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Strategies to generate added value for mountain livestock farming systems

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Filastrocca viaggiatrice

Lunga lunghissima sia questa strada
dovunque porti, dovunque vada
giorni con notti, paura, coraggio
lungo lunghissimo sia questo viaggio
partire presto, tornare tardi
dietro i ricordi, davanti gli sguardi
che non arrivino mai fino in fondo
perché c’è sempre più mondo

(Bruno Tognolini. Da: *Roma Rimani*, Salani 2002)

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List of abbreviations

Technical

Abbreviation	Meaning
AIC	Akaike Information Criterion
ADG	Average Daily Gain
AP	Acidification Potential
BW	Body Weight
BWI	Body Weight Initial
BWF	Body Weight Final
BWS	Body Weight Sold
CAP	Common Agricultural Policy
Cfb	Temperate Oceanic Climate
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
CV	Coefficient of Variation
DM	Dry Matter
DTM	Digital Terrain Model
EAFRDP	European Agricultural Fund for Rural Development
ECR	Gross Energy Conversion Ratio
ES	Ecosystem Service
ERGM	Exponential Random Graph Model
GE	Gross Energy
GEI	Gross Energy Intake
GHG	Greenhouse gas
GIS	Geographic Information System
GWP	Global Warming Potential
GWESP	Geometrically-Weighted Edgewise Shared Partnerships
HeE	Human edible fraction of animals' diet
HeECR	Potentially Human Edible-Gross Energy Conversion-Ratio
HNVF	High Nature Value Farmland
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LFS	Livestock Farming System
LU	Livestock Unit
MEA	Millennium Ecosystem Assessment
N_2O	Nitrous Oxide
N_{av_p}	N available at pasture
N_{av_s}	N available fertilized soils pasture
N_{vol_field}	N volatilisation from fertilized soils pasture
N_{vol_ms}	N volatilized from manure storage
NE	Net Energy
NE_a	Net Energy Requirement for Activity
NE_l	Net Energy Requirement for lactation
NE_m	Net Energy Requirement for Maintenance
NE_p	Net Energy Requirement for Pregnancy
NH_3	Ammonia
PCA	Principal Component Analysis

RDP	Rural Development Program
SNA	Social Network Analysis
SO_2	Sulfur dioxide
SO_2-eq	Sulfur dioxide Equivalent
SWOT analysis	Strength, Weakness, Opportunity and Threat Analysis
TEEB	The Economics of Ecosystems and Biodiversity
TMR	Total Mixed Ration
UAA	Utilized Agricultural Area
VS	Volatile Soil Excretion Rate

Institutions

Abbreviation	Meaning
AVEPA	Veneto Agency for Payments in Agriculture
CITA	Centro de Investigación y Tecnología Agroalimentaría de Aragón
CREV	Regional Centre for the Veterinarian Epidemiology
DAD-IS	Domestic Animal Diversity Information System
EC	European Commission
EEA	European Environmental Agency
EU	European Union
FAO	Food and Agriculture Organization
IDESCAT	Institut d'Estadistíca de Catalunya
INRAE	Institut Nationale de Recherche pour l'Agriculture , l'Alimentation et l'Environnement
IPCC	Intergovernmental Panel on Climate Change
ISTAT	Italian National Institute of Statistics
IAEST	Instituto Aragonés de Estadistica

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Abstract

In the last decades, mountain areas were affected by a strong abandonment due to the increasing competition with the lowland areas where mostly industries and services are located. Specifically, the abandonment of livestock activities and the associated pasture and meadows led to a loss of Ecosystem Services (ES), including both environmental and cultural benefits, such as forest fire prevention, nutrient cycle, landscape maintenance and cultural heritage.
Moving from the assumptions that viable livestock chains contributes to the sustainable development of mountainous areas, contrasting the depopulation and the abandonment, this thesis analysed different strategies to generate added value to mountain Livestock Farming Systems (LFS), based on a strong cooperation between farmers and other local stakeholders. The thesis is composed by three chapters, in which case studies in different Countries and based on different farming systems are analysed and critically discussed. Paper I underlined the strong relationships between organic beef production and mountain agroecosystems in the Catalan Pyrenees. The farms managed large surfaces of pasture and meadows, including highlands pasture. Their activities, mainly based on use of local forage resources, are characterized by few off-farms inputs and very low feed-food competition. Indeed, environmental impacts are mostly related to on-farms stages. Paper II is focused on smallholders' farms involving local sheep breeds in Italian Eastern Alps. Results showed the important role of farmers in conserving endangered local sheep breed; through a correct management of mating plans, they were able to contrast the risk of inbreeding and the genetic erosion. Moreover, mountain LFS involving small ruminants allowed to maintain a mosaic landscape, characterized by small patches with high biodiversity and high natural value. Finally, paper III highlighted a good level of exchange of knowledge and opinions as well as a good confidence' level among the local stakeholders despite the different labour sectors. Results showed that, the local stakeholders involved in the study, were interested in the initiative concerning the development of a beef quality brand in Hecho and Ansó vallyes (Aragonese Pyrenees). Indeed, for them, the initiative could generate new opportunities, especially for young people, and for local development in the two valleys.
Moving from a local to a global perspective, the strategies identified can serve as recommendation for other mountain areas, located both within and outside Europe. Results of the three contributions referred to some mountainous regions of Mediterranean basin; however, the positive externalities related to the mountain LFS as well as their important role in managing large surface of pasture and meadows, in delivering high-quality and healthy products and in conserving local breeds should be considered as general implications even for other mountain areas. Moreover, our results are consistent even with the European policies concerning pasture

and meadows maintenance (Navarro and López-Bao, 2018; EEA, 2009), the provision of high-quality products (EU, 2020) but even with the Global Plan of Action regarding the practices and the important role of farmers in conserving the animal genetic resources (FAO, 2007). The adoption of participatory methodology to collect data and to performthe results could be considered as a multidisciplinary approach, having both positive and negative aspects. Indeed, to achieve the main objective of this thesis, different indicators were adopted as well as different local stakeholders were involved. This may represent limitations due to the difficulties in combining both different methodological approaches and local stakeholders with different interests and expertise. However, on the other hand, this also allows to have a more global and comprehensive perspective of the entire supply chain linked to the mountain LFS as well as to the the mountainous regions in general.

1 Background and general introduction

In the last decades, mountain Livestock Farming Systems (LFS) were affected by a strong abandonment (MacDonald et al., 2020). The main drivers were related to the lack of generational turnover and to the increase competition with other sectors, such as services and industries, mostly located in the lowland areas. The abandonment of livestock activities and the associated mountain agroecosystems led to a loss of environmental and non-environmental benefits, namely as Ecosystem Services (ES). The ES are all the direct and indirect contributions to human well-being which frequently have a no-market value. Indeed, mostly mountain LFS, are based on pasture and meadows, which are maintained through the animals' grazing and farming activities. European Union (EU) recognizes the important role of this type of production systems in delivering ES and provides a series of financial aid to contrast the rural depopulation and to support farming activities in mountainous regions. Furthermore, the recent Farm To Fork Strategy, even established at European level, is moving towards conversion to organic farming and to awareness consumers in choosing healthy and high-quality products.

Mountain LFS are frequently defined as extensive systems since they used natural local resources with off-farms inputs. Their abandonment causes a loss of both environmental and cultural ES. Indeed, the main consequences related to the abandonment of LFS in mountain areas are: i) loss of open areas, e.g. pastures and meadows, which contribute to forest fire prevention and to biodiversity conservation; ii) reduced nutrient cycle; iii) reduced water flow regulation; iv) loss of traditional farming practices, which are part of the local cultural heritage. This thesis focuses on find strategies to generate added value to mountain LFS considering three different mountain regions: Catalan Pyrenees, Aragonese Pyrenees and Italian Eastern Alps. The papers included in this thesis proposed to give a contribution in contrasting both the rural depopulation and the loss of ES by: i) highlighting the positive externalities related to mountain LFS and their relationships with the associated agroecosystems; ii) analysing the feasibility as well as the exchange of opinions and knowledge concerning an emergent initiative, i.e. a beef quality brand, which aimed to create local development in Hecho and Ansó valleys (Aragonese Pyrenees).

1.0 Added value of mountain livestock farming systems

The concept of multifunctional agriculture was introduced in Western countries in 1980s (Tipraqsa et al., 2007) emerging from the Uruguay Round Agreement, which took place in 1994 (Barnaud and Couix, 2020) and is related to the different benefits and no-benefits provided by agriculture. Potter and Burney (2002) defined agriculture as multifunctional, as it provides not only food but also environmental benefits, such as biodiversity and landscape maintenance. It also contributes to creating new employment opportunities. A study conducted in Northeast Thailand addressed four aspects of multifuncionality: social, economic, environmental and food security (Tipraqsa et al., 2007). Mountain LFS, based on pasture and meadows, are also considered as multifunctional since several studies recognised their contributions to the environment, to local communities and to society in general, for each environmental, social and economic aspect as well as the provision of food (Salvador et al., 2016; Bernués et al., 2019; Huber et al., 2020; Barnaud and Couix, 2020). Mostly LFS are located in marginal areas and/or less favoured areas (Bernués et al., 2011; González-Díaz et al., 2019; Battaglini et al., 2014) and are classified as High Nature Value Farmland (HNVF). A typical HNVF is an '*extensively grazed upland, alpine meadows and pasture, steppic areas in eastern and southern Europe and deheas and montados in Spain and in Portugal*' (Paracchini et al., 2018). The HNVFs are maintained through the extensive farming practices (O'Rourke et al., 2016), essentially based on the use of local forage and local resources, with reduced off-farm inputs, such as pesticides and concentrates (Porqueddu et al., 2017; Cosentino et al., 2017; Insausti et al., 2021). Mountain LFS guarantee food security (Garibaldi et al., 2017) and also are low competition systems between feed and food since they are based on non-human-edible feed sources. Herbivores are able to transform forage resources into high-quality food and non-food products, such as milk, meat and wool (Wilkinson et al, 2018; Mottet et al., 2018; Boyazoglu et al., 2001). Furthermore, since these type of livestock systems are based on pasture and meadows, they contribute to maintain a high level of biodiversity as well as semi-natural habitats (O'Rourke et al., 2016) in many regions of Europe, e.g in English uplands (Vigani and Dwyer, 2019) and in the Mediterranean regions (Campedelli et al., 2018).

Regarding the above-mentioned social and economic aspects, extensive farming practices are linked to traditional ecological knowledge (Lomba et al., 2020), based on seasonal use of pastures and the associated seasonal movements of herds (Beaufoy and Poux, 2014). They contribute to maintain a mosaic landscape (Insausti et al., 2021; Plieninger et al., 2021; Guadilla-Sáez et al., 2019) as well as animal and plant diversity (Gaüzère et al., 2020; Goded et al., 2019).

