with lower lamb meat consumption and low prices by reducing livestock size: the lesser the lamb on the market, the higher the price. But it did not work, so we had to improve the farm by diversifying and moving productive assets to other types of activities other than lamb production, such as intensive crop farming." [F3, 470 heads, 210 ha]

The impact of the re-orientation pattern could be ambiguous, as it reduces the lamb production while setting up different productive activities. On the one side, it reduces but maintains socio-ecological functions linked to pasture-based management and food provision; on the other it provides more jobs and profitability by running more viable activities (e.g. intensive pigs or crops). Nevertheless, it is challenging to

Table 4
Attributes' definitions and conceptual linkages with the literature.

The identified Attributes	Our definitions	Conceptual linkages to attributes defined in previous research
On-farm diversity	The availability of different sources of revenue, means of productions, and skills on the farm, which refers both to functional and response diversity.	'Response Diversity' (Kerner and Thomas, 2014) 'Response Diversity' & 'Optimally Redundant' (Cabell and Oelofse, 2012; Reidsma, 2019) 'Complementary Diversity' (Worstell and Green, 2017) 'Diversity' (Carpenter et al., 2012) 'Diversity & Redundancy' (Biggs et al., 2012)
Alignment with legislation	The extent to which farms are adjusted and adapted to the requirements of the existing legislation and the regulatory framework..	'Diverse Policy' & 'Legislation coupled with local and natural capital' (Reidsma, 2019)
Financial resources	Revenues and savings that constitute the economic buffer in case of shocks or a resource for investments of the farm.	'Abundance/Reserves' (Kerner and Thomas, 2014) 'Reasonably Profitable' (Cabell and Oelofse, 2012) 'Responsive Redundancy' (Worstell and Green, 2017) 'Economic Resources' (Darijani et al., 2019)
Available labour force	The availability of workers to enter the sector and their skills.	'Human Capital' (Cabell and Oelofse, 2012; Darijani et al., 2019) 'Support Rural Life' (Reidsma, 2019)
Learning capacity	The farmers' propensity to learn, exchange knowledge with others, engage in group learning, and be pro-active in experimentation processes.	'Learning Capacity' (Kerner and Thomas, 2014) 'Reflective & Shared Learning' (Cabell and Oelofse, 2012; Reidsma, 2019) 'Social Learning' (de Kraker, 2017) 'Learning & Experimentation' (Biggs et al., 2012)
Farmers' traditions & perspective	A sense of attachment to sheep farming due to traditions, familial heritage, identity and/or emotions. This includes the farmers' perception of farm continuity	'Honor Legacy' (Cabell and Oelofse, 2012) 'Succession and successors effects' (Inwood and Sharp, 2012) 'Conservative Innovation' (Worstell and Green, 2017)
Subsidies buffer	CAP direct payments and other aids bringing exogenous economic resources into the farms..	'Abundance/Reserves' & 'False subsidies' (Kerner and Thomas, 2014) 'Diverse Policy' (Reidsma, 2019)
Matching with natural resources	Availability of and accessibility to pastures, grassland and forage lands, and the ability to use them.	'Coupled with Local and Natural Capital' (Cabell and Oelofse, 2012; Reidsma, 2019) 'Ecologically self-regulated (works with nature)' (Worstell and Green, 2017)
Farmers' network	The farmers' propensity and capacity to build relations, to self-organize, and to address coordinated actions for specific responses (strategies).	'Collaborative Capacity' & 'Connectivity' (Kerner and Thomas, 2014) 'Socially Self-organized' & 'Appropriately Connected' (Cabell and Oelofse, 2012) 'Modular Connectivity' & 'Locally Self-organized' (Worstell and Green, 2017) 'Connectivity' (Biggs et al., 2012)

determine if functions related to biodiversity, natural resources, and ecosystem services have been affected positively or not by the re-orientation. It could be due to, for example, the kinds of diversification, which in some cases are found to be ecologically positive (Bell et al., 2014). As Sanderson et al. (2013) pointed out, crop-livestock diversification can enhance resilience and sustainability by delivering additional ecosystem services. To this regard, however, specific investigations are needed.

4.4. *Intensification pattern*

Farmers belonging to the intensification pattern describe a shift from extensive management based on grazing, to a 'more intensive' management of livestock based on stables, and less dependence on pastures, with a low degree of innovation (limited to insemination and forage selection), and no cooperation (except F13). Most of the land is usually dedicated to intensive crops for feeding the livestock on the stable, and/or diversified to agricultural and perennial crops. In this pattern, there is the highest average livestock per farm, which is likely due to the increasing stocking rate (number of sheep per hectare) typical of intensive productions.

