Agricultural Systems 186 (2021) 102983

Contents lists available at ScienceDirect

Agricultural Systems

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

Drivers of change in mountain agriculture: A thirty-year analysis of trajectories of evolution of cattle farming systems in the Spanish Pyrenees

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ARTICLE INFO

Keywords:
Sustainability
Longitudinal analysis
Tourism
Agricultural policy
Household
Resilience

ABSTRACT

Mountain regions are characterized by complex interrelations between human and natural systems. Political and socioeconomic drivers at various scales affect mountain farming systems functioning, resulting in farm structural changes (management, structure and economic performance). Longitudinal studies help fully understand the dynamics of these systems, identify their main drivers of change, and prepare for foreseeable future events. This study aimed to (i) analyse the main changes of cattle farming systems in the Pyrenees from 1990 to 2018, (ii) identify the different trajectories of farm evolution and (iii) to determine the key drivers of those trajectories at global, regional and household levels. We monitored 50 cattle farms in three valleys with different socioeconomic contexts, which were surveyed in 1990, 2004 and 2018. We observed clear changes regarding land and labour production factors. Over the 1990–2004 period, farming systems experienced a land use extensification (one-month increase of grazing season) and capital intensification (55% increase of livestock units (LU) per work unit (WU)) processes, coinciding with a switch from dairy to beef farming with on-farm fattening. Over the 2004–2018 period, land use stabilised but the capital intensification process went on (17% increase of LU/WU) while farms reduced their inputs (43% decrease of feeding costs per LU), in parallel to the decreasing importance of fattening. These changes allowed to globally maintain stable farm economic margins (around 40,000 €/WU). Multivariate statistical analyses enabled to identify four trajectories of evolution, three of them specific to each valley under study and a common across-valleys trajectory. These trajectories resulted from the interaction between global and regional drivers and household particularities. The CAP played a major role at the global level (representing an average of 70% of farm gross margin in 2004 and 2018), while tourism development and household characteristics were the main drivers at the regional level. Several farms responded by maximising their output related to the most limiting production factor (i.e. agriculture land or labour) in each valley. However, the across-valleys trajectory, which comprised 44% of farms, showed limited changes during the studied period. The ability of farms to maintain their adaptation capacity while keeping economic and social viability will determine the future of cattle farming in the region. Our findings highlight the need of reorienting agricultural policies towards promoting new entrants into mountain farming, better integrating CAP instruments with other EU sectorial policies and improving farm monitoring by disaggregating follow-up processes by agroecosystem and management regimes.

1. Introduction

Mountain agroecosystems, which constitute a third of Europe's land area and hold 17% of its population, deliver crucial provisioning, regulating and cultural services to society (European Environment Agency, 2010; Patru-Stupariu et al., 2020) In particular, mountain livestock farming systems play a key role in: environment and climate regulating services, such as forest fires prevention, conservation of biodiversity, preservation of water and soil quality and carbon storage; cultural services such as maintenance of cultural landscapes

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https://doi.org/10.1016/j.agsy.2020.102983
Received 9 July 2020; Received in revised form 14 October 2020; Accepted 16 October 2020
Available online 22 October 2020
0308-521X/

(heterogeneous mosaic), gastronomy heritage and traditional management practices (transhumance) that maximize the use of natural feed resources all year round; and provisioning services such as production of quality products linked to mountain territories while also contributing to maintain population and economic activity (Bernués et al., 2014; Faccioni et al., 2019; Ryschawy et al., 2019). Mountain livestock farming systems are highly diverse complex social-ecological systems characterised by a dynamic equilibrium of multiple human and nature components, in which maintaining their functions requires a constant adaptation process (Holling, 2001; Simane et al., 2013). The resilience and adaptive capacity of farming systems to cope with external and internal changes will determine their ability to maintain their functioning over time or not (Lomba et al., 2019; Meuwissen et al., 2019). The evolution and transitions of these systems are conditioned by and, in turn, condition human activities at global, regional and household levels (Lambin et al., 2001). The extent of farm adaptation to policy drivers and socioeconomic changes on those three levels determine different trajectories of evolution of rural areas in general and livestock farming systems in particular (Bernués et al., 2014; Brunner and Grêt-Regamey, 2016; Valbuena et al., 2015). The necessary changes that occur during the adaptation process on the different trajectories lead to modifications of the services, resources and goods provided and regulated by livestock systems (Ghahramani et al., 2020; Schirpke et al., 2017). Thus, understanding the diversity of current states and past trajectories of mountain livestock farming systems can generate relevant knowledge to better contextualise and support optimal agricultural policy strategies for future scenarios. This understanding becomes particularly relevant in the worrying context of farmer ageing and decreasing mountain livestock farming which is taking place across European mountains (MacDonald et al., 2000). Specifically in Pyrenean villages, the farming sector was traditionally organised in farm households, where the family house and business used to be inherited by the firstborn or, if there were no successor, the farm collapsed (Mottet et al., 2006).

Previous research on livestock farming systems evolution has shown that farms adapt to global socioeconomic context, local/regional factors related to production potential and market access, household structure, economic and social characteristics (García-Martínez et al., 2009). At the global context of European livestock farming, the Common Agricultural Policy (CAP) has played and plays a major role in shaping the socioeconomic context. The CAP has undergone several major reforms, moving from coupled subsidies to hectares or animal heads to decoupled subsidies and a focus on rural development, to lately promote more integrated approaches that incorporate the support for young farmers and the provision of public goods (Détang-Dessendre et al., 2018; Veysset et al., 2005). In mountain areas, the CAP has contributed to a process of specialization, technological development and reduction in the number of farms, while also experiencing a stagnation of farmer's incomes (Terres et al., 2015; Veysset et al., 2019). At the regional level, similarly to most European mountain areas, the Pyrenees have experienced a rural-urban migration seeking for better economic opportunities, which is known as one of the main drivers of agricultural abandonment, particularly in remote and marginal mountain areas (Lasanta-Martínez et al., 2005; Lasanta et al., 2017; Mottet et al., 2006). Simultaneously, the disappearance of the traditional sheep transhumance system led to the replacement of sheep by beef cattle (Garcia-Ruiz and Lasanta-Martinez, 1993), which is now the predominant type of livestock in the Spanish Pyrenees. Meanwhile, in the last decades mountain tourism has become a main economic activity and a major driver of socioeconomic development of many mountain regions. Tourism occasionally supports agriculture with extra income for the household (Casasús et al., 2014; Cocca et al., 2012; Genovese et al., 2017), but competes in other cases for the labour force (Bernués et al., 2014). This competition for the labour force may be decisive for the future of farming in mountain areas where tourism development is usually highly supported by policy statements. At the household level, the ageing of farmers, the absence of succession and the preferences of potential successors for a more qualified and less hard-working condition employment have been extensively proved to generate a transition out of agriculture (e.g. Davis et al., 2009; MacDonald et al., 2000). In this sense, farmers' characteristics can be decisive in determining their adaptive strategy (Darnhofer, 2010; van Vliet et al., 2015), which is crucial to understand how and why different paths are followed under common regional and global environments.

In this complex context, longitudinal studies can help to understand the changes that have occurred in the past and identify the main drivers, with the final aim of forecasting changes under possible future scenarios (Brunner and Grêt-Regamey, 2016; Dearing et al., 2010; Santos-Martín et al., 2013; Valbuena et al., 2015). Despite the irreplaceable role of livestock farming systems in providing crucial services in mountain areas only few studies have analysed the long-term evolution of mountain livestock farming systems in Europe (García-Martínez et al., 2009; Rueff et al., 2012; Veysset et al., 2015). The lack of recent studies is particularly relevant given the fact that several signs (e.g. farmer ageing, absence of succession, low farm profitability, high subsidies dependence) indicate that mountain livestock farming systems in Europe might be at an inflection point (Veysset et al., 2005; Wright and Brown, 2019).

In this context, the objective of this study was threefold: (i) to analyse the main changes occurred in cattle farming systems in the Pyrenees from 1990 to 2018, (ii) to identify the different trajectories of evolution of farms that have taken place and (iii) to determine the key drivers of those trajectories at global, regional and household levels.