Besides, mountain LFS raised mainly local breed, contributing to genetic diversity conservation which are linked to local social-cultural traditions (FAO, 2007; Porqueddu et al., 2017). LFS are strongly rooted to mountainous regions, as they have been linked to the culture of local traditions for centuries. In the majority of mountain regions, LFS represent the main source of income for local communities (Plieninger et al., 2016) which are insufficient to their sustainment (Montrasio et al., 2020); for this reason, the European Union (EU) provides financial aid even in order to maintain HNVF. The challenge is finding a strategy in order to give added value to the livestock supply chain, located in mountain areas. According to the LPP et al. (2010), it is fundamental to focus on the production process as well as on the actors involved in the supply chain (farmers, institutions, sellers etc.) in order to organize local communities and to associate the products to a specific market. Cooperation between local stakeholders, such as tourism operators, restaurateurs or institutions can lead to new synergies and opportunities for mountain pasture-based LFS. Indeed, according to Bernués et al. (2011) and to Alary et al. (2019), beyond the financial aid, mountain LFS should move towards a diversification of income. Pasture-based LFS generate a series of further activities, both at farm and local level, including agriculture, green-tourism, farm-education, etc. Even the promotion of typical local products is fundamental, since it is related to the identity and traditions of a specific geographical area (Dalvit et al., 2009; Bentivoglio et al., 2019; Battaglini et al., 2014), e.g. "Sapori di Malga" in province of Trento (Pachoud et al., 2020) or the Alpagota breed, famous for lamb production and which even certified as Slow Food Presidium (Bittante et al., 2021).

1.2 The ES framework and the benefits provided by the pasture based LFS

The Millenium Ecosystem Assessment (MEA) defined the ES as '*the benefits that people obtained from ecosystems*' (MEA, 2005). ES are, therefore, all the direct and the indirect contribution of ecosystems, including mountain agroecosystems, to human well-being, most of which have no-market value. (TEEB, 2010; de Groot et al., 2010; Rodríguez-Ortega et al., 2014); ES delivers a series of private goods, i.e. food and fibres, but even public goods without market value (Cooper et al., 2009; TEEB, 2010). The MEA identified four main categories of ES (Figure 1):

- Supporting ES: all the services necessary for the production of all the other ES, such as soil formation, nutrient cycle, primary production;
- Regulating ES: benefits obtained from the regulation of ES processes, such as pollination, water regulation, climate regulation etc.;
- Provisioning ES: products obtained from ecosystems, such as food, fibres, raw materials, genetic resources etc.;
- Cultural ES: non-material benefits obtained from ES, such as cultural heritage, aesthetic, spiritual and religious values, recreation and tourism etc.

Mountain agroecosystems deliver a series of regulating, cultural, provisioning and supporting ES not only to local communities but also to tourists and to the society in general (Martín-López et al., 2019; FAO, 2014). Mountain agroecosystems are mainly related to grazing livestock systems (Bernués et al., 2014) which are able to utilize and to manage marginal and other unfavourable areas. Pasture-based livestock systems, through the maintenance of pasture and meadows, provide several ES, such as carbon sequestration (Canedoli et al., 2020), forest fire prevention (Bernués et al., 2022; Sil et al., 2019), water flow regulation (Battaglini et al., 2014), pollination (Rakosy et al., 2022), conservation of genetic resources (Leroy et al., 2018), mosaic landscape and biodiversity conservation (Ameztegui et al., 2021; Cocca et al., 2012; Guadilla-Sáez et al., 2019). Several studies have shown that these benefits are recognised and evaluated positively not only by local stakeholders but also by people who visit mountainous regions for recreational and touristic reasons, even though they do not normally live there. (Faccioni et al., 2019; Muñoz-Ulecia et al., 2022; Bernués et al., 2014). A positive social evaluation of the benefits provided by pasture-based LFS and by the associated mountain agroecosystems, can generate added value to the whole supply chain, also considering a global perspective.

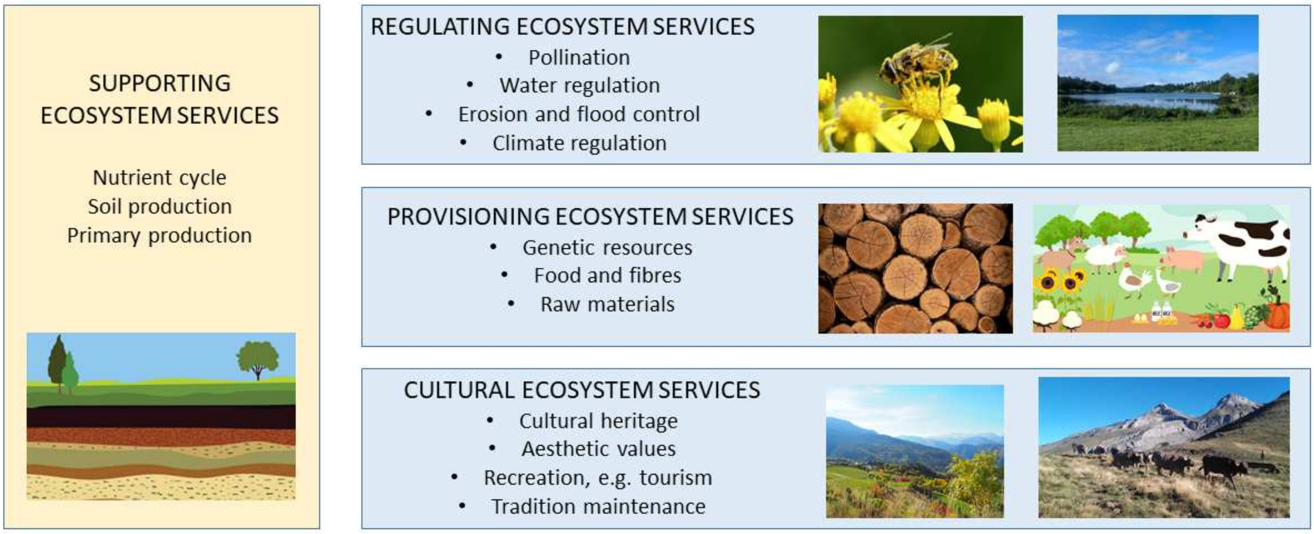

Figure 1: the four categories of ES identified by MEA (2005).

1.3 Abandonment of farming systems in mountain areas and loss of Ecosystem Services

In the last decades, mountain areas have been affected by a strong abandonment, with a consequent loss and decline of traditional farming systems (MacDonald et al., 2000, Cocca et al., 2012). The abandonment and the consequent depopulation, with the exodus of people towards the lowland areas, affected many mountainous regions all over the world (Quintas-Soriano et al., 2022). Since 1990, the abandonment of Utilised Agricultural Area (UAA), which included mainly grasslands (pasture and meadows) in Europe was approximately of 120 Mha (FAOSTAT, 2017; Levers et al., 2018). Schuh et al. (2020), revealed that within 2030, around 30% of agricultural areas in EU (56 million of ha) are at risk of abandonment. Indeed, by 2030, 173 Mha could be the effective UAA abandoned (Schuh et al., 2020). The abandonment led to a loss of provisioning ES (Durán et al., 2020), regulating ES, such as water cycling (Benayas et al., 2007), supporting ES (Rodrigo-Comino et al., 2017) and cultural ES (Schirpke et al., 2020). Leal Filho et al. (2017), through a literature review, found that many drivers were related to socio-economic, environmental, topographic, geographic and political constrains. However, according to Muñoz-Ulecia et al. (2021), in the majority of cases the abandonment was due to the increasing competition with other production sectors where topographic and geographic conditions are less favourable. Indeed, the reduced accessibility, e.g. the distance from the road and from the city centre as well as the lack of infrastructures and the few accesses to a market chain (Leal Filho et al., 2017; Munroe et al., 2013; Benayas et al., 2007) contributed to the abandonment of farming activities.

Considering the socio-economical, environmental, topographical, geographical and political aspects identified by Leal Filho et al. (2017) and according to Subedi et al. (2022), the main issues of the aspects mentioned before are:

- Socio-economic aspect: the lack of generational turnover and the increasing competition with other production sectors and with intensive livestock farming systems, both mostly localized in the lowland areas;
- Environmental aspect: the seasonal availability of the forage and the seasonal use of the pasture lead these farming systems to be highly dependent on the environmental conditions, e.g. weather conditions, water availability, soil proprieties etc.;
- Topographic and geographic conditions: the majority of LFS are localized in marginal areas characterized by reduced accessibility, harsh conditions and high slope;

- Political aspects: mainly related to political actions as well as the absence of clear government policies.

Some aspects are widespread in various European states, others only in some of them. The socio-economic aspects as well as the environmental, the topographical and geographical conditions, are the most common drivers contributing to the abandonment.

The main driver of generational renewal is the rural depopulation, due to the emigration towards more urbanized and industrial areas, as they guarantee more employment opportunities (Lasanta et al., 2017) and more possibilities for agriculture intensification given by the productive land (Levers et al., 2018). Indeed, farming activities are characterized by a very low income and most farmers have another employment to increase their remuneration. Furthermore, the increasing competition with the intensive systems, less dependent on forage seasonality and on resources availability, as well as the more suitable conditions in comparison with marginal areas, contribute to rural depopulation and to the associated livestock activities (Monteiro et al., 2020; Terres et al., 2015; Muñoz-Ulecia et al., 2021).

Regarding the political aspects, the EU is moving towards financial aid which will be discussed in the next paragraph, since European Commission (EC) recognized the important role of farming systems in managing HNVF and in providing a series of benefits to human well-being, i.e. ES.

Moving forward the consequences related to the abandonment of farming activity and to the rural depopulation, these are mainly related to the loss of ecosystems and the rural depopulation (Quintas-Soriano et al., 2022). In accordance with the statements of the paragraph 1.2, farming activity and animal's grazing contribute to maintain pasture and meadows, which deliver a series of ES. The abandonment of farming activity led to a loss of ES, which correspond to an increase of forest encroachment (Claps et al., 2020; Sidiropoulou et al., 2015; Subedi et al., 2022), and to a growth of natural hazard, e.g. forest fire (Ustaoglu and Collier, 2018; Sil et al., 2019). The loss of ES led also to an increase in soil erosion (Cerdà et al., 2018), the loss of biodiversity, plant community, forage quality and soil proprieties (van der Zanden et al., 2017; Cislaghi et al., 2019) as well as the loss of traditional landscape, cultural heritage and traditions (Schirpke et al., 2020; Ustaoglu and Collier, 2018). The abandonment of farming activity and the linked traditional farming practices led to a loss of cultural heritage as well as the lack of generation renewal, which strongly affect local communities and their cultural traditions, typical of mountainous regions.