The choice to intensify originates from the need to increase profitability and competitiveness on the one hand, and improve the quality of life on the other. Accordingly, these farmers are concerned about the effort required in extensive management, and do not show particular attachment to the traditional way of producing lamb. Besides, it is interesting to note that these farmers neither show learning capacity, nor engage in farmers' networks. However, two important attributes underlying this pattern are the availability of workers and financial resources. In fact, while more efficient, intensive sheep production requires a significant rise in specific costs (e.g. feed and sanitary costs) and investments in stables and a different feeding system. This farmer explains:

> "The issue is that if you leave extensive farming, that is the less costly management, then you move to intensive farming that implies higher feeding costs, and so you need a basic, higher profitability to cover the costs". [F6, 1000 heads, 340 heactres]

The 'Alignment to policy' remarkably favours the transition from extensive management to intensification (and re-orientation too), especially due to a couple of factors. Firstly, the decoupling of basic payments does not bind farmers to maintain the sheep extensive production, allowing farms to gain payments for sheep even if sheep production is not standing anymore. Secondly, the connection of CAP payments to hectares aggravates the competition between extensive management of land, and other diversified or more intensive productions. For instance, this farmer explains the misalignment of CAP as following:

> "The new CAP does not bind you to certain productions or yields, so you can put cereals, forages, sweet pepper or whatever, because you already have the right on those basic payments, and you gain the same aid (….), Those who owned sheep, and then stopped or reduced the sheep livestock, are still gaining aids on the original amount of sheep". [F5, 700 heads, 1300 heactres]

According to Ilea (2009), the pattern intensification might reduce characterizing functions of pasture-based livestock, such as animal welfare, ecological benefits and landscape conservation, which underline the transformability of the pattern. Although the potential loss in traditional functions could remark an approach to what is called 'non-resilience' (Cumming and Peterson, 2017), such interpretation could be biased by subjective assumptions on what is desirable or not, which are intrinsic in resilience assessments (Ashkenazy et al., 2018). In fact, as proven also by previous research (Riedel et al., 2007), we should consider that while reducing some functions, this pattern strengthens

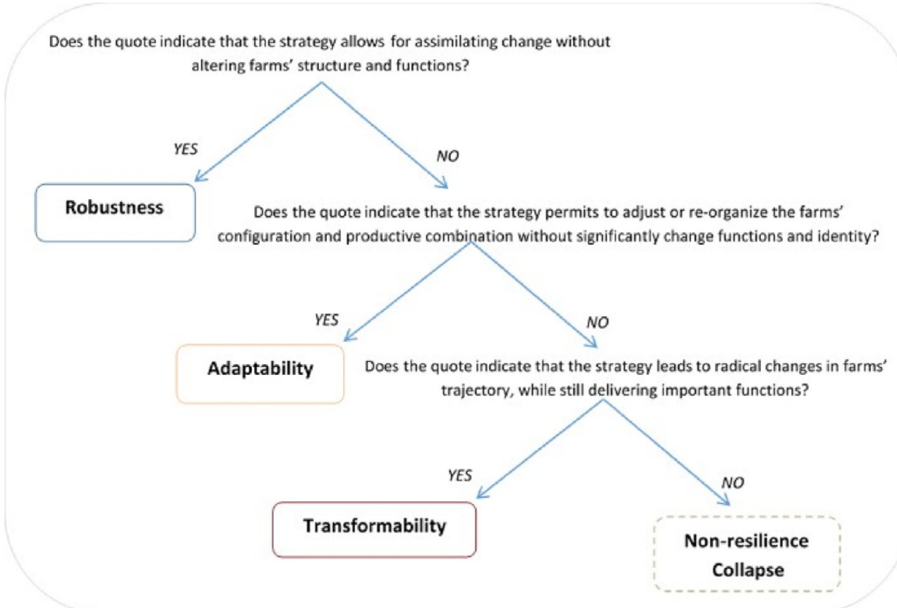

Fig. 1. Deductive scheme to infer resilience capacities.