2. Material and methods

2.1. Study area and data collection

The study area was in the Central Spanish Pyrenees, namely the valleys of Broto, Benasque and Baliera-Barrabés in Huesca province (Aragón Autonomous Community), which consist of 2, 7, and 3 municipalities, respectively, with a total population of 5117 people, covering an area of 104,600 ha that ranges in altitude from 900 to 1450 m a.s.l. (Fig. 1). The study area was chosen because of the availability of previous information that allowed analysing a constant sample of farms over a 30-year period. The valleys were originally selected to represent diverse livestock farming systems as well as different biophysical and socioeconomic contexts, enabling to analyse how regions with different opportunities and constraints evolved under common global pressures.

This study focused on the farm level and resulted from the monitoring of 101 cattle farms which have been surveyed through and in-depth face-to-face questionnaire at three dates (1990, 2004 and 2018). The first survey sample was evenly distributed across the three study valleys; 32 farms were surveyed in Broto, 33 in Benasque and 36 in Baliera-Barrabés. The second survey was conducted to the 71 remaining cattle farmers (30 farms ceased their activity from 1990 to 2004). The third and last survey was conducted to 54 cattle farmers (17 farms ceased their activity from 2004 to 2018). The results of the 1990 and 2004 surveys have led to different publications (Bernués, 1994; García-Martínez et al., 2009; Olaizola, 1991). In this study we analysed the evolution of the 50 farms that kept operational during the whole studied period (4 farms were removed from the study due to the lack of complete data). Fifteen farms corresponded to Broto, 15 to Benasque and 20 to Baliera-Barrabés valleys (representing 30.1%, 19.5% and 25.4% of the total cattle farms in the valleys, respectively).

The questionnaire gathered information about (i) farm structure, (ii) farm management and orientation, (iii) farm economic performance, and (iv) farmer profile (Table 1).

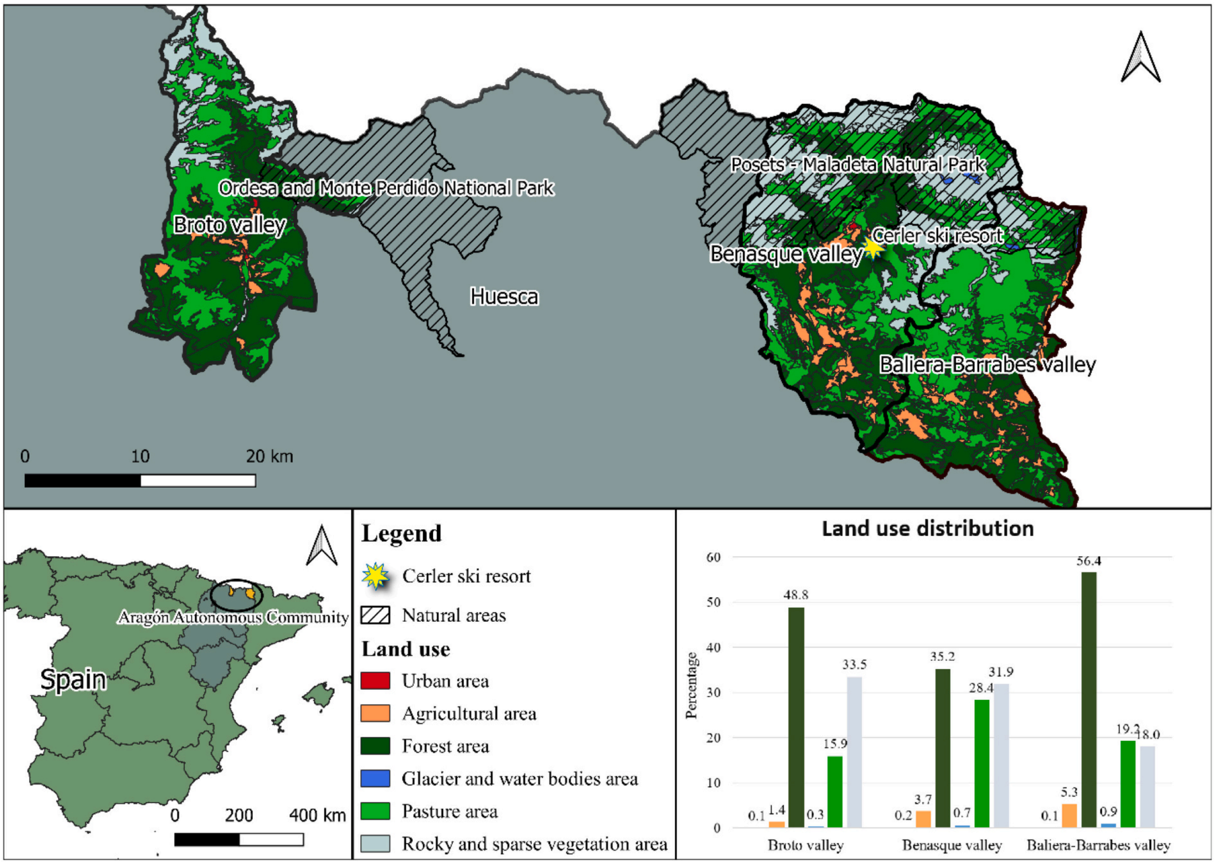

Fig. 1. Map of the study area, including land use and main tourist attractors.
Sources: Corine Land Cover (2018) for land use and Geographical Institute of Aragon (IGEAR) for spatial data about natural areas, ski resorts, municipalities and valleys.

2.2. Data analysis

2.2.1. Analysis of the socioeconomic context

Firstly, we explored the evolution of general socioeconomic and cattle farming contexts in the three valleys during the studied period. Specifically, we analysed in the valleys municipalities the population size, number of cattle farms and cattle heads, the percentage of people working in agriculture, services and industry and the number of tourism bed places in the three dates when farms were surveyed (1990, 2004 and 2018) (Fig. 2). Data were collected from official sources at the Aragón Statistics Institute at the closest available date to the times of the survey implementation unless unavailable, in which case data from García-Martínez et al. (2009) were used (see Fig. 2 footnotes).

2.2.2. Analysis of general evolution of cattle farming systems

Secondly, we analysed the general evolution of the monitored farms, as an indicator of the general evolution of cattle farming in the area, using 27 variables that define farm structure, management and economic performance (Table 2). These variables were obtained directly from the questionnaire (described above) or were calculated on the basis of data included in it, such as, total output (TO; the sum of the incomes obtained from farm activity), total income (TO plus subsidies), gross margin (GM; calculated as total income minus variable costs), and net margin (NM; calculated as total income minus variable and fixed costs; net margin was not available for 1990 as not all fixed costs were gathered). All economic variables were converted to 2018 constant euros. Differences between the start and end time points of the whole analysed period (1990 to 2018) and of the two sub-periods (1990 to 2004 and 2004 to 2018) were evaluated by ANOVA test. All statistical analyses were conducted using R software (R Core Team, 2019).

2.2.3. Analysis of trajectories of evolution of farming systems

Thirdly, we analysed in-depth the trajectories of evolution of farming systems using 9 variables as key indicators of changes in structure, production and economic performance of farms (Appendix, Table A1). These variables were: utilized agricultural area, herd size, livestock units managed per work unit, stocking rate, grazing season length, percentage of herd on mountain pastures, variable cost per livestock unit, percentage of income from fattening calves, and gross margin per working unit. Variables were selected based on García-Martínez et al. (2009) to represent key aspects of farm structure, farm management, land use and economic performance. We followed a methodology proposed by Doledec and Chessel (1987) and modified by Gibon et al. (1999). Specifically, we focused on inter-farm trajectories because they allow analysing differences per farm and their evolution once the general common trend of evolution, time dependent, is eliminated. We built a data table composed by *p* columns (i.e. 9 variables with normalized values) and *s* observations (i.e. 50 farms) in *t* dates (i.e. 3 time points 1990, 2004, and 2018). The value of each variable on each date is the deviation to the average per farm in the three time points.