1.4 Participatory process and collective action in mountain LFS

Mountain LFS are complex and multi-dimensional systems hence, farmers and other local stakeholders have different perceptions and perspectives, that have to be taken into consideration since, with their interactions, shared knowledge and resources (Belanche et al., 2021; Tengö et al., 2014). According to Schirpke et al. (2021), the involvement of local communities, belonging to different labour sectors as well as belonging to different countries, could improve the provision of ES in mountain areas, both at local and global level. However, in mountainous regions regional proximity is a key factor to allow the exchange of feedback between residents. In accordance with paragraph 1.3, mountain areas are frequently characterized by a lack of infrastructure, i.e. roads, which could inhibit the interactions between people. Closeness, in terms of regional proximity, as mentioned before, enhances interactions and collaborations between farmers and other stakeholders. Participatory approaches help to overcome these barriers, as they promote inclusive projects, i.e. adding value to a local chain of beef production (contribution 1), adding value to local breeds (contribution 2) and, finally, contributing to the development of an emergent initiative (contribution 3). Edelmann et al. (2020), for example, showed how participatory processes and collective actions increase the recognition of the link between a local product and to a specific geographical area, since it included also the traditions and the cultural heritage of that territory (Fusté-Forné, 2020). The valorisation of local products is a main challenge for disadvantages areas since, several studies, demonstrated the willingness of people to pay more for high quality local products (Poux and Pointereau, 2014; Meemken and Qaim, 2018) which lead to an increase in the market value (Bryła, 2015).

The capability of local mountain communities to collaborate in common projects and to act collectively contribute to improve the environmental benefits as well as to valorise the territory and its resources (Orchard et al., 2020; Vollet and Torre, 2016). Indeed, collective action is defined as a voluntary process of cooperation that involves different stakeholders with shared interests (Barnaud et al., 2018; Scott and Marshall, 2009), which is relying on exchange of resources (Lazega, 2006), sharing knowledge to increase their capacities (Nieto-Romero et al., 2016) and aiming to achieve common objectives.

Collective action favours participatory approaches since, being based on collaboration, they foster cooperation, which is very important for the success of common initiatives; these are useful for adding value to mountain areas, such as the mating plans implemented by farmers for Lamon and Alpagota breed and the development of a smartphone application (contribution 2) or the development of a beef quality brand in the Aragonese Pyrenees (contribution 3).

1.5 The financial aid provided by EU and the Farm To Fork Strategy

The benefits provided by mountain livestock farming systems, which contribute to maintaining pasture and meadows, as well as the consequences of their abandonment and the consequences of rural depopulation, are getting attention both at local and a global level. For this reason, the EU provides financial aid with the specific aim of contrasting the abandonment and its consequences. The European Common Agricultural Policies (CAP) recognize the important role of extensive farming systems in delivering positive externalities (EU, 1992), as well as in managing HNVF (EEA, 2009) and provides subsides to support farming activities, especially those located in disadvantaged areas. Mostly of HNVF across Europe are maintained by CAP financial support, in order to favour the conservation of biodiversity and the provision of ES (Merckx and Pereira, 2015) as well the cultural landscape, i.e. mosaic landscape, (Guadilla-Saez et al., 2019). CAP payments support mountain LFS, since they acknowledge the importance of grazing activity in delivering a range of socio-ecological benefits to the society (Torreiro, 2014; Galán et al., 2022).

Besides the environmental benefits, CAP aim at sustaining agricultural production also in terms of food security (Lomba et al., 2019) and health. According to Garmendia et al. (2022), e.g. extensive sheep farming systems are able to produce healthy and high-quality products but they are also able to transform no-human-edible feed into high quality edible products (Wilkinson et al., 2018).

For these reasons, the Farm to Fork strategies, established in 2020 by the European Commission (EC), provided new subsides to support pasture-based LFS, located in marginal and unfavourable mountain areas, as well as to support the conversion to organic farming. By 2030, the EU, through the Farm to Fork Strategy, aims to converting 25% of the total farmland under organic farming located in Europe. Besides, among its goals, it includes a food labelling framework to increase the customer awareness in healthy and sustainable organic food choices. Indeed, as mentioned in paragraph 1.4, several studies demonstrated the willingness to pay more for local high-quality and organic products, also in food safety perspective (Poux and Pointereau, 2014; Meemken and Qaim, 2018; Bryła, 2015). The main goal of European financial aid and of the recent Farm to Fork Strategy, is moving from a local perspective (creating added value for local products and for the whole supply chain) to a global a perspective (highlighting the several benefits provided by these farming systems to the environment and to the society, also considering the increasingly emerging Climate Change issue).

As several studies highlighted, the main issue is the strong dependence of these farming systems on financial aid, as they are characterized by low income (Batáry et al., 2015; Lomba et al., 2019; Muñoz-Ulecia et al., 2021). The threat is if these were no longer provided, mountain farming systems and their benefits would decay. Fayet et al. (2022), for example, found that financial aid should be provided also for long-time nature-conservation initiatives. Another strategy that should be implemented is improving these farming systems' self-sufficiency, creating added value to the supply chain guaranteeing their source of income that allows them to be self-sufficient. An example of that could be the introduction of sustainable forms of tourism or niche markets for local products. Another strategy should be creating a new marketing strategy which highlight the benefits that these production systems bring to the environment and society.

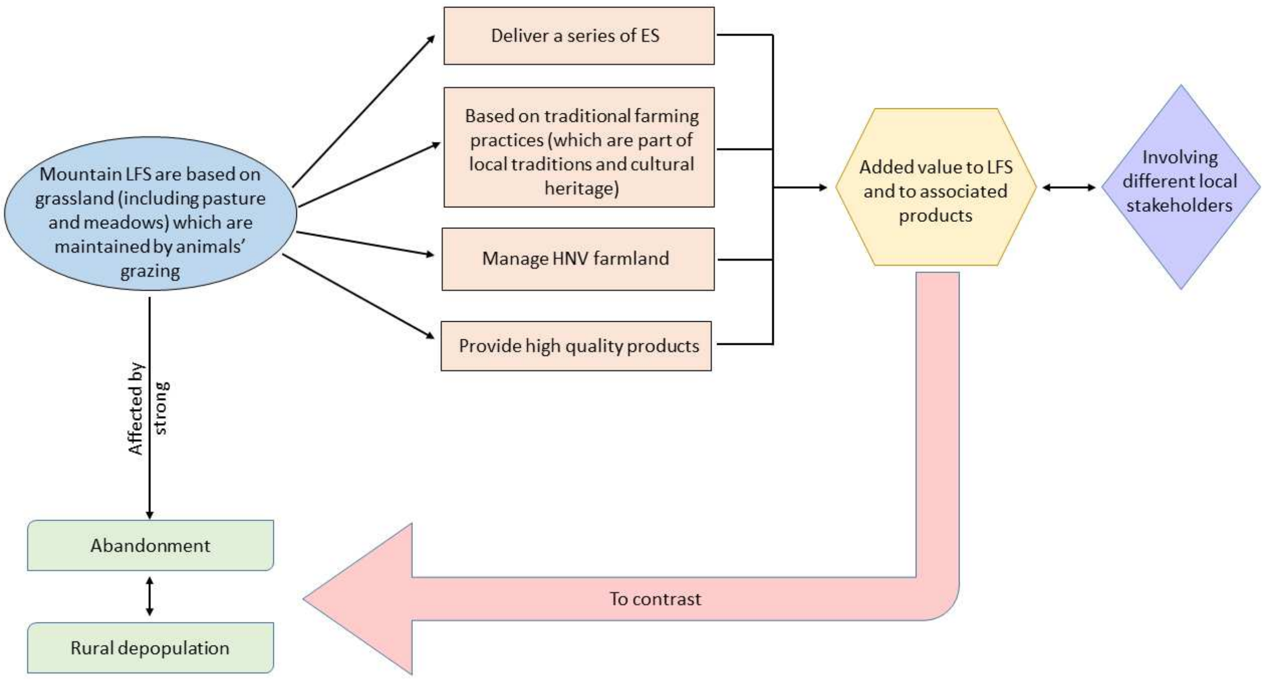

Figure 2: main steps analysed in the introduction as well as in the strategies identified in the three contribution to generate added value to mountain LFS

2 Research gaps

The abandonment in mountain areas are increasingly apparent and it is getting attention at the European level. To maintain the livestock activities, it is necessary to identify new strategies which should be different from those adopted by the intensive systems, since they aim to maximise production. For this reason, it is important to consider local initiatives should be considered to create added value to supply chains that would be marginalised. The objective of this is thesis is to encourage generational turnover in farming activities as well as promoting initiatives which involved different local stakeholders. The strategies that the contributions of this thesis highlight go beyond the already planned EU subsides.

The three papers aim to fill gaps that were found in the literature following a detailed bibliography research. Indeed, mostly paper focused on the benefits provided by mountain LFS to human well-being but very few analysed how these benefits could be utilised to create added value to mountainous regions. Paper I focused on the relationships between livestock activities and mountain agroecosystems and on the associated environmental impacts. Paper II focused on the important role of smallholders in conserving local genetic resources. Indeed, the cooperation between farmers in managing the mating plans allows to contrast the risk of inbreeding, preserving local sheep breeds. Within the results of the project reported in paper II, a smartphone application was developed to support farmers during the mating plans. Besides, the paper highlight the important role of livestock systems, which involved small ruminants, in maintaining mosaic landscape.

Finally, paper III, using a methodology based on participatory approach, aim to test the feasibility and the exchange of information and opinions, among local stakeholders, involved in the development of an emergent initiative. Specifically, the focus groups and SNA allows to analyse the interest, the relationships and the trust level between the local stakeholders taking part in an initiative concerning a beef quality brand.

The strategies founded involved farmers but even other local stakeholders which could have an interest in giving added value to mountainous regions and to the linked LFS.

3 Thesis aims and journal contribution

The aim of this thesis is to analyse different form of strategies, in order to generate added value to mountain LFS. According to the previous paragraph's statement, mountain LFS, based on pasture and meadows, are mainly located in disadvantages areas (marginal and/or less favourable), characterized by: i) very low income ii) strong dependence on national and European financial aid and a strong abandonment. On the other hand, traditional farming practices represent the cultural heritage and the traditions of a specific mountain areas, since livestock activity has a very strong impact on local communities as it maintains cultural landscape and it represents a form of employment to contrast the rural depopulation.

The three contributions refer to studies conducted in different LFS located in different mountain regions with specific production drivers. The studies are based on the same specific aim: finding and developing new strategies in order to generate added value to the livestock farming systems located in disadvantages areas.

For each contribution, a participatory approach was adopted to survey a sample of farmers and no-farmers.

Contribution 1: the study was conducted in the Catalan Pyrenees (Province of Lleida, North of Spain). A sample of 8 farmers, involved in the organic beef production, was surveyed with three specific goals: i) assessing the structural and management features of each farm ii) comparing the productivity and manure loads of different farmland parcels compared with the management intensity (natural meadows, seminatural meadows and temporary crops); assessing the environmental impacts related to this type of farming systems through the Life Cycle Assessment (LCA) methodology.