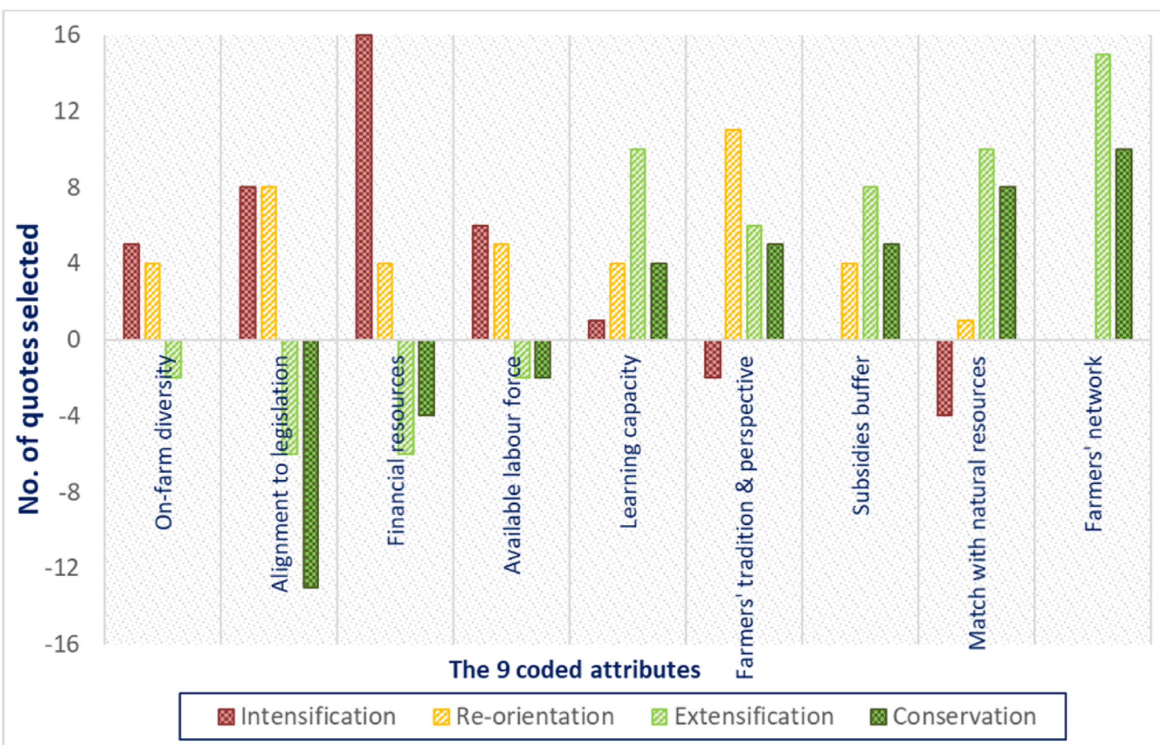

Fig. 2. The no. of quotes coded into the resilience attributes, by management patterns.

others such as food production, farm income, and job provision.

5. Discussion

In our case study, we found that sheep farms are able to build diverse resilience capacities to keep delivering important functions through alternative trajectories, whose difference strongly depends on the resilience attributes on which the farms rely. We found clear distinction among resilience attributes determining transformative patterns like intensification and re-orientation (e.g. labour availability and financial resources), and those favouring the conservation or re-adjustment of traditional extensive management (e.g. match with natural resources and farmers' networks). All farm management patterns show some degree of adaptability. However, conservation and extensification patterns appear to reinforce robustness, whereas patterns of intensification and re-orientation address mainly transformability.

The literature usually addresses single trajectories shaping a farming system dynamic, such as intensification of extensive systems (e.g. Caraveli, 2000), the development of labelled quality products in conventional production systems (e.g. Iraizoz et al., 2011), or the diversification from livestock to crop productions (e.g. Sanderson et al., 2013). Rather, our analysis highlights that more trajectories can

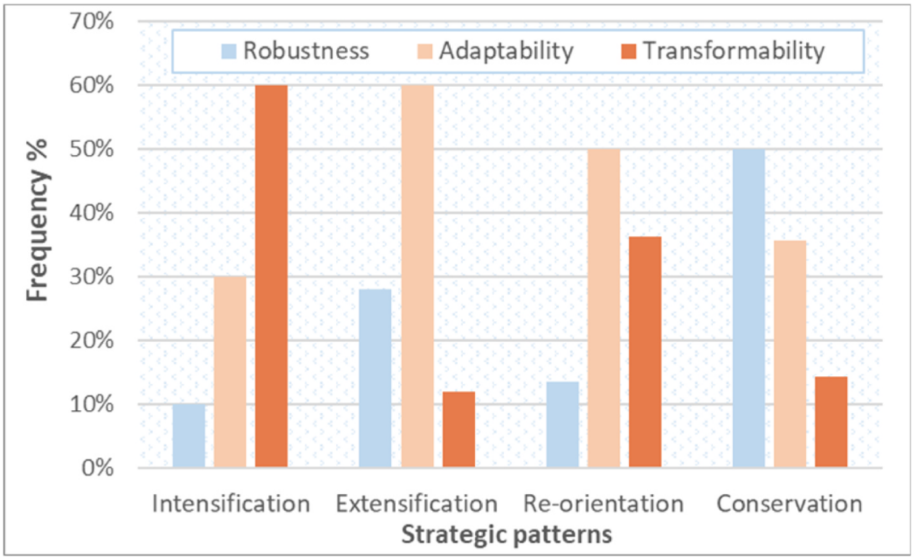

Fig. 3. The % frequency of quotes coded into the resilience capacities across the four farm management patterns.

characterize the same farming system simultaneously, due to all the alternative farm management patterns to be potentially pursued by farms. For example, Perrin et al. (2020) identified a single farming model (i.e. grazing-based) as more resilient than others in a dairy system, while we found that, at farm level, alternative patterns of extensification, conservation, re-orientation, or intensification can contribute to build resilience in Huesca, but through diverse capacities. This is consistent with de Roest et al. (2018), who show that agricultural systems encompass different types of farms operating in diverse conditions and employing different management models. Accordingly, Huttunen (2019) underlines the importance of the interplays between farms undertaking different models for the overall development of a rural system, whereas Bruce (2018) highlights that the existence of alternative pathways can favour the farm continuity.