Then, a principal component analysis (PCA) was performed on the data table to determine the main factors that summarised the changes occurred. Finally, a k-means cluster analysis (CA) was carried out on all the Principal Components (PC) with eigenvalues above 1, to establish a typology of farms according to their trajectories of evolution. The selection of the number of clusters was based on the loss of inertia (within cluster sum of squares) at each partitioning of clusters. The trajectories of evolution (i.e. clusters) of farming systems were described using the 9 variables defining the trajectories plus 10 extra variables not used in the determination of clusters but that were considered of interest due to their capacity to explain the changes in farm functioning (Table 3), as

Table 1
Description of the main variables collected in the survey.

Category	Variable	Description
Farm structure	Utilised agricultural area (UAA)	Sum of area used for cash crops, forage crops, pastures, grazing land and other agricultural uses, expressed in ha
	Herd size (LU)	Livestock units of cattle, where the coefficient used was: 1 for cows and bulls; 0.7 for heifers; 0.4 for calves, and; 0.1 for sheep and goats (Ministerio de Agricultura, Pesca y Alimentación (MAPA), 2019)
	Labour input (work unit, WU)	One unit is equivalent to the work of one person, full time, for one year
Farm management and orientation	Stocking rate (LU/UAA)	Livestock units per land area
	Grazing season length (days)	Days of grazing without external feeds input
	Productive orientation	Whether the farm was devoted to dairy production, on-farm fattening or weaned calves; or a variable mix between these three options
	% of herd on mountain pastures	Percentage of herd that used mountain pastures
Farm economic performance	Total output (€)	The sum of incomes obtained from the sale of farm products.
	Total income (€)	Total output plus subsidies.
	Feeding costs (€)	The sum of purchased roughages, grains, concentrates and mountain pastures fees
	Variable costs (€)	Feeding costs plus veterinary costs, water and electricity, transport, fertilizers and miscellaneous items
	Fixed costs (€)	Financial costs, machinery and facility maintenance, and depreciation of animal, machinery and facilities, at 6, 10 and 30 years, respectively
	Subsidies (€)	Aids for agriculture maintenance and development
Farmer profile	Farmer age (years)	Farmer age at the time of the survey
	Farmer education level	Ranging from 0-no school education, 1-primary school, 2-secondary school, and 3-university
	Household size and composition	Number of members living in the household, including children under and above 18
	Farmer dynamism index	0 to 10; calculated as the sum of the technological innovations adopted by the farmer in the 5 years previous to the implementation of the questionnaire, such as breed change, feeding management change or producing under a quality brand

have been used in similar studies (Bernués et al., 2011; García-Martínez et al., 2009; Veysset et al., 2014). We analysed the relative importance of each trajectory of evolution in the three valleys under study, by looking at the proportion of farms following each trajectory in each valley.

2.2.4. Analysis of trajectory drivers

Finally, discriminant analysis was used to identify the drivers of farm trajectories by determining the socioeconomic factors that best discriminate among trajectories of evolution (i.e. clusters). We considered 17 independent socioeconomic variables which referred to farmer and household profile ($n = 6$), farm economy ($n = 2$), and to the socioeconomic context at the municipality level ($n = 9$). These variables were measured at different time points during the studied period, making a total 36 variables explored (Appendix, Table A2). We checked the normality and homogeneity of variances of the independent variables to determine the type of discriminant analysis to use; linear discriminant analysis (for normally distributed and homoscedastic variables) or quadratic discriminant analysis (QDA; for non-normally distributed and heteroscedastic) (Hair et al., 2014). Explanatory variables were usually not normally distributed and most times heteroscedastic, therefore, the analysis of drivers of farm evolution was carried out using QDA. The discriminant functions were built following a forward selection procedure, and their discriminant power was evaluated based on their classification/misclassification rates (Table 4).

3. Results

3.1. Socioeconomic context of the region

The three valleys under analysis differed in their socioeconomic development pathways during the study period (Fig. 3). In general, Broto valley has focused on a development based on rural ecotourism around the Ordesa and Monte Perdido National Park. While maintaining a constant population during the studied period the main economic activity in the valley has moved from agriculture to services, which currently involve around 80.0% of the working force. In accordance with this swift of economic activity there has been a sharp decrease of employees dedicated to agriculture (−72.6% from 1990 to 2018) and the number of tourism bed places (i.e. hotels, apartments and country house lodges) nearly quadrupled. However, the number of cattle heads in the valley have remained relatively constant due to a process of structural adjustment (increase of the number of heads per farm) despite the number of farms being reduced (−52.0% from 1990 to 2018).

The socioeconomic development of Benasque valley during the studied period revolved around both winter tourism based on ski (i.e. Cerler ski resort) and rural ecotourism with the Posets-Maladeta Natural Park as the main attractors. The valley experimented an important increase in population (52.7%) during the first sub-period 1990–2004, which stabilised in the second sub-period (2004–2018). As in Broto valley, Benasque has suffered a sharp reduction of people working in the agriculture sector (−78.8% from 1990 to 2018), in favour to an increase in the services sector (52.5% from 1990 to 2018), also manifested in the increase of tourism bed places. Besides, the number of cattle farms decreased (−50.0% from 1990 to 2018) but the number of cattle heads in the valley have remained more or less stable.

Contrary to Broto and Benasque, Baliera-Barrabés valley has suffered a continuous reduction of population (−22.6% from 1990 to 2018) while maintaining a strong dependence on the agricultural sector. Although, the percentage of people working in agriculture has slightly fallen (−15.9% from 1990 to 2018), 41.0% of the active population in the valley remain in the sector. The decrease of people working in agriculture has not been even but suffered a relevant fluctuation likely related to the evolution of the construction sector (Fig. 3). The proportion of people working in construction fell sharply during the second sub-period because of the 2007–2008 global financial crisis, which coincided with an increase of people working in agriculture. These fluctuations likely reflect a flow of workers between both sectors. This flow has also been observed to a lower extent in Broto and Benasque valleys. The number of cattle heads have increased slightly during the studied period but in an unsteady manner; a strong increase during the 1990–2004 sub-period (50.2%) followed by a relevant decrease in the second studied sub-period (−21.6% from 2004 to 2018). The number of farms has also been reduced, but to a lesser extent (−23.0% from 1990 to 2018) to that observed in Benasque and Broto.

3.2. General evolution of cattle farming systems

Cattle farming systems have undergone major changes throughout the studied period, which occurred at different intensities in the two sub-periods studied (Table 2). Farmers' average age at the date of the survey has increased about fifteen years during the studied period ($P < 0.001$). Utilised agricultural area remained stable, while the proportion of grazing land per UAA increased from 1990 to 2018 ($P < 0.01$) until almost reaching 100%. There was an increase in herd size and a decrease of labour input per farm especially during the first sub-period