Contribution 2: the study was conducted in Belluno province (Italian Eastern Alps, Veneto region, North of Italy); we surveyed a sample of 35 farmers who raised two local sheep breeds: Lamon and Alpagota, both endangered. The specific aims were: i) developing and implementing a smartphone application to support the farmers during the mating plans, improving the cooperation between them and limiting the risk of inbreeding; ii) developing a "territorial marketing" strategy, highlighting the relationships between these livestock systems and the landscape, as well as the mountain agroecosystems; iii) using the SWOT analysis approach to find out strengths, opportunities, weaknesses and threats related to the conversion into organic farming for the Alpagota breed.

Contribution 3: the study was conducted in Hecho and Ansó valleys (Aragonese Pyrenees, province of Huesca, north of Spain); we surveyed a sample of 32 people, farmers and other local stakeholders, involved in the development of a high-quality beef brand. Using a methodology based on participatory approaches, the specific aims were to test the feasibility of the initiative's development by: i) analysing the interest of the local stakeholders involved; ii) analysing the exchange of information and opinions among local stakeholders involved; iii) assessing the confidence level among local stakeholders surveyed. This study should be considered as an example of application of participatory approaches methodology to test the feasibility as well as to support participatory and inclusive processes, in order to create a major cooperation for new project development.

4 Research approach and thesis outline

For all three contributions, participatory approaches were adopted to collect data. Indeed, different surveys were designed according to the type of data needed for the analysis.

Paper I aims to underline the relationships between livestock systems, orientated to organic beef production, and mountain agro-ecosystems, located in the Catalan Pyrenees. The survey was develop covering three parts: i) general features of farmers and farms (including herd size and their characteristics, reproduction management, diet composition during in-house period etc.); ii) general features about land use managed; iii) productivity (kg DM/ha), manure loads (kg/ha) and presence of irrigation (yes/no) for each farmland parcels managed. In addition, for each parcel, we asked to farmers their willingness to change or not the land use (from natural/seminatural meadows to temporary crops). A comparison of forage productivity and manure loads between farmland with different management intensities (natural meadows, seminatural meadows and temporary crops) was performed to test whether there is significant difference between them. Besides, to estimate the environmental impacts, a cradle-to-farm gate model, according to the Life Cycle Assessment (LCA) method, was adopted with the farm as reference unit.

Paper II focuses on the results obtained with the Sheep Al.L. Chain project, which had the main goal to improve the competitiveness of two local breeds of Veneto Region, Alpagota and Lamon, both endangered. The survey was designed: i) to collect information about farms and farmers features, focusing on the characteristics of local sheep breed' herds; ii) to gather information, such as surface, number of parcels, etc., concerning the grassland (including pastures and meadows), managed. Data regarding land use were implemented using the Geographic Information System (GIS) approach. Besides, to test the genetic variability, we collected blood sample from the breeding rams to genotype them and a Principal Component Analysis was carried out. Finally, a SWOT analysis was conducted to explore the potential of Alpagota sheep farms to conversion to organic farming.

Paper III will be submitted in a scientific journal as soon as we have collected all the revisions from all the authors involved. We collected data through focus groups and surveys. Concerning the latter, since the main aim was to carry out a SNA, the survey was design according to the Roster method: we presented a list of people involved in the development of the quality brand and we asked for each actor surveyed to with whom of the people of the list had discussed concerning the initiative. Within the SNA, we even assess the level of trust, asking to each respondent to indicate for each person named in the list, on a scale from 0 (very low) to 10 (very high), how much they relied on that person's opinions and ideas as contribution to the development of the brand. Furthermore, the survey included other two parts covering: i) general information about the respondent: age, labour sector, education level, place of residence; ii) information about the quality brand (number of meetings to which they took part regarding this initiative, from whom they first heard about the initiative, whether they think it will create added value in the Hecho and Ansó valleys).

The three contributions, which will be reported in the next chapters, will be followed by a general discussion and by general conclusions.

5 Contributions

5.1 Paper I: Relationships between LFS and mountain agro-ecosystems

Relationships between Organic Beef Production and Agro-Ecosystems in mountain areas: The Case of Catalan Pyrenees

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Relationships between Organic Beef Production and Agro-Ecosystems in Mountain Areas: The Case of Catalan Pyrenees

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Abstract: This study analyzed the link between organic beef production and agroecosystems in mountain areas and the potential effects of land use change in eight farms of Catalan Pyrenees with a three step approach: (i) assessment of structural and management features; (ii) comparison of forage productivity and manure loads of 71 farmland parcels in relation with management intensity (natural meadows, seminatural meadows, temporary crops) and, for meadow parcels, with the farmers' willingness to convert them to temporary crops; (iii) life cycle assessment of the environmental impacts. Each farm managed around 150 ha of pastures and 23 ha of farmland (of which only 5 as temporary crops), and maintained a herd of around 130 livestock units. Forage productivity and manure loads of farmland were modest and extremely variable, and no productive advantages could be predicted from the conversion of meadows to temporary crops. Environmental impacts were mostly related to the on-farm stages, because of low-input management and very high feed self-sufficiency, and the diets used showed very low feed/food competition. These results indicate a balance between organic beef production and management of mountain agroecosystems, which is a key point for sustainability and should be a priority in European policies and strategies.

Keywords: livestock systems; mountain areas; grassland; organic production; life cycle assessment

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1. Introduction

Grassland-based extensive livestock farming systems play a central role in managing and conserving High Natural Value Farmland (HNVF) areas in less productive regions, such as in European mountains [1–4]. These systems are highly multifunctional, because they indirectly or directly deliver a series of public, non-marketable benefits to the society, which can be described as non-provisioning ecosystem services (ES) [5,6]. The ES provided by mountain agroecosystems include, for example, the conservation of grassland habitats and the associated biodiversity, soil carbon storage and health [7,8], or the maintenance of cultural landscape and heritage and the provision of space for recreation and cultural experiences [9–11], protection from invasive species [12] and, particularly in Mediterranean regions, protection from forest fires [3,13,14]. Often, additionally, these extensive grassland-based systems are engaged in the production of typical high-quality products [15–17] such as organic beef. During the last decades, in the European mountain areas the traditional livestock systems based on extensive management of pastures and meadows have been strongly affected by two processes: intensification of farmland and herds management in suitable areas and abandonment in marginal areas [18,19]. As a result, mountain agroecosystems have been profoundly altered, with either a conversion to arable crops and intensification of farmland management or reforestation of abandoned grasslands [14,20], with the resulting loss of the associated ES [10,21,22], which, although non-marketable, are highly valued by society [11,23] such as the maintenance of pasture and meadows guaranteed by animals' grazing. The main factors determining abandonment are family constraints, topographic and climatic conditions, economic and social elements [24,25] since, for example, farming profitability is lower and not sufficient for the families' sustenance. In order to overcome these constraints, the European Common Agricultural Policy (CAP) recognizes the important multifunctional role of extensive livestock systems in delivering positive externalities [26] and provides financial support to maintain pastures and meadows through regional Rural Development Programs, as for example with Agro-Environmental and Climate measure 10 (M10) that, in the Catalonia region of Spain, provides financial incentives to management of pasture and meadows [27].

With the recent rise of public concern on climate change and, more in general, on the environmental impacts of anthropic activities, the contribution of livestock farming has been debated and the need for mitigation measures clearly outlined [28]. In this perspective, grassland-based livestock systems have been reported as notable contributors to the total anthropogenic greenhouse (GHGs) or acidifying gases emission, especially if beef systems [29]. Assessments based on the life cycle assessment (LCA) methodology [30] reported higher impacts per unit of product for roughage-based with respect to concentrate-based beef systems, because of lower growth rates, longer finishing periods and greater enteric methane emissions [31,32]. In the recent years, an increasing number of grassland-based beef farms have been converted to the organic production system, since characteristics such as the use of meadows and pastures and the low off-farm feedstuffs purchase share favor the accountability to organic label regulations [33,34], and the beef may be marketed at higher prices [35]. However, organic beef production has generally a lower productivity than conventional production, and consequently, greater impacts per unit of product [29]. Improvements in feeding strategies with use of high-energy feeds would mitigate emissions [36], but would also require an intensification of farmland management that could impact on the various ecosystem services that are linked to extensively managed grasslands [6]. Improving knowledge on this trade-off is therefore important for addressing the sustainability of organic beef farming in mountain areas [37].

In the Catalan Pyrenees, the number of farms engaged in organic beef production has been steadily increasing during the last years. We found a gap in literature regarding these livestock systems and their relationships with the use of local resources and mountain agroecosystems. This research aims to give new insights for farmers and policy makers, useful to define strategies and policies for the sustainable development of organic grassland-based beef systems.

With this general goal, this study examined the link between mountain agroecosystems and the environmental impacts of the organic beef systems in the Catalan Pyrenees. We surveyed a representative sample of farms with three specific aims. First, we described the land and herd management features, to assess the type of agroecosystems used and the farming management intensity. Second, with the of aim of determining whether an intensification of land management would predictably lead to an increase in productivity, we compared forage production and manure loads among meadows and temporary crops parcels, and, for meadows, in relation with the willingness of farmers to convert them to temporary crops. Third, we assessed with an LCA approach the environmental impacts and the diet energy efficiency of the farms sampled, to analyze the contribution given by each emissions source and the competition between feed and food (potential human-edible fraction of animals' diet) related to this organic beef production.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Alta Ribagorça and Cerdanya comarcas (counties) in the Catalan Pyrenees (Province of Lleida, North of Spain) (Figure 1). Alta Ribagorça has a surface of 427 km², corresponding to 1.3% of the total surface of Catalonia, and an altitude between 800 and 3000 m a.s.l. Cerdanya is divided into High Cerdanya (the northern part, in France) and Low Cerdanya (the southern part, in Spain) with a total surface of 1806 km² (547 km² in Spain, corresponding to 1.7% of the total surface of Catalonia). The climate is influenced by the transition between the Atlantic climate, with humid influences in the western Pyrenean regions, and the continental Mediterranean climate of the eastern Pyrenees [38], and is classified as temperate oceanic (Cfb, according to the Köppen-Geiger climate classification). In Alta Ribagorça the average annual temperature is of 10.1 °C (maximum in June and July and minimum in January) and the average precipitation of 639 mm, in Cerdanya the average annual temperature is of 9.8 °C (maximum in July and minimum in February) and the average precipitation of 619 mm.

Figure 1. Study area. The red polygons on the right panel indicate the two comarcas: Alta Ribagorça on the left and Cerdanya on the right. Blue dots indicate the farms' locations. Source: Institut Cartogràfic i Geològic de Catalunya (ICGC). https://www.instamaps.cat/visor.html?businessid=155012c20c330e3f60e6edd0251ab210&3D=false.