Stringer et al. (2020) explain that different types of farms (e.g. conventional/traditional, large/small scale) emphasize economic, environmental or socio-cultural imperatives to a different extent (e.g. conventional, large scale emphasizes productivity and profitability), but sustainability (and the balance among its dimensions) should be sought at overall scale. Accordingly, while building its own resilience, a single farm could be unable to deliver equally all the desirable public/private services, though the whole farming system might be. This evidence is relevant for either practitioners or policymakers, since farms' resilience does not appear as a matter of a unique, successful farm model to be identified and enhanced, but as an array of alternative and equally valuable solutions that can be flexibly tailored to diverse farming needs and characteristics.

Following this reasoning, a further consideration is that, while sheep farms seem able to build their own resilience by following diverse alternatives, there could be significant implications at farming system scale in terms of functions to be delivered. Farm trajectories determine dynamics at higher scale (Debolini et al., 2018), including changes in land use (Celio and Gret-Regamey, 2016), agro-ecosystems (Schirpke et al., 2017), and cultural landscape (Schulp et al., 2019). Yet, our results suggest that the interplay and balance among alternative trajectories should be considered when assessing the resilience of farming systems. As Andersen (2017) indicates, in order to design the agricultural landscape, all the patterns involved should be targeted to some extent.

Consistent with previous research in the case study area (Becking et al., 2019), our findings indicate that the socio-economic and policy environment seems to favour the transitions from extensive to intensive and crop farming, which could have serious implications for the functions delivered by the system overall. Policymakers may be called to define the system orientation which any intervention should be addressed to (Ashkenazy et al., 2018), which might reflect the policymakers' understanding of what is desirable and what is not in terms of functions to be delivered (Nelson et al., 2007). Hence, an indication for policymakers could be the need to define the extent to which patterns are desirable in Huesca, based on the functions that policymakers (and the society) expect to be delivered by the whole system in the future. In our understanding, this appears as a key step to operationalize an evidence-based resilient policy in the region. As Sneessens et al. (2019) pointed out in the context of economic vulnerability of farming systems, policy could promote not only the diversity into the farms, but also the diversity among farms.

6. Conclusions

This paper aimed to explore the alternative management patterns undertaken in the extensive sheep farming system of Huesca (northeaster Spain), and to understand the resilience attributes enabling them, and the emerging resilience capacities. Our findings demonstrate that, within the extensive sheep system of Huesca, farms build resilience by following very diverse farm management patterns, namely extensification (more reliance on pasture-based), intensification (more stable-based), re-orientation (reduction of sheep and diversification), and conservation (farms' structure maintenance based on quality production). The patterns extensification and conservation mainly contribute to adaptability and robustness to reinforce the original farms' structure, whereas the patterns re-orientation and intensification lead to much more transformability.

We found clear distinction among resilience attributes determining transformative patterns like intensification and re-orientation, and those favouring the conservation or re-adjustment of traditional extensive management. Specifically, match with natural resources, the farmers' network, and the traditions and perspective behind sheep farming are crucial for preserving or extensify existing farms, whereas learning capacity is crucial for adaptability in extensive farms. In contrast, financial and labour resources, and on-farm diversity characterize re-oriented and intensified farms.

While investigating the alternative farm management patterns to build resilience, this paper casts light on the significant diversity of ways through which farms keep delivering functions within the same farming system that, by our interpretation, could be considered as a strength of resilient systems. Equally, the paper suggests that predominant trajectories (as intensification or re-reorientation in our case) are likely to affect the overall capacity of a system to keep delivering functions, highlighting the importance to balance the diverse patterns to ensure the resilience of the extensive sheep system of Huesca as a whole.

Author contribution

Bertolozzi Caredio, Daniele: Writing – Original Draft, Investigation, Visualization, Formal Analysis, Conceptualization, Methodology, **Garrido, Alberto:** Supervision, Writing – Review & Editing, Conceptualization, **Soriano, Barbara:** Investigation, Visualization, Methodology, Conceptualization, **Bardaji, Isabel:** Investigation, Writing – Review & Editing, Conceptualization.

Declaration of competing interest

None.

Acknowledgment

This research has been carried out within the framework of the SURE-Farm Project - Towards SUstainable and REsilient EU FARMing systems, a H2020 project funded by the European Commission (no.727520).

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