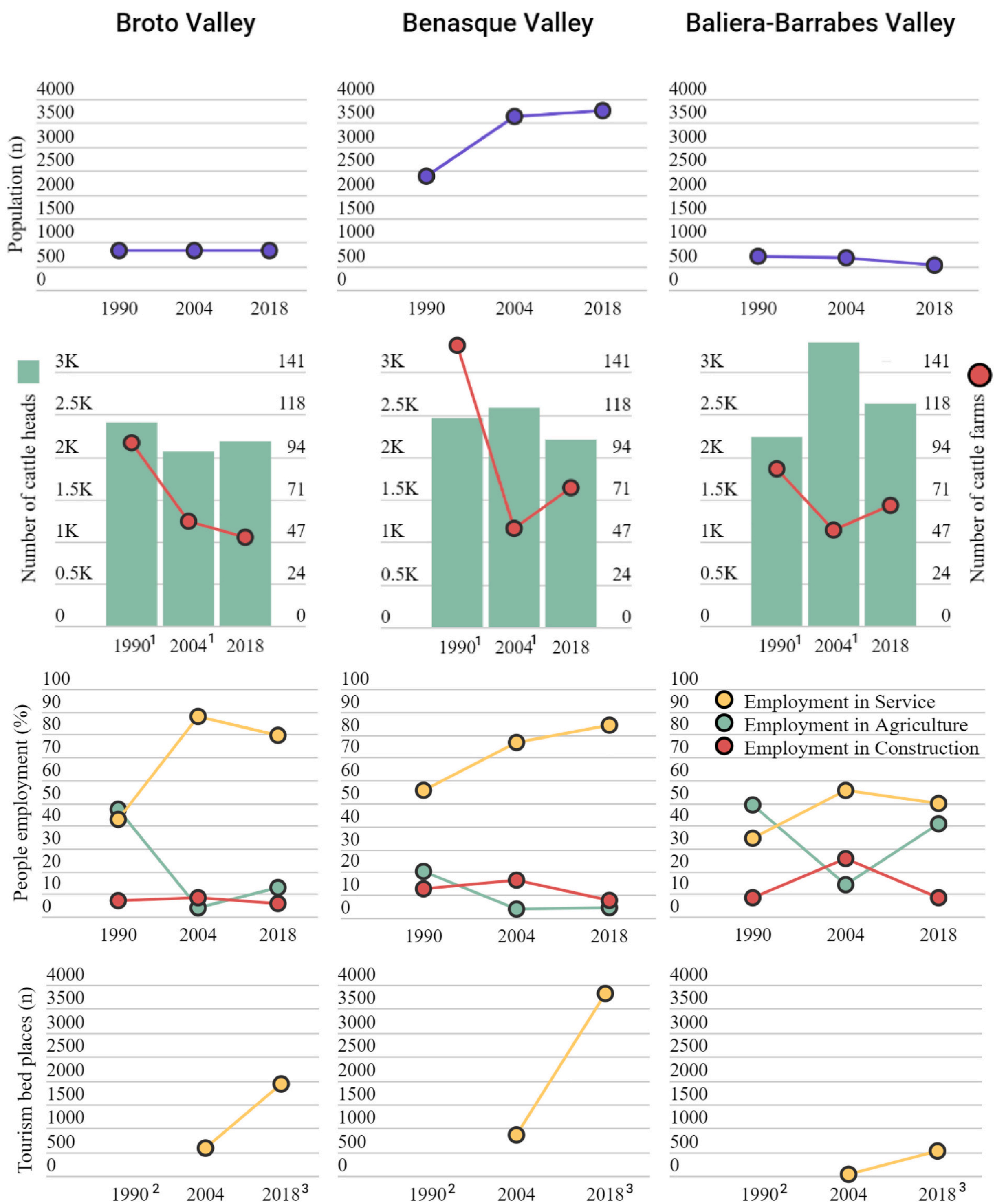

Fig. 2. Evolution of socioeconomic context and of the number of cattle heads and farms during the studied period in Broto, Benasque and Baliera-Barrabés valleys. Data from Aragón Statistics Institute unless unavailable. [1]Data from García-Martínez et al., 2009. [2]Data not available. [3]Data from 2017.

($P < 0.001$). Consequently, the herd size managed per WU increased by 173% from 1990 to 2018 ($P < 0.001$) and the stocking rate followed a trend of increase without significant changes. Regarding farm orientation, the first sub-period was characterised by a strong change from mixed dairy-weaned calves production to specialized beef systems with on-farm fattening and weaned calves, and to suckler cattle farms selling mostly weaned calves in the second sub-period ($P < 0.001$). On-farm fattening decreased from 40% of farms in 2004 to 20% in 2018. The length of the grazing season increased about one month during the first sub-period ($P < 0.01$) due to the changes in orientation of production and stabilised in the second one. Total variable costs increased during the first sub-period ($P < 0.05$) parallel to the increase of herd size. However, variable costs per LU decreased ($P < 0.05$). Feeding costs, which constituted a large share of the variable costs (63.6%, 35.2% and 39.8% of total variable costs for 1990, 2004 and 2018, respectively) decreased per LU during the second sub-period ($P < 0.05$). Despite the increase in herd size, total output was stable during the whole period, and labour dedicated to farming decreased specially in the first sub-period. However, the importance of subsidies increased significantly ($P < 0.001$), allowing to maintain a constant total income, and livestock productivity (GM and NM per LU). Finally, labour productivity (GM/WU) increased during the first sub-period ($P < 0.001$) and then stabilized.

3.3. Trajectories of evolution of farming systems

Principal Component Analysis resulted in four components with eigenvalue above 1 explaining 69.0% of the total variance. Herd size and LU per WU were the main variables contributing to Factor 1. Percentage of income from on-farm fattening per total output and variable costs per LU contributed to Factor 2. Factor 3 was mainly explained by utilized agricultural area and stocking rate. Finally, Factor 4 was defined by grazing season length and proportion of the herd on mountain pastures (Appendix, Table A1). The cluster analysis on those four factors resulted in four clusters that defined different trajectories of evolution of farming systems (Fig. 3 and Table 3). Below, we describe in detail the four trajectories. Three trajectories were mostly specific to each of the individual valleys, whereas one trajectory was common across valleys.

Trajectory 1 'Broto trajectory - Small land area and large herd growth' (22% of farms, mostly in Broto valley: 9 farms from Broto, 1 in Benasque and 1 in Baliera-Barrabés). This cluster was characterised by small and stable UAA (31.2 ha in 2018), constant labour input and the highest stocking rate (4.3 LU/ha in 2018) due to a large increase in herd size during the studied period (106% of increase from 1990 to 2018;

Table 2
General evolution of farm structure, management and economic performance (average and standard deviation).

Variables	Dates		
	1990	2004	2018
Farmer age (years)	35.8^{a} ± 9.6	45.2^{b} ± 9.0	51.5^{c} ± 11.7
Utilized agricultural area (UAA) (ha)	44.1 ± 48.4	53.3 ± 36.5	51.4 ± 36.5
Grazing land per UAA (%)	94.3^{a} ± 14.0	98.3^{ab} ± 4.0	99.7^{b} ± 1.8
Herd size (LU)	44.1^{a} ± 22.7	65.1^{b} ± 30.3	82.9^{b} ± 48.0
Labour input (WU)	1.87^{a} ± 0.6	1.33^{b} ± 0.5	1.36^{b} ± 0.6
LU/WU	23.7 ^{a} ± 9.5	53.7^{b} ± 26.4	64.7^{b} ± 33.1
Stocking rate (LU/ha)	1.6 ± 1.2	1.7 ± 1.2	2.2 ± 2.0
% Dairy farms (%)	78.0^{a} ± 41.9	2.0^{b} ± 14.1	2.0^{b} ± 14.1
% Fattening farms (%)	4.0^{a} ± 19.8	42.0^{b} ± 49.9	20.0^{b} ± 40.4
% Suckler cattle farms (%)	90.4^{a} ± 29.8	67.3^{b} ± 47.4	92.3^{a} ± 26.9
Grazing season length (days)	232.3^{a} ± 40.8	259.1^{b} ± 43.7	248.7^{ab} ± 45.6
% herd on mountain pastures (%)	79.1^{a} ± 28.5	100^{b} ± 0.0	98.8^{b} ± 7.6
Variable costs (€)	19523^{a} ± 14845	31204^{b} ± 24,633	30315^{b} ± 26417
Variable costs/LU (€)	440.6^{a} ± 224.4	476.4^{ab} ± 400.8	346.4^{b} ± 127.4
Feeding costs/LU (€)	329.0^{a} ± 194.3	339.8^{a} ± 378.6	199.4^{b} ± 117.3
Total output (€)	47695 ± 30577	46333 ± 31855	49829 ± 35839
Total income (€)	52548^{a} ± 32457	81768^{b} ± 47470	86987^{b} ± 56437
Subsidies/GM (%)	16.2^{a} ± 6.85	72.6^{b} ± 19.0	67.6^{b} ± 17.0
Total income/LU (€)	1195 ± 409.1	1266 ± 615.3	1062 ± 363.4
GM/LU (€)	755.5 ± 267.0	789.2 ± 295.8	715.1 ± 358.4
GM - subsidies/LU (€)	646.6^{a} ± 270.3	243.8^{b} ± 207.2	246.3^{b} ± 239.0
GM/WU (€)	17566^{a} ± 8546	40869^{b} ± 20594	42228^{b} ± 17919
GM - subsidies/WU (€)	14963 ± 7828	12260 ± 10063	14552 ± 11586
NM/LU (€)	–	501.7 ± 250.8	502.7 ± 349.1
NM - subsidies/LU (€)	–	- 43.7 ± 210.8	34.0 ± 260.5
NM/WU (€)	–	26557 ± 15930	29438 ± 17394
NM - subsidies/WU (€)	–	- 2052 ± 9960	1762 ± 14317

a, b Different letters refer to significant differences between different years for each trajectory according to ANOVA test. LU = livestock unit; WU = work unit; GM = gross margin; NM = net margin. All economic figures expressed in 2018 constant euros. The aggregation of the percentages of dairy, fattening and suckler cattle farms are higher than 100% because farms can have more than one kind of product.