In Catalonia, 2048 km² of Utilized Agricultural Area (UAA) are managed according to practices complying with the organic farming regulations; 1093 km² are located in the province of Lleida, predominantly (81.8%) represented by pasture and meadows [27] (see Figures 2a and 2b). The livestock farms engaged in organic beef production are 971, 260 of which are located in the province of Lleida with a total production of 407.7 tons of carcass weight [39].

In both Alta Rigaborca and Cerdanya, land cover is mostly "forest" (95% and 88.1% of total surface, respectively) which includes woods, scrubland, meadows, pastures and other grasslands, wetlands (Table 1; meadows, pastures and other grasslands are merged into forest because there is no clear distinction between grazed forest and grasslands). More specifically, 26% of the study area is covered by mid-elevation or highland pastures. The density of cattle farms is close to 1/km² of UAA and the cattle stocking rate is 0.2–0.3 LU/ha of UAA, in both comarcas [40].

Table 1. Total surface and land cover, utilized agricultural area (UAA), number and density of cattle farms and livestock units (LU) in Alta Ribagorça (AR) and Cerdanya (CE). Source: Institut d'Estadística de Catalunya (IDESCAT).

Variable	AR	CE
Total surface, km^2	426.8	546.7
Forest [1], km^2	403.6	481.6
Land with no vegetation [2], km^2	11.6	10.7
Cropland, km^2	7.9	33.7
Urban land, km^2	3.9	21.0
UAA, km^2	114.2	286.0
Farms [3], N	77	299
Farms/km^2 UAA	0.7	1.0
LU, N	2644	9884
LU/farm	34.3	33.1
LU/km^2 UAA	23.2	34.6

[1] Forest includes woods, scrubland, meadows, other grassland, pasture and wetlands. [2] Land with no vegetation includes bare soils, rocky land and glacier. [3] The data refer to dairy milk and beef farms.

Part of Alta Ribagorça is occupied by the Parc Nacional d'Aigüestortes i St. Maurici, a protected area located between the Alta Ribagorça, Pallars Jussà and Pallars Sobirà comarcas (400 km^2), whereas in Cerdanya the Cadí-Moixeró Natural Park is located between the Berguedà, Alt Urgell and Cerdanya *comarcas* (410 km^2).

In the province of Lleida, in particular in the Catalan Pyrenees, organic beef production is linked to the management of organic pastures and meadows. According to the Rural Development Program of Catalonia, the number of organic farms is growing and becoming very important in the local livestock production [27]. In the province of Lleida, the number of farms engaged in organic beef production has increased from 4 in 2000 to 260 in 2019. Specifically, in Alta Ribagorça and Cerdanya, organic livestock farms account for 47% and 12% of total livestock farms, respectively [41].

Figures 2a and 2b. On a (on the left), hay mowed for hay; on b (on the right) cows at highland pastures.

2.2. Data Collection

The survey took place in 2018, involving eight farms specialized in organic beef production, which had already established a collaboration with the University of Lleida. The farms were representative of the study area's production context, and all the farmers engaged in this study were employed part-time, because livestock farming alone does not supply for the family sustenance. Data collection and data editing are illustrated in Figure 3.

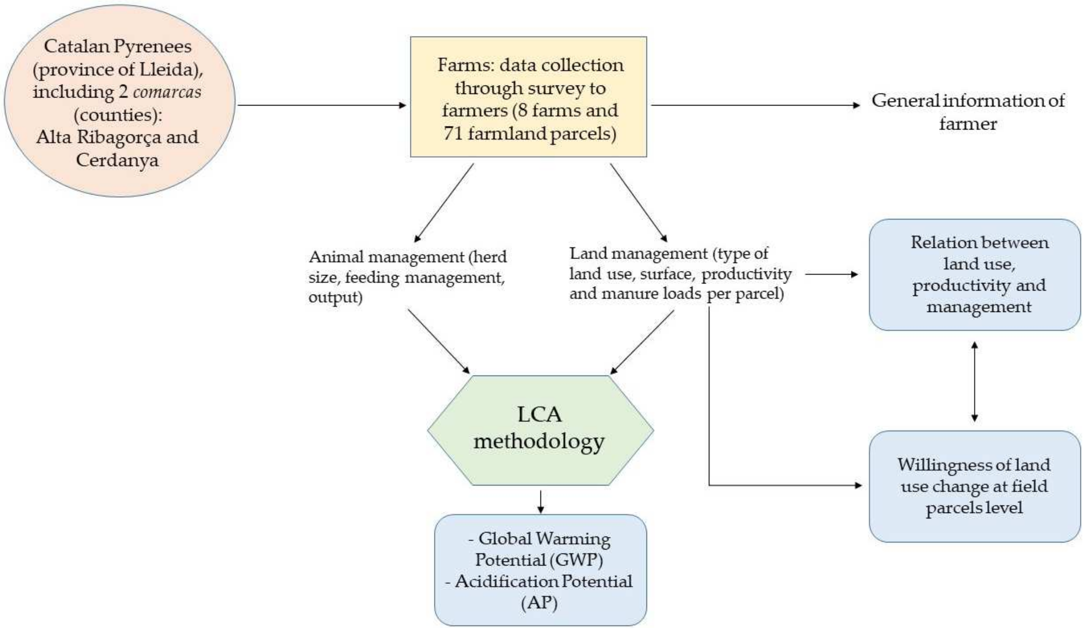

Figure 3. Flow chart illustrating the steps of the methodology used, including the data collection and the study area.

The survey was divided into three parts, and collected a large set of data for each farm (see Table S1 for a detailed description of variables collected). The first part described the general features of the farms and specified data on herd size (number of suckler cows and replacement heifers), breed, reproduction management (calving seasonality), calf management and the relative fattening period. In addition, the diet composition during the in-house period (amount and type of forages and concentrates) was collected for both fattening calves and cows. The second part described the utilized land and its features. Land uses comprised natural meadows, seminatural meadows, and temporary crops, which we will define hereafter as "farmland," in addition to highland and transition pastures. The distinction between natural and seminatural meadows is based on the past management (plowing and reseeding, see Table S1), while temporary crops include forage and cereal crops (Alfalfa, sorghum, etc.) Highland pastures are summer pasture located at high altitudes, above the treeline (2200–2400 m a.s.l.), which are grazed during summer (June–September), whereas transition pastures are located at mid elevations and are grazed during the spring and autumn transhumance to and from the highland pastures. Both types of pastures do not pertain to a single farm, but are municipal properties and collectively managed. Most of the natural/seminatural meadows and temporary crops are instead owned by the farms, and the few others are rented. Meadows are mowed to produce hay but may also be grazed at the beginning of spring and end of summer, before and after the use of transition and highland pastures.

Each parcel of farmland was geo-referenced (Google Earth and Digital Land Parcel Identification System, LPIS), and its average slope was calculated considering the slope of each fenced sub-parcel weighted by its surface. Information on productivity (kg DM/ha), manure inputs (kg/ha) and irrigation management (yes/no) was also recorded (Table S1). Besides, for each parcel, the willingness of farmers to change or not land use was recorded, with land management shift and the reasons for the desired change.

2.3. Environmental Impacts

The environmental impacts were computed using the LCA methodology [30]. This methodology aims to evaluate the environmental burden associated with one unit of a product, considering the different phases of its cycle and including both the direct impacts related to its production, use and disposal and the indirect impacts embodied in the inputs in its production [30,42]. The ISO standard prescribes four different phases: goal and scope definition (setting on the model characteristics), life cycle inventory (data collection and emission calculation), life cycle impact assessment (computation of each impact category) and interpretation of the results.

2.3.1. Goal and Scope Definition

To compute the environmental impact, a cradle-to-farm gate model was adopted, with the farm as reference unit. Since the farm output consists of animals sold to slaughterhouse (fattened male and female calves, culled suckler cows), 1 kg of Body Weight (BW) sold was chosen as the functional unit to which the impact is referred. The impact categories were global warming potential (GWP, kg CO_2-eq), as livestock systems are notable contributors to anthropogenic GHG emissions, and acidification potential (AP, g SO_2-eq) as acidifying N-related compounds released by livestock systems could have negative effects on a local scale [43]. The system boundaries considered the management of animals, manure, farm-land for on-farm feedstuffs production (in house and pasture period) and the purchase of off-farm feedstuffs included in the animal diets.

2.3.2. Life Cycle Inventory and Life Cycle Impact Assessment

Emissions computation was performed for each animal category (suckler cows, weaning calves, male and female calves for fattening, female calves for replacement, heifers at the first year and heifers at the second year). Information was collected for each animal category and concerned the number of animals, age, in-house and grazing periods, the initial (BWI) and final (BWF) body weight and diet (Supplementary Tables S1 and S2). The average daily gain (ADG, kg/day) was calculated as (BWF-BWI)/days of presence.

Feed intake (kg DM) was computed for each animal category, considering the relative in-house and grazing periods during the year. For each animal category, feed intake during the in-house period was computed as the ratio between net energy (NE) requirements [44,45] and the NE content of the diet (MJ/kg DM, values derived from INRA 2007) [46]. The consumption of each feedstuff was computed on the basis of its relative percentage of inclusion in the ration. The total farm consumption of each diet was computed as the sum of the daily intake of each feed per animal category multiplied for the in-house period days and for the number of animals. Feed intake during the grazing period was computed with the same procedure used for the in-house period (NE value for grass at pasture derived from INRA (2019) [47].

Nitrogen (N) input–output balance was calculated considering each animal category and following Katelaars and Van der Meer (1999) [48] (Supplementary Table S3). Specifically, the N intake was calculated as the feed intake (kg DM/d) × presence days (in-house/grazing) × crude protein diet content/6.25. The N retention was computed considering the retention due to BW gain (retention factors: 0.025 kg N/kg BW for sucker cows and heifers, 0.028 kg N/kg BW for weaned calves for fattening or replacement, 0.032 for pre-weaning calves) [49], retention in the milk (mean production: 6.5 kg/cow/day [50]) and pregnancy. N excretion was calculated as the difference between N intake and N retention. The data collected regarded also the age and the final body weight sold at the time of sale, the number of the days in-house and on pasture and the relative diet, in particular the quantity of N.

2.3.3. Emissions Computation and Life Cycle Impact Assessment

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) contribute to GWP. Emissions derived from manure storage at the farm (CH_4 and N_2O) and agricultural soils management (N_2O from manure and fertilizers spreading) were computed with the equations of the International Panel of Climate Change [45] (Supplementary Table S3), applying the approach derived from Berton et al. 2017 [51]. Enteric CH_4 was calculated according to the IPCC procedure, using enteric methane yields based on the diet composition according to Ramin and Huhtanen, (2013) [52]. The acidification potential was computed considering the emissions of ammonia (NH_3), sulphur dioxide (SO_2). Nitrogen volatilization from manure storage and crop fertilization was calculated according to the IPCC equations [45]. The emissions related to GWP and AP due to purchased feedstuffs were derived from the Ecoinvent database [53]. Conversion of each pollutant compound into the relative unit of every impact category, relative to GWP and AP, was derived from Myhre et al. (2013) [54] for GWP (the common unit is kg CO_2-eq converted as: CO_2 = 1; CH_4 = 28 and N_2O = 265) and from Guinée et al. (2002) [55] for AP (the common unit is SO_2-eq:1 converted as: SO_2 = 1; NH_3 = 1.88).

2.3.4. Gross Energy Conversion Ratio

The ECR, defined as gross energy conversion ratio (MJ feed/MJ beef) and the HeECR, defined as potentially human edible–gross energy conversion ratio (MJ feed/MJ beef) were estimated according to Berton et al. (2017) [51] (Supplementary Table S3) considering each animal's categories. The computation of the potential human-edible fraction of animals' diets was based on Ertl et al. (2015) [56] The carcass yield, the boneless fraction of the carcass and the value of gross energy/kg of edible beef were the same as used by Berton et al. (2017) [51].

2.4. Statistical Analysis

We log-transformed productivity and manure load values of the 71 parcels to obtain a normal distribution, and analyzed them using the nlme package [57] in R 3.6.1 [58], with a linear mixed model including the effects of land use (natural meadow, seminatural meadow, and temporary crop), irrigation (yes, no) and their interaction, plus the willingness of the farmer to shift land use (yes/no), and the random effect of the farm. We included the willingness to shift land use as a factor because we wanted to verify whether the assertion of farmers that they wanted to shift land use in the most productive meadow parcels was based on a real difference in productivity.

3. Results

3.1. Farms Structural and Managment Features

Table 2 reports the descriptive statistic of the farmers' age and general land and herd management features. Farmers' average age was 40 ± 17 years; the variability was great, with a range from 26 to 73. Grasslands were largely predominant in the agroecosystems managed. Highland pastures were used by most of the farmers (7 out of 8) and showed the largest average surface (147 ± 116 ha) while transition pastures were smaller (17.0 ± 21 ha) and used only by five farmers. Farmland covered on average 22.6 ha, mainly composed of natural and seminatural meadows (15.4 ± 8.3 ha and 2.8 ± 2.7 ha, respectively), with temporary crops being 4.9 ± 3.4 ha. All these land uses showed a very wide variability between farms, with coefficients of variation (CV) close to, or exceeding, 100%, with the only partial exception of natural meadows (CV = 65%). Natural meadows were also the only land use present in all the farms.

The average herd size was 133 ± 52 LU, which corresponds to an average stocking rate (including collective pastures) of 0.7 LU/ha. The cow replacement rate was 14.8% per year, indicating a long lifespan. Male and female calves were sold at similar BW sold (479 ± 93 and 469 ± 97 kg/head/year, respectively) and showed similar average daily gains (ADG) (1.10 ± 0.08 kg/day and 1.07 ± 0.07 kg/day, respectively). The computed average daily feed intake of cows was 9.8 ± 0.2 kg DM, almost all deriving from forages, with an important contribution of pastures (39.7% of DM intake from grass at pasture). For pre-weaning calves the average daily feed intake was 3.4 ± 0.1 (32.4% derived from pasture) whereas for calves replacement females the average daily feed was 5.7 ± 0.5 (32.4% derived from pasture). The total yearly feed intake per LU averaged 3764 ± 362 kg DM, with only 8% (306 kg DM) deriving from concentrates, and an average crude protein content of 12% DM. For the detailed diet of cows and fattening calves see Table S3.

Table 2. Descriptive statistics of farmers' age, surface and type of managed land, herd size, management features and feeding.

Variable	Unit	Mean	SD	Minimum	Maximum
Age of farmer	N	40	17	26	73
Managed land [1]					
Highland pastures	ha	147.8	115.5	0.0	386.0
Transition pastures	ha	17.0	21.2	0.0	51.4
Farmland	ha	22.6	6.5	11.2	30.7
Natural meadows	ha	15.4	8.3	5.5	25.1
Seminatural meadows	ha	2.8	2.7	0.0	6.7
Temporary crops	ha	4.9	3.4	0.0	9.9
Herd size and management					
Cows	N	80	32	51	130
Bulls	N	3	1.2	1	5
LU [2]	N	133	52	77	215
Replacement rate	%	14.8	4.6	9	22
Season of calving		S, A [3]			
Calves/cow/year	N/year	0.9	0.0	0.8	0.9
Calves sold/cow/year	N/year	0.7	0.1	0.6	0.8
Calves performance					
Age at sale (male and female)	months	13.1	2.0	12	18
BW [4] sold/year (male)	kg BW	479	93	400	700
BW sold/year (female)	kg BW	470	97	400	700
ADG [5] male	kg/day	1.10	0.08	0.99	1.21
ADG female	kg/day	1.07	0.07	0.99	1.21
Feeding					
Feed intake, cows	kg DM [6]/cow/day	9.8	0.2	9.5	10.1
Grass at pasture	% feed intake	39.7	14.9	27.7	70.5
Hay and other forage	% feed intake	58.8	17.2	22.2	72.3
Corn silage	% feed intake	0.2	0.6	0.0	1.7
Concentrates	% feed intake	1.3	2.6	0.0	7.2
Feed intake, calves pre-weaning (0–6 months)	kg DM[6]/calve/day	3.4	0.1	3.3	3.5
Grass at pasture	% feed intake	32.4	31.1	0.0	75.5
Hay and other forage	% feed intake	41.4	31.5	0.0	75.9
Concentrates	% feed intake	1.5	3.9	0.0	11.2
Milk	% feed intake	24.7	0.6	24.0	25.7
Feed intake, calves female for replacement [7] (6–12 months)	kg DM/calve/day	5.7	0.5	4.9	6.4
Grass at pasture	% feed intake	32.4	40.0	0.0	100.0
Hay and other forage	% feed intake	67.6	40.0	0.0	100.0
Feed intake, LU	kg DM/LU/year	3764	362	3504	4365
concentrates	kg DM/LU/year	306	184	139	712
crude protein	% crude protein	12.0	0.6	11.2	13.0

[1.] Managed land includes municipal proprieties (highland and transition pastures) plus farmland. [2] LU: Livestock Unit, including cows, bulls and replacement. [3] S: spring, A: autumn. [4] BW: Body Weight. [5] ADG:

Average Daily Gain. [6] DM: Dry Matter. [7] The calves (male and female) for fattening were not considered in this table because any farm provided pasture.

3.2. Farmland Productivity and Manure Inputs

None of the effects included in the linear mixed models analyzing productivity and manure load reached statistical significance (Supplementary Table S4). For an easier presentation, we will show the data as boxplots of the non-transformed values. Median productivity values (Figure 4, left panel) were 4696 kg DM/ha for the natural meadows, 3264 kg DM/ha for the seminatural meadows, and 4159 kg DM/ha for the temporary crops, but variability was extremely high. The organic fertilization with solid manure had median values of 27090 kg/ha for natural meadows, 30104 kg/ha for seminatural meadows and 38366 kg/ha for temporary crops. As for productivity, variability was very wide.

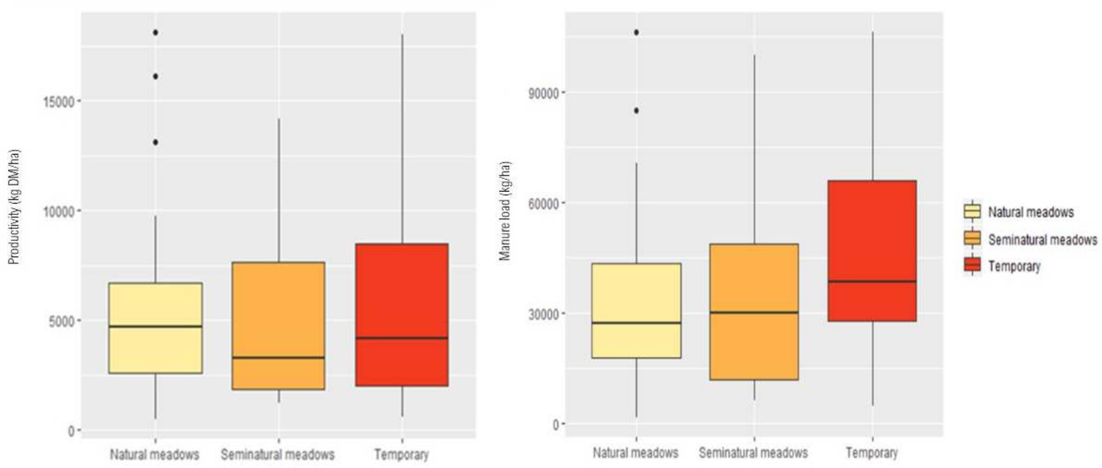

Figure 4. Box plots of productivity (a panel, on the left) and manure load (b panel, on the right) per type of land use.

Sixty percent of the farmers declared that they would like to change the use of part of the parcels, in all cases by shifting from natural or seminatural meadows to temporary crops in order to produce more, because they considered these parcels to be more productive and very fertile, or because their location was near the farm and easily accessible. After correcting for land use, however, productivity and manure load values did not differ between parcels candidate or not candidate to a shift in land use (Figure 5).

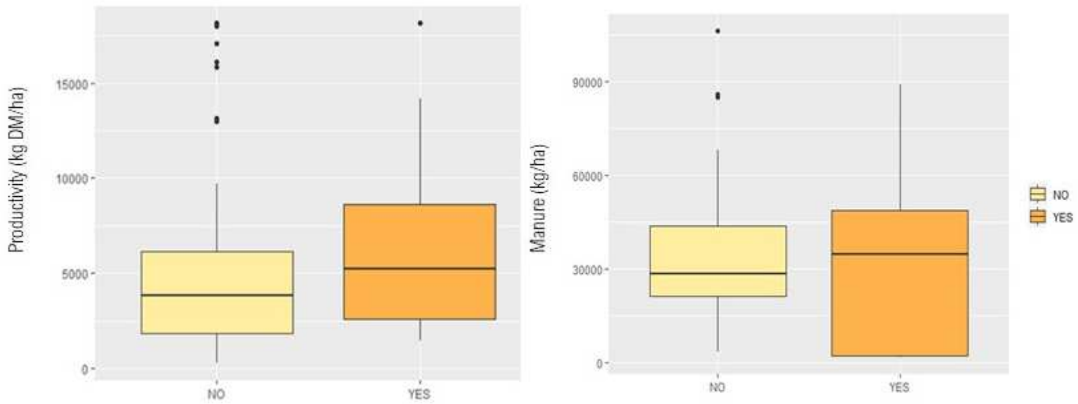

Figure 5. Box plot of distributions of productivity and manure loads of land parcels according to the willingness of farmers to shift or not their land use.