Table 3
Changes observed in farm trajectories of evolution. Average values and standard deviation of farm structure variables across trajectories throughout the studied period across years.

Trajectories	Broto trajectory 'Small land area and large herd growth'			Benasque trajectory 'Labour extensification'			Baliera-Barrabés trajectory 'Large land area and temporal fattening focus'			Common trajectory 'Small farms with little changes'		
Number of farms (%)	11 (22)			9 (18)			8 (16)			22 (44)		
Variable	1990	2004	2018	1990	2004	2018	1990	2004	2018	1990	2004	2018
Labour input (WU)	1.6 ± 0.4	1.5 ± 0.5	1.4 ± 0.4	1.9^{a} ± 0.5	1.0^{b} ± 0.2	1.1^{b} ± 0.7	2.3 ± 0.8	1.7 ± 0.6	1.7 ± 1.0	1.8^{a} ± 0.5	1.2^{b} ± 0.5	1.3^{b} ± 0.5
Feeding costs/LU (€)	315.9 ± 130.3	409.1 ± 279.5	280.9 ± 144.7	447.2 ± 335.5	351.6 ± 165.5	179.6 ± 99.6	322.7^{ab} ± 182.2	736.0^{b} ± 742.7	256.6^{a} ± 136.3	289.5^{a} ± 135.5	156.4^{b} ± 72.6	145.9^{b} ± 65.5
Subsidies (€)	5416^{a} ± 3032	40965^{b} ± 15,289	40682^{b} ± 21,001	3913^{a} ± 1474	39581^{b} ± 20,111	32908^{b} ± 27,869	8613^{a} ± 6578	50569^{b} ± 17,329	57065^{b} ± 32,803	3590^{a} ± 1818	25472^{b} ± 15,637	28897^{b} ± 15,417
Subsidies/GM (%)	16.3^{a} ± 6.6	71.6^{b} ± 9.2	65.7^{b} ± 16.8	11.8^{a} ± 6.6	78.1^{b} ± 25.0	61.5^{b} ± 18.0	17.7^{a} ± 5.8	67.0^{b} ± 17.9	71.7^{b} ± 20.0	17.3^{a} ± 7.1	72.9^{b} ± 20.7	69.6^{b} ± 15.9
Gross Margin-subsidies/LU (€)	636.6^{a} ± 220.7	228.6^{b} ± 99.4	245.7^{b} ± 129.8	868.6^{a} ± 349.9	202.4^{b} ± 162.0	232.3^{b} ± 129.1	530.6^{a} ± 203.1	362.3^{ab} ± 249.7	211.3^{b} ± 163.6	603.0^{a} ± 242.0	225.2^{b} ± 241.0	265.1^{b} ± 330.3
GM/LU (€)	747.7 ± 214.9	810.5 ± 231.5	699.8 ± 217.6	967.7 ± 338.2	745.3 ± 262.2	603.1 ± 158.0	637.7 ± 214.3	1053.3 ± 395.8	721.2 ± 145.1	715.5 ± 243.2	700.5 ± 253.6	766.3 ± 502.4
GM/WU (€)	21718^{a} ± 8146	42916^{b} ± 17,482	45557^{b} ± 19,972	20238^{a} ± 9584	49288^{b} ± 21,851	51974^{b} ± 19,270	20504^{a} ± 7950	47189^{b} ± 12,989	50257^{b} ± 15,713	13329^{a} ± 6969	34104^{b} ± 22,587	33657^{b} ± 13,694
NM - subsidies/LU (€)	–	2.3 ± 182.3	22.4 ± 175.1	–	- 31.7 ± 166.3	73.5 ± 127.5	–	- 7.3 ± 239.7	−26.3 ± 259.2	–	−84.9 ± 233.9	45.5 ± 335.9
Off-farm Job (farmer) (%)	10.0 ± 31.6	45.5 ± 52.2	18.2 ± 40.5	0.0 ± 0.0	33.3 ± 50.0	44.4 ± 52.7	12.5 ± 35.4	25.0 ± 46.3	0.0 ± 0.0	25.0 ± 44.7	27.3 ± 45.6	22.7 ± 42.9
Off-farm Job (family) (%)[1]	60.0 ± 51.6	63.6 ± 50.4	81.8 ± 40.5	0.0 ± 0.0	55.6 ± 52.7	66.7 ± 50.0	14.3 ± 37.8	62.5 ± 51.8	37.5 ± 51.8	33.3 ± 48.8	63.6 ± 49.2	63.6 ± 49.2

a, b Different letters refer to significant differences between different years for each trajectory according to Kruskal-Wallis test. [1] Off-farm job conducted by the farmer and other members of the family.

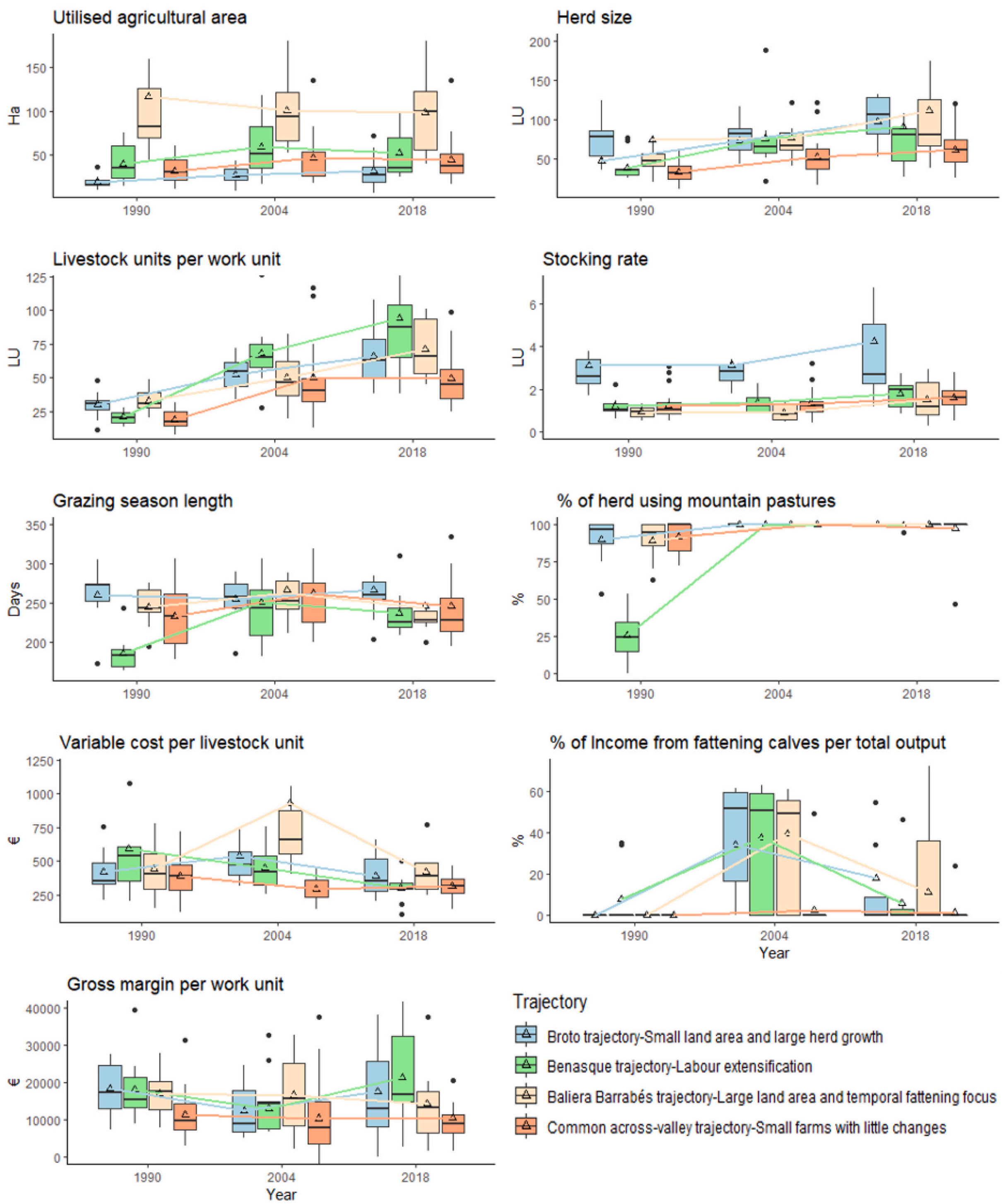

Fig. 3. Trends of change observed in the variables defining trajectories.
Boxplots represent the mean (triangle), median (solid horizontal lines), first and third quartiles (contained in the boxes), dispersion (vertical lines) and outliers (black points) of the distribution of the variables within trajectories and years.