3.3. Nitrogen Balance, Environmental Impacts and Production Efficiency

The results of nitrogen balance, expressed per LU and year, are given in Table 3. Due to the low DM intakes and crude protein contents, nitrogen intake was also low (72 ± 7 kg N/LU/year). This, despite the low nitrogen retention (10 ± 1 kg N/LU/year) due to the moderate intensity of beef production, led to a modest nitrogen excretion (62 ± 6 kg N/LU/year). Concerning the environmental impacts, GWP was 13.4 ± 0.7 kg CO_2-eq/kg BWG, and AP averaged 189 ± 23 g SO_2-eq/kg BWG. The ranges were from 12.5 to 14.4 kg CO_2-eq/kg BWG for GWP and from 161 to 223 g SO_2-eq/kg BWG for AP.

The energy efficiency values (MJ feed/MJ of raw boneless beef) were low for total energy (ECR = 52.2 ± 2.6 MJ feed/MJ beef) but high for the human-edible energy (2.6 ± 1.3 MJ feed/MJ beef) (Table 3).

Table 3. Values of nitrogen input–output, environmental impacts and energy efficiency.

Variable	Mean	SD	Min	Max
Nitrogen balance				
Nitrogen intake, kg N/LU [1]/year	72	7	65	84
Nitrogen retention, kg/LU/year	10	1	9	12
Nitrogen excretion, kg N/LU/year	62	6	56	73
Nitrogen to field, kg/LU/year	28	3	23	32
Environmental impacts				
GWP [2] (kg CO_2-eq/kg BWG [3])	13.4	0.7	12.5	14.4
AP [4] (g SO_2-eq/kg BWG)	189	23	161	223
Energy efficiency				
ECR [5] (MJ feed/MJ beef)	52.2	2.6	47.4	55.2
HeECR [6](MJ feed/MJ beef)	2.6	1.3	1.3	5.6

[1] LU: Livestock Unit. [2] GWP: Global Warming Potential. [3] BWG: Body Weight Gain. [4] AP: Acidification Potential. 5 ECR: Gross Energy Conversion Ratio. [6] HeECR: Potentially Human Edible-Gross Energy Conversion Ratio.

Figure 6 shows the contribution of each emission source to GWP and AP. For GWP, the main contributor was enteric CH_4 (around 70%), with manure and land management contributing less (around 20%). The contribution of off-farm inputs, essentially purchased feedstuffs, was around 10%. For AP, off-farm inputs contributed to 10–22% of emissions. Regarding AP, the main contribution was due to manure management (storage) whereas the fertilization given by the release of animal manure to pasture, the solid manure fertilization of meadows and crops and the off-farm feedstuffs gave a similar contribution.

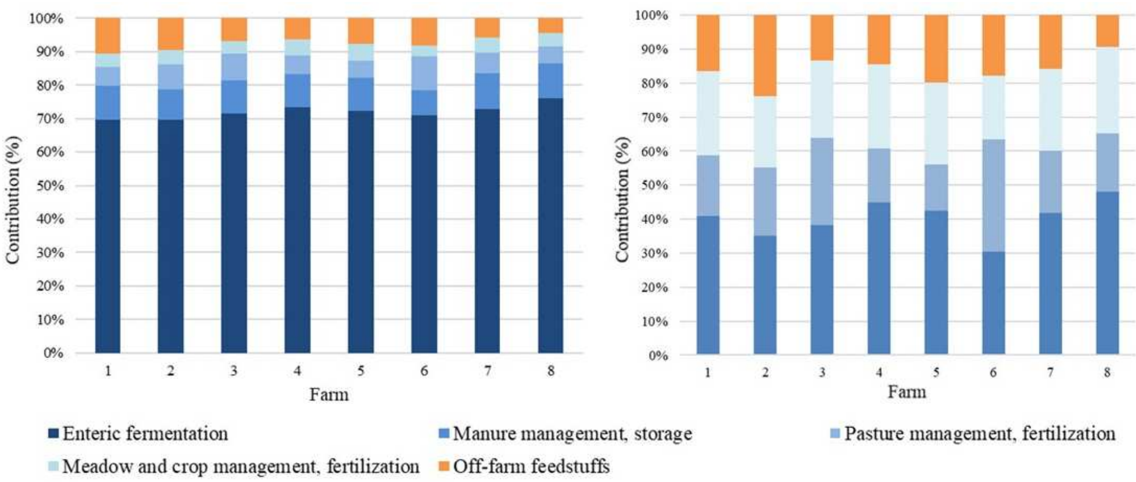

Figure 6. Contribution of each emission source to AP (left panel) and to GWP (right panel), for each farm. Enteric fermentation (due to microbial anaerobic fermentation in the rumen) only contributed to GWP.

4. Discussion

Organic beef production is typical of the Catalan Pyrenees and the number of organic farms is rapidly growing [27,41]. In this study, the farming systems implicated in such production demonstrated a strong link with the local grassland agroecosystems and, considering the specific context, good productive traits. Our results suggested also that no advantages can be automatically expected by intensifying farmland management through converting meadows to temporary crops. The LCA assessment finally complemented these findings by indicating that the impacts per LU or unit of BW are moderate, and that the low input management and the high feed self-sufficiency of these farms keep very low the contribution of off-farm stages. The conversion efficiency of diet energy was low when the total energy was considered, but high when only feeds not edible for humans were considered. We will discuss below these findings and their implications for the farms and organic beef sustainability.

4.1. Farms Features, Land and Herd Management

The age of the farmers interviewed was on average lower than that observed in other studies addressing the evolution of livestock systems in marginal areas of Spain [25,59], and showed a wide variability, which reflects a generational turnover (in various cases, the farm was managed by the son, and five of the eight farmers were less than 40 years old) essential for the continuity of farming. This turnover seems to happen without remarkable changes in the traditional land use and management, that was essentially based on grazing collective pastures and on cultivating natural and seminatural meadows in the private farmland. The use of pastures is linked to the practice of summer transhumance to high elevation collective pastures, which is still widespread in the mountain areas of Europe [60] and can be essential for reducing labor and costs and for complementing the forage farm budget of traditional, extensive farming systems [61]. Interestingly, here this practice has not been simplified, as for instance has happened in other mountain areas [62] with the direct transhumance from the permanent farms to the highland pastures and the abandoning of the transition pastures, which has resulted in their loss because of natural re-afforestation [63]. Meadows in farmland are mostly natural and managed extensively with low stocking rates and little external inputs (see below). These findings suggest that the farms surveyed play an important role for the conservation of local high natural value farmland, the associated biodiversity, and the cultural landscape [64]. In this respect, it is also interesting that the average surface of land managed per farm, both because of a larger size of the farmland and of the use of collective highlands and transition pastures, was wider than that observed in other studies [65,66].

Herd sizes were also larger than those reported in other studies conducted in Spain [25,59], and the herd management was characterized by a long cow lifespan which reduced the replacement rate and by fattening performances of calves that are lower than those that can be obtained with intensive fattening practices [67,68] but are still remarkable. This implies that the calf BW marketed annually by a farm, especially having in mind that all farmers are part-time employed, may substantially contribute to their families' budget. This is remarkable also because it is obtained mostly using the local forage resources. Considering together in-house diets of fattening calves and cows, and the substantial contribution of the grass grazed at pasture, the annual feed budget of the farms included a very modest proportion of purchased concentrates, even in comparison with suckler cow–intensive calf fattening systems in other areas [33].

Within this general picture, however, we also found very high variability between farms in the size of pastures used and farmland, and consequently in herd size, which was associated with extremely high variability in the duration of the in-house period for cows and also, although less marked, for fattening calves (see Table S2). Additionally, although the use of traditional individually administered diets was still predominant for fattening calves, three farmers (Table S2) used group feeding with total mixed rations. Apparently, therefore, there is an ongoing process of modification of farming practices. We suggest that future studies, on a larger sample of farms, should address how these practices are evolving in relation to size of managed land and herd, and in general, with the structural and management conditions that it was not possible to address in this study.

4.2. Farmland Forage Productivity and Manure Load

We found that there were no differences in forage production and manure loads between different intensities of farmland management, respectively, natural meadows, seminatural meadows and temporary crops. This result was surprising and mostly depending on the high variability observed between parcels of the same management regime, which was not reduced by using slope, irrigation and farm as explanatory variables in the statistical analysis. In accord with Chocarro and Reiné (2008) [69], this variability most probably depended on interactions between geographical and topographical conditions (soil features, density of vegetation cover and shrubs/trees presence, aspect, accessibility, distance from the farm, etc.) and management practices (number of cuts, amount of irrigation water provided, nutrient balance and periods of manure spreading, etc.) that were not considered in this study. Similarly, the meadow parcels that the farmers would like to convert to permanent crops did not show higher productivities and manure loads than the other parcels, suggesting that they were not actually more fertile or already managed more intensively. The implication of these findings is that a change of land use from natural/seminatural meadows to temporary crops would not automatically lead to higher forage productions, as farmers believed and desired in order to reduce the off-farm feed purchase.

In absence of an improvement in the forage budget of the farms, conversion choices could result in an increase of costs and impacts (see below) due to mechanization and intensification of cultivation practices, and in a loss of incentives for the maintenance of permanent grasslands that are provided by the European CAP [66]. Alternatively, increased farmland productivity could be potentially obtained by improving the management practices of meadows. For wise decisions on either option, we argue that priority should be given to obtaining knowledge on the stationary and management factors determining the wide variability observed in parcel productivity, in order to ascertain their suitability to temporary crops and/or to rationalize present practices of meadow management and reduce yield gaps. Additionally, grassland management choices should be balanced against their potential consequences on the associated ES [62], as the natural biodiversity and conservation of specific grassland habitats, which would be lost with the conversion to temporary crops [70,71] or even with the intensification of grasslands management [61,69], which generally implies a trade-off with their natural biodiversity, as observed in the study region and other mountain areas [46,47]. The role of extensive grasslands management for ensuring both forage production and quality and conservation of biodiversity, vegetation and landscape dynamics and landscape is complex [3,72,73] and linked to the local conditions, and we stress the importance of improving knowledge on these interactions.

4.3. Farms Impacts and Efficiency Ratios

The nitrogen excretion values estimated per LU in this study were higher than those indicated for Spain by Šebek L. B. et al. (2014) [74], similar to those estimated in other studies regarding suckler cow–calf systems in Germany by Dämmgen et al. (2013) [75], and lower than those of integrated suckler cows–fattening bulls in other mountain areas [51]. The remarkable variability between farms depended on that of permanence at pasture, which influenced the nitrogen ingestion and excretion at the farm (grass at pasture contained a higher percentage of crude protein). In fact, the use of pastures can be a strategy not only to reduce costs and complement the forage budget of mountain farms, but also to reduce the on-farm emissions [76].