$P < 0.05$). Grazing season length and percentage of LU using mountain pastures was constantly high. Variable costs per LU fluctuated slightly between sub-periods without significant changes. Income from fattening calves increased in the first sub-period from zero to more than a third (34%) of TO ($P < 0.01$) and then halved in the second sub-period. Gross margin per WU doubled during the first sub-period ($P < 0.01$) and continued high in the second one (45,557 €/WU in 2018). However, GM/LU was constant (700 €/LU in 2018) due to the large increase of subsidies in the first sub-period ($P < 0.001$).

Trajectory 2 'Benasque trajectory - Labour extensification' (18% of farms, mostly in Benasque valley: 8 farms in Benasque and 1 in Baliera-Barrabés). Utilized agricultural area in this trajectory did not change significantly (52.7 ha in 2018) throughout the study period, however, farms suffered a sharp decrease in labour input ($P < 0.01$) and the highest increase of LU/WU ($P < 0.001$), as a consequence of labour reduction and herd size increase during the first sub-period. Grazing

Table 4
Confusion matrix of the Quadratic Discriminant functions to discriminate between trajectories within valleys. Values represent number of farms.

Quadratic discriminant functions	True trajectories	Assigned trajectories according to Quadratic Discriminant functions				Correctly assigned (%)
		Broto trajectory	Benasque trajectory	Baliera-Barrabés trajectory	Common trajectory	
Broto Valley	Broto trajectory	8			1	88.9%
	Common trajectory				6	100.0%
Benasque Valley	Benasque trajectory		8			100.0%
	Common trajectory				6	100.0%
Baliera-Barrabés Valley	Baliera-Barrabés trajectory			7	1	87.5%
	Common trajectory			1	9	90.0%

Table 5
Relationship between socioeconomic factors and farm trajectories across valleys. Average values for the best discriminatory factors.

Socioeconomic factors	Broto Valley farms		Benasque Valley farms		Baliera-Barrabés Valley farms	
	Broto trajectory	Common trajectory	Benasque trajectory	Common trajectory	Baliera-Barrabés trajectory	Common trajectory
Farmer age in 2018	51.3 ± 11.5	52.3 ± 8.7	47. 9 ± 17.6	58.8 ± 12.9	43.5 ± 9.0	56.3 ± 7.1
Farmer level of education in 2004	1.44 ± 0.5	0.83 ± 0.4	1.50 ± 0.5	1.17 ± 0.4	1.63 ± 0.5	1.70 ± 0.8
Household size in 1990	3. 6 ± 1.3	3.2 ± 1.2	$6.5^{a} \pm 1.9$	$4.3^{b} \pm 1.5$	3.9 ± 1.2	3.0 ± 1.3
Farm dynamism in 2018	3.33 ± 3.1	1.33 ± 2.2	2.88 ± 2.9	2.33 ± 2.0	2.8 ± 1.5	1.60 ± 1.3
Change (%) in pop. Working in services in the municipality in 1990–2004	111.0 ± 8.5	106.0 ± 10.6	53.9 ± 28.2	48.7 ± 23.7	66.6 ± 8.8	57.4 ± 21.4

season length and the proportion of the herd using mountain pastures at the beginning of the period was the lowest of all trajectories. Both variables increased substantially during the first sub-period ($P < 0.05$ and $P < 0.001$, respectively) and then stabilised. Variable costs/LU had a decreasing trend during both sub-periods, despite the fact that the income from fattening calves increased to more than 35% of TO in the first sub-period and then halved in the second one. Gross margin/WU increased in the first sub-period ($P < 0.01$) due to both an increase in the share of subsidies per GM ($P < 0.001$) and a decrease of labour input ($P < 0.01$), and then stabilised in the second one (51,974 €/WU in 2018).

Trajectory 3 '*Baliera-Barrabés trajectory - Large land area and temporal fattening focus*' (16% of farms, only in Baliera-Barrabés valley: 8 farms). This trajectory was characterized for having the highest UAA and the lowest stocking rate of all clusters throughout the studied period. Grazing season length and the proportion of the herd using mountain pastures were mainly constant during both sub-periods. On-farm fattening increased significantly during the first sub-period ($P < 0.01$) and then was reduced by more than 70% in the second one. Variable costs/LU fluctuated between sub-periods without significant changes. Gross margin per WU increased during the first sub-period ($P < 0.01$) to then stabilise in the second sub-period (50,257 €/WU in 2018), following a similar path to the importance of subsidies in GM ($P < 0.001$).

Trajectory 4 '*Common across-valleys trajectory - Small farms with little changes*'. (44% of farms: 6 farms from Broto, 6 from Benasque and 10 from Baliera-Barrabés). This trajectory was characterised by a constantly low UAA during both sub-periods, the smallest herd size (61.8 LU in 2018) despite the significate increase during the first sub-period ($P < 0.01$) and a labour input reduction during the first sub-period ($P < 0.01$), resulting in a labour extensification ($P < 0.001$). In contrast with the rest of trajectories, the importance of income from on-farm fattening was low during the whole period. Grazing season length and the proportion of the herd using mountain pastures remained constant. Variable costs/LU tended to decrease during the first sub-period with no significant changes. Subsidies had a very large increase in the first period ($P < 0.001$) which was translated into an increase of both GM/WU ($P < 0.001$) and % subsidies/GM ($P < 0.001$). Despite this increase, this trajectory had the lowest GM/WU (33,657 €/WU in 2018) throughout the study period.

3.4. Socioeconomic characterization of trajectories

Because three trajectories were almost specific to each valley and the fourth one was composed by farms from the three valleys, we carried out one QDA per valley to identify the socioeconomic factors that best discriminate between the valley-specific trajectory and the common trajectory. The best discriminate functions had very high discriminatory power ratios: 0.94, 1 and 0.89 for Broto, Benasque and Baliera-Barrabés trajectories, respectively (Table 4). Total number of observations ($n = 50$) is higher than the aggregation of observations in each valley ($n = 47$), because Baliera-Barrabés and Benasque valleys had farms belonging to trajectories 1 and 2, which was insufficient for statistical analysis. The functions of the three QDA contained the same 5 explanatory variables: farmer age in 2018, farmer education in 2004, size of the household in 1990, farm dynamism in 2018, and percentage change in the population working in services sector in the municipality (Table 5).

In the three valleys, the farmers that followed the common across-valleys trajectory tended to be elder, to have lower education level, and smaller household size, and showed lower farm dynamism than the farmers of the other trajectories (Table 5). The farms of the common across-valleys trajectory were usually located in municipalities where the increase of population working in services was smaller than in the municipalities where farms followed the valley-specific trajectories. The farms of the three valley-specific trajectories showed similar average value of the farm dynamism index but tended to have different values in the rest of the socioeconomic factors.

4. Discussion

There are very few examples of longitudinal studies monitoring real farm data from surveys, despite the importance of this kind of studies for understanding farm management and development strategies to survive and adapt (Rueff et al., 2012). Going back to the same farms, over a 30-year period, allowed us to analyse how mountain cattle farming systems have adapted to changing policy and socioeconomic factors at the global and regional levels. Below we discuss in detail the relationship between global policy drivers and common farm trends, and how farms react to regional environment conditioned by household factors by exhibiting different trajectories of evolution.

4.1. Global drivers - the EU CAP

Our research shows that mountain cattle farming systems in the studied region have followed a common general evolution of their structure, management and performance, which seems to be driven by socioeconomic and policy drivers, as we discuss below. We observed clear changes regarding both land and labour force production factors in which we can distinguish two sub-periods. In the first sub-period (1990–2004), farming systems experienced a process of land use extensification (enlargement of the grazing season length; higher use of grazing land and mountain pastures) and capital intensification (LU per WU). This process coincided with a switch of farm productive orientation from dairy farming to beef farming with large importance of on-farm fattening. These processes have already been described in García-Martínez et al. (2009). These authors showed how the process coincided with a sharp decrease of outputs per animal (mainly due to the abandonment of dairy production) that was compensated by a large increase of the 1992 CAP subsidies paid on a per head basis (see below). Subsidies provision together with the reduction of labour dedicated to farming allowed maintaining GM per WU more or less constant. During the second sub-period (2004–2018), land use stabilised but the capital intensification process went on. Cattle farming systems continued to increase herd size which led to large numbers of LU managed per WU, as it have also been seen in other areas of Europe (Veysset et al., 2016). The increase in herd size was very likely related the continuation of the decrease of outputs per animal (Veysset et al., 2019) which pushed farmers to increase the herd size to compensate for the loss of unitary income. Furthermore, farms reduced their inputs, in parallel to the decreasing importance of fattening, leading to a decrease of farm variable costs, specifically feeding cost per LU. These farm structural changes allowed to maintain stable the average NM and GM per WU in constant figures.

The general trend of evolution of cattle farming systems observed here confirms the great influence that CAP had during the last three decades in shaping European livestock farms, as has also been shown by other authors (Détang-Dessendre et al., 2018; Franco et al., 2012; Guerra et al., 2016). In the first sub-period, the observed changes in the productive orientation followed CAP policy updates such as the introduction of milk quotas and specific programmes that promoted the abandonment of milk production in marginal areas. Later CAP upgrades in 1992 and the Agenda 2000 aimed at reducing intervention and introduced compensation payments through subsidies coupled to hectares of land and heads of livestock (Veysset et al., 2019). These CAP modifications, together with the 2003 Mid-Term Review, disconnected ('decoupled') most direct subsidies from production. In particular, the specific slaughter premium attributed for fattened livestock sold (Veysset et al., 2005) promoted on-farm fattening in our study area, as already noted by García-Martínez et al. (2009). These productive orientation changes may have had positive effects on the provision of ecosystem services due to the increase in grazing season length (Rodríguez-Ortega et al., 2014), but also ended the production of dairy products and led to an intensification associated to indoor fattening. In the second sub-period, the 2009 'Health Check' and the 2013 Reform moved towards a more intense decoupling and the development of rural areas with more integrated approaches. Consequently, on-farm fattening was drastically reduced, producing a return to a less intensive orientation based on suckler cows.

Since the 1992 reform, CAP subsidies have been crucial to maintain farm profitability, as well as livestock and labour productivity, in a context of decreasing per head income, as has been reported in French beef cattle farms in a similar period (Veysset et al., 2015). We found that subsidies represented an average of 70% of GM both in 2004 and in 2018. This figure demonstrates the huge CAP subsidies dependency of mountain cattle farming systems in the Spanish Pyrenees, as other studies have shown for other livestock systems in different areas of Europe (e.g. Franco et al. (2012) in the Extremadura dehesa in Spain; Guerra et al. (2016) in Mediterranean silvopastoral systems in south Portugal; MacDonald et al. (2000) in an across-Europe analysis of mountain agricultural abandonment). This situation might have resulted in farmers having a capture-of-subsides behaviour as suggested by Veysset et al., (2005).

4.2. Regional drivers - the development of tourism

Besides the general trend described above, we identified three trajectories that correspond with specific valleys with differential socio-economic context, which highlights the existence of regional (i.e. within valley) factors that influence farming systems evolution (Godde et al., 2017; Valbuena et al., 2015). The different economic development of non-farming sectors across valleys and municipalities, in particular tourism, often associated to construction, has been a decisive driver of farming systems evolution in the studied area. Tourism and the resulting urbanization decreases land availability for agriculture and increases land price, displacing agricultural activities (Gellrich et al., 2007; Lasanta et al., 2007). In addition to its impact on land use, tourism development creates economic opportunities that have both negative and positive impacts on farming. On the negative side, tourism increases labour opportunity costs which usually reduces the workforce available for agriculture and creates problems of farm generational turnover (Bernués et al., 2011; Lasanta et al., 2007; Strijker, 2005). On the positive side, tourism creates off-farm job opportunities that can be exploited by the farmer and his/her family to complement household income (Casasús et al., 2014). The final outcomes of these confronting processes might depend on the policy design and social capacity to effectively integrate agriculture, tourism and rural development (García-Martínez et al., 2009, 2011). All these consequences of tourism development were observed in our study area. Tourism development has indeed marginalized cattle farming in the study area as shown by the largest decrease of number of cattle farms in the valleys with largest tourism development (Broto and Benasque). This process was already described in the area for the first sub-period by García-Martínez et al. (2009) and deeply discussed by Lasanta et al. (2007). Since then, despite the fact that the tourism has continued to experiment an intensive development in terms of visitors and industry size, farm abandonment has been less intense and the percentage of people working in the agriculture sector has remained more or less constant. This might reflect that the tourism and agriculture sectors have reached an equilibrium in Broto and Benasque and that the future of the few farms that remain in the valleys will no longer depend on the evolution of tourism but on the other driving factors discussed here. On the other hand, it is also true that in the trajectories of those touristic valleys, off-farm family job is more common, generating an economic complement to farm income. To what extent the opportunity provided by tourism development for family economy diversification will increase farm resilience by helping farms to overcome periods of low profitability of farming activity, in line with the synergy narrative (Genovese et al., 2017; Vik et al., 2010), requires a deeper investigation.

Other valley-specific limiting production factors influenced the way in which cattle farming systems evolved. Despite the different adaptation strategies to limiting factors described below, all farms that followed the valley-specific trajectories reached a similar level of labour productivity. In Broto valley, agricultural area is the limiting factor due to its biophysical conditions. According to Corine Land Cover 2018, meadows and pastures cover 3.3% and 12.5% less of Broto total land area compared to Baliera-Barrabés and Benasque, respectively, representing an average of 25.5 ha available per existing farm in 2018 (compared to 52.0 and 36.1 ha per farm in Benasque and Baliera-Barrabés, respectively). As a response to this limitation, farms of Broto specific trajectory have maximized the use of their UAA and increased the stocking rate, being the highest of all trajectories. In Benasque valley, the limiting production factor is labour. Benasque has currently the lowest percentage of people working in agriculture of the three valleys, very likely due to a very high labour opportunity cost created by the tourism development. The sector is mostly based on a large ski resort co-owned (50%) by the Autonomous Community Government with the objective of fixing population and increasing economic activity. Consequently, the valley-specific farm trajectory of Benasque has minimised labour input, getting the highest herd size managed per worker of all trajectories. Contrary to Broto and Benasque valleys, Baliera-Barrabés farming systems have evolved without a strong influence of tourism and neither agricultural area nor labour input have been limiting factors in the valley. The low increase in the tourism offer is likely revealing structural constraints of this valley for further developing the sector. Therefore, it is unlikely that agriculture will suffer important competence for labour use with other economic sectors in the near future. In 2018, the agriculture sector occupied 40% of the valley working force, four and ten times more than in Broto and Benasque valleys, respectively. The lack of limiting factors and the few economic alternatives to farming in the valley have encouraged farmers of Baliera-Barrabés specific trajectory to maximise agricultural income.

4.3. Household drivers – farmer age and dynamism

In addition to the three valley-specific trajectories, farms from all the valleys grouped up in a common across-valleys trajectory, including around 40% of the farms. These farms were characterized by being relatively stable throughout the whole period and by focusing on a low-input and low- investment strategy. They had the smallest herd size and the lowest feeding costs/LU, which resulted in the lowest productivity of labour of all strategies. It is not clear if this is a deliberated business strategy or a consequence of farmer risk aversion and low adaptation capacity. The literature findings discussed below point out to the latter.

The farms that followed this common across-valleys trajectory were different from the rest in relation to key household factors (i.e. oldest farmer age, and lowest education level and smallest household size), revealing that in addition to regional socioeconomic factors, household particularities can be crucial in determining cattle farming evolution (Darnhofer, 2010; Tenza et al., 2019). High age and low education level have been related with risk aversion and lack of dynamism in several studies (Brown et al., 2019; Dessart et al., 2019) and in our case might explain why farmers with these characteristics did not try to maximise farm outputs. Furthermore, these farms had the smallest household size that might indicate a larger problem of lack of succession than the farms following the valley-specific trajectories and, as a consequence, a farmer lack of interest in farm investments with return in the long or mid-term. The weakening of agrarian family traditions clearly disrupts the process of incorporating young farmers, leading to the abandonment of family farms (Góngora Pérez et al., 2020). The fact that these farms, with doubtful adaptation capacity and uncertain succession, represent more than one third of the surveyed farms is a reason of concern for the future of cattle livestock systems in the studied region.

4.4. Implications

The findings of our study have three key implications for agricultural and rural development policies, related to farm data needs and sustainability pillars. First, the fact that farms in different regions followed different trajectories of evolution under similar global and national drivers highlights the need of better targeting agricultural policies and assessing their impact. To do so, the European (FADN) and national statistics should improve farm monitoring and evaluation (Scown et al., 2020), performing annual follow-ups on constant samples of farms disaggregated by agroecosystem and management regimes. Second, we have shown that the maintenance of mountain farming activity depends largely on social factors (social pillar) in addition to the often-alleged low profitability of farming (economic pillar). In fact, 85% of the farms (of those we could contact) that ceased their activity during the second sub-period did so due to lack of successors (data not shown). Therefore, the policies focusing on fostering farming generational turnover are clearly not achieving their objectives, and the ageing of farmers is becoming the most pressing and urgent issue for the future of mountain farming. A potential learning for policy design is the need to integrate new policy tools, for example appropriate transition programs, mentoring and financing of new entrants into farming, which have shown hither dynamism and adaptive capacities (Góngora Pérez et al., 2020; Sutherland, 2016). Third, we show that farm profitability depends critically on CAP subsidies. However, the distribution of subsidies concentrates on a minority of farmers according to farm size, rather than on social and environmental outcomes (Scown et al., 2020). The need to transform subsidies into payments for ecosystem services have been pointed out in several studies as a potential way forward for agrienvironmental policies (Rodríguez-Ortega et al., 2014). In this regard, a further integration of the CAP with other EU sectoral policies such as the environmental policy (e.g. Natura2000, HNV farmland areas), or general frameworks such as the UN Sustainable Development Goals (Plieninger et al., 2012; Scown et al., 2020), would increase the coherence, efficiency and fairness of public policies.

5. Conclusions

This study contributes to the understanding of mountain agriculture changes in the last thirty years, showing how the trajectories of evolution of cattle farming in the Spanish Pyrenees resulted from the interaction of European, regional and household drivers.

At the European scale, agricultural policy had an enormous influence, resulting in high economic dependence of subsidies, increase of herd size and reduction of the labour force. Variable costs decreased, in parallel to an increase of grazing and a change in the productive orientation.

At the regional level, tourism created a scenario of competence for labour and land in some valleys, but also the possibility of extra income for the household. This circumstance, joined with the dependence on subsidies, is leading to a strained relation between farming and tourism.

At the farm level, household factors were crucial in determining the specific trajectory followed by the farm. Under similar global and regional conditions, different socioeconomic development pathways happened depending on factors such as farmer age, level of education and household size.

Just over half of the farms showed adaptive strategies to global, regional and local political and economic context changes, through maximizing the output related to the most limiting production factor in their region. However, the remaining farms showed limited modifications to adapt to changes, which questions their capacity to face the challenges ahead. The ability of farms to maintain either their response capacity or their resistance to change, while keeping their economic and social viability, will likely determine the future of cattle farming systems in European Mountain areas.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The research leading to these results has received funding from European Union's Horizon 2020 research and innovation program - GenTORE - under grant agreement N° 727213, and from the Government of Aragón under the Grant Research Group Funds (A14_17R). E. Muñoz-Ulecia is supported by a pre-doctoral contract from the Government of Aragón, D. Martín-Collado is supported by a post-doctoral contract from INIA-ESF.

Appendix A. Appendix

Table A1
Contribution of variables to main PCA factors and eigenvalues and explained variance.

Variables	Factors			
	F1	F2	F3	F4
Herd size (LU)	***0.551***	−0.128	0.040	−0.089
Utilized agricultural area (UAA)(ha)	0.337	0.114	***−0.626***	−0.116
Livestock units per work unit (LU/WU)	***0.511***	−0.295	−0.004	0.186
Percentage of income from fattening per total income	0.352	***0.446***	0.196	−0.280
Grazing season length (days)	−0.039	−0.388	−0.149	***−0.422***
Variable costs /LU (€)	0.179	***0.559***	0.117	−0.338
Gross margin - subsidies /WU (€)	0.397	−0.185	0.098	0.377
Stocking rate (LU/ha)	0.079	−0.222	***0.714***	−0.201
% herd on mountain pastures	−0.004	−0.371	−0.111	***−0.626***
Eigenvalue	2.12	1.61	1.36	1.12
% of cumulative variance	23.55	41.44	56.52	68.98

All variables were transformed as explained in the Material and Methods section.
In bold are the variables with a higher contribution to the factors of the PCA.

Table A2
Socioeconomic factors considered in the study of drivers of change of farm trajectories.

Factor	Level
Percentage of change of population in the municipality from 1990 to 2004	Municipality
Percentage of change of population in the municipality from 2004 to 2018	Municipality
Percentage of change of the number of cattle farms in the municipality from 1990 to 2004	Municipality
Percentage of change of the number of cattle farms in the municipality from 2004 to 2018	Municipality
Percentage of change of the number of cattle heads in the municipality from 1990 to 2004	Municipality
Percentage of change of the number of cattle heads in the municipality from 2004 to 2018	Municipality
Percentage of change of the rural tourism places from 2004 to 2018	Municipality
Distance from the farm to valley capital village (mins.)	Municipality
Percentage of change of active population working in agriculture in the municipality from 1990 to 2004	Municipality
Percentage of change of active population working in agriculture in the municipality from 2004 to 2018	Municipality
Percentage of change of active population working in services in the municipality from 1990 to 2004	Municipality
Percentage of change of active population working in services in the municipality from 2004 to 2018	Municipality
Percentage of change of active population working in construction in the municipality from 1990 to 2004	Municipality
Percentage of change of active population working in construction in the municipality from 2004 to 2018	Municipality
Percentage of change of active population working in industry in the municipality from 1990 to 2004	Municipality
Percentage of change of active population working in industry in the municipality from 2004 to 2018	Municipality
Farmer age in 1990	Household
Farmer age in 2004	Household
Farmer age in 2018	Household
Pluriactivity of the household in 1990 (WU/WUtotal)	Household
Pluriactivity of the household in 2004 (WU/WUtotal)	Household
Pluriactivity of the household in 2018 (WU/WUtotal)	Household
Number of members of the household in 1990	Household
Number of members of the household in 2004	Household
Number of members of the household in 2018	Household
Level of education of farmer in 2004	Household
Level of education of farmer in 2018	Household
Number of children above 18-year old in 2004	Household
Number of children above 18-year old in 2018	Household
Percentage of income coming from milk on total income in 1990	Farm
Percentage of income coming from subsidies on total income in 1990	Farm
Percentage of income coming from subsidies on total income in 2004	Farm
Percentage of income coming from subsidies on total income in 2018	Farm
Index of dynamism of farmer in 2004 (values from 0 to 10 according to the technological innovations adopted by the farmer in the 5 years previous to the questionnaire)	Farmer
Index of dynamism of farmer in 2018 (values from 0 to 10 according to the technological innovations adopted by the farmer in the 5 years previous to the questionnaire)	Farmer

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