The values of GWP and AP obtained cannot be directly compared with the literature because the system boundaries did not consider other inputs like the bedding or the fuel (due to lack of information); however, these inputs are likely low in systems with a high use of pasture, and the range of impact values found here were within the variability observed in other studies on suckler cow–calf systems, e.g., de Vries et al., 2015 [33] and Berton et al., 2017 [51]. As expected, and in agreement with Battaglini et al. (2014) [77] and Horillo et al. (2020) [78] the main contributor to GWP was enteric fermentation followed by off-farm feedstuffs and by manure management. Regarding AP, the most important emission source was manure management.

Apart from these results, which confirm that the livestock systems have moderate impacts per LU and, given the low stocking rates, also per unit of land, the most important indication of the LCA assessment was that GWP and AP emissions were predominantly related with the on-farm stages, with a share on the total emissions that, especially for GWP, was higher than that observed not only in intensive systems, but also in other extensive systems [29,36]. Even considering that the off-farm stage in this study is slightly underestimated because we could not compute bedding and fuel, this implicates that most of the resources used in the production process are obtained from the local territory, in a balance between production and mountain agroecosystems resources. The link with local resources is a feature of many mountain extensive livestock systems [79,80] but is particularly strong in the farms surveyed in this study, demonstrating an almost closed cycle at the farm level between production inputs and outputs. This self-sufficiency is important when evaluating the energy efficiency of the farms. The ECR values, which indicate the total diet energy needed to obtain a beef energy unit, were higher than those computed in other studies e.g., Wilkinson (2010) [81] or the Italian contribution to the integrated France–Italy beef production system estimated by Berton et al. (2017) [51], indicating lower efficiency; the HeECR values, which indicate the diet energy of feed potentially edible for humans needed to obtain a beef energy unit, were lower, indicating high efficiency. The results of various recent studies clearly indicate that there is a trade-off between total energy efficiency and human edible energy efficiency in ruminant feeding and that extensive ruminant systems compete less than intensive systems with the use of land and derived food suitable for humans [56,80,82,83]. The interest in the feed/food competition and the role of ruminants in the future sustainable food systems is recent but growing rapidly [84,85] and, in this respect, the very high self-sufficiency and the use of grassland-derived feed are positive features of the livestock systems examined here.

According to Ripoll-Bosch et al. (2013) [86], it was possible to state, therefore, that these livestock systems presented a great multifunctionality because they produced high-quality organic beef and, by animal grazing and extensive management practices, guaranteed a series of ES. Pasture-based LFS present a lot of synergies that allow to develop complementary activities (green and agro-tourism, education, etc.), a new market way based on consumer demands based on safety, quality and organic food products, a series of ES in terms of public goods (landscape maintenance, biodiversity, cultural heritage, etc.) [64]; evaluating the synergies is important to create an added value to the organic beef supply chain and to enhance its relationship with the land.

Farmers could reduce emissions through their work, but it was important to remember that these farms were not located in areas with high productive vocation.

5. Conclusions

This study has outlined a set of positive synergies between the production of organic beef and the use of mountain grassland agroecosystems. The farms surveyed here manage a remarkable surface of pastures and meadows, with extensive practices and low stocking rates, manure loads and emissions per LU. The herd productivity is moderate but, given the part-time employment of farmers and the low labor management practices, it seems to be economically sustainable and able to provide additional income for the farmers' families. An encouraging indication in this respect derives from the generational turnover which is ensuring the continuation of farming.

Our results also suggest that caution should be used in attempting to improve productivity by converting meadows to temporary crops, or by intensifying management practices of grasslands. Indeed, we found no significant differences in terms of productivity and manure loads between different intensities of farmland management (natural meadows, seminatural meadows and temporary crops), which means that a change of meadows to temporary crops, as farmers would like, would not directly lead to an increase in production. The land management choices should be therefore supported by an understanding of the environmental and management factors that actually influence productivity, and weighted against the possible consequences on the non-marketable benefits associated with the present agroecosystems, e.g., a loss of ES such as biodiversity, protection from invasive species, cultural landscape.

Regarding the environmental impacts, results show that the emissions are mainly related to on-farm stages, with respect to off-farms ones. External inputs are very low, and this farming system shows a very high self-sufficiency and ability to transform feeds non edible for humans into organic beef, a high-quality food. Overall, these findings suggest a strict and positive link between the production of organic beef and the conservation of agro-ecosystems of high natural value, with the associated ES.

Although we did not directly address the sustainability of the livestock system examined, our results can provide indirect indications and suggestions for future investigations. In a perspective of sustaining the organic beef production chain, identifying and assessing the various benefits delivered by this production could be useful to devise strategies both for the market valorization of the product and for designating sectorial policies. The organic label is a plus on the market, which could be further supported by communicating to consumers the ES associated with this specific production chain. Payments to farmers within the PAC framework could be better tailored according to the definition of the farming practices that support the agroecosystems and their services. We maintain that this is a key point for the sustainability of these farming systems and should be considered a priority in the European PAC. Finally, although we focused on organic systems, we believe that the general implications of our study could be extended also to conventional, grassland-based systems.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Table S1: Information collected during the survey about farm characteristics and management, Table S2: composition of the diet fed to suckler cows and calves (male and female) (kg DM/head/day). Regarding the calf (male and female) for fattening, a distinction has been made between farms with TMR and farms with a traditional fattening system, Table S3: equations used to compute the environmental impacts, Table S4: Coefficients of the linear mixed models analyzing log-transformed data of productivity (Kg DM/ha) and manure load (Kg/ha) of parcels with the fixed effects of land use, irrigation, slope and their interaction, the willingness to change land use the random effect of farm.

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Supplementary Materials:

Table S1: Information collected during the survey about farm characteristics and management

Variable	Description	Unit	Standardization
Age of farmer		years	
Municipality			
Herd size and composition			
Cows	Suckling cows	Number	Livestock Unit (LU) = 1
Bulls		Number	Livestock Unit (LU)= 1
Calves before weaning (male and female)	Calves from 0 to 6 months	Number	Livestock Unit (LU)=0.6
Calves for fattening (male and female)	Calves from 6 to 12 months	Number	Livestock Unit (LU)=0.6
Heifers at the first year	Heifers from 12 to 24months	Number	Livestock Unit (LU)=0.6
Heifers at the second year	Heifers from 24 to 36 months	Number	Livestock Unit (LU)=0.6
Female calves for replacement		Number	
Season of calving		% for month	
Grazing period		days	
In-house period		days	
Birth weight		kg/head	
Body Weight Initial (BWI)	Body weight at the beginning of the period, for each animals' category	kg/head	
Body Weight Final (BWF)	Body weight at the end of the period, for each animals' category	kg/head	
Body Weight Sold (BWS)	Body weight at the time of sale		
Surface and use			
Highlands	High-altitude pasture, grazed during the summer	ha	
Transition pasture	Pasture located at mid elevation, grazed during the spring and autumn transition to and from highland pastures	ha	
Natural meadows	Meadows that have not been plowed and reseeded in the last 50 years. Production of hay or silage can be associated with early and late grazing	ha	
Seminatural meadows	Meadows that have not been plowed and reseeded in the last 15 years. Production of hay or silage can be associated with early and late grazing		

Temporary crops	Cultivated fields that have been plowed and reseeded in the last 5 years. Crops can be cereals, alfalfa, sorghum etc.		
Productivity of parcels	Production of natural and seminatural meadows and temporary crops. The data given by farmers have been converted in DM	Bale of silage Bale of hay kg DM	kg DM/ha
Organic fertilization	Manure input	kg	kg/ha
Willingness to change the land use	For each parcels, first it was asked whether it was classified as natural, seminatural or temporary crops and then whether, for each parcels classified as natural/seminatural meadows was asked to farmers if they were going to change the land use into temporary crops to produce more	Yes/No	
Irrigation		Yes/No	
Off-farm purchased food		kg	

Table S2: composition of the diet fed to suckler cows and calves (male and female) (kg DM/head/day). Regarding the calf (male and female) for fattening, a distinction has been made between farms with TMR and farms with a traditional fattening system.

	Mean	SD	Min	Max
Cows				
In-house period, days	201	86	0	259
Hay	7.9	4.5	2.3	13.5
Straw	0.3	0.4	0.0	1.0
Grass silage	2.5	3.5	0.0	7.0
Corn silage	0.0	0.0	0.0	0.1
Alfalfa	0.9	1.3	0.0	3.5
Barley	0.3	0.5	0.0	1.0
Calf for fattening (male and female)				
Fattening period[2], days	217	62	183	213
Farms with TMR[1], N=3				
Feed intake	7.6	0.8	7.0	8.5
Hay	4.6	0.5	4.2	5.1
Barley	3.0	0.3	2.8	3.4
Farms with traditional feeding system, N=5				
Feed intake	7.8	1.3	6.6	10.1
Hay	4.9	0.5	4.0	5.4
Concentrate	2.9	1.2	1.8	5.0

[1] TMR: Total Mixed Ration
[2] The fattening period was calculated after weaning (six months from birth)

Table S3: equations used to compute the environmental impacts

Variable	Description	Unit	Reference
Nitrogen balance			
N intake	= Feed intake (kg DM/d) x presence (days at pasture/in-house) x crude protein diet content/6.25	kg N/year	Katelaars and Van der Meer (1999)
N retention	=(BW[1] final-BW initial) x retention factors[2]	kg N/year	Katelaars and Van der Meer (1999)
N excretion	=N intake - N retention	kg N/year	Katelaars and Van der Meer (1999)
Net energy (NE) requirement			
NE for maintenance (NE_m)	= (Cfi[3] x $(BW)^{0.75}$) x 4.184	MJ/head/day	IPCC, 2006
NE for activity (NE_a)	= Ca[4] x NEm	MJ/head/day	IPCC, 2006
NE for lactation (NE_l)	= Milk yield (kg/d) x (0.0929 x fat[5] (%) + 0.0547 x protein[6] (%) + 0.192) x 4.184	MJ/head/day	IPCC, 2006

NE for Pregnancy (NE_p)	= 0.45	MJ/head/day	IPCC, 2006
NE requirement	= $NE_m+NE_a+NE_l+NE_p$	MJ/head/day	IPCC, 2006
Global Warming Potential (GWP)			
Enteric CH_4	= (GEI[7] x (γm[8]/100) x 365) / 55.65	kg CH_4/head/day	IPCC, 2006
Volatile solid excretion rates (VS)	= [GEI[7] x (1 − DE%/100) + (0.02 x GE[9])] x [(1-ASH[10])/18.45]	kg VS/day	IPCC, 2006
CH_4 from manure storage	= (VS x presence (days)) x (Bo(T)[11] x 0.67 x 0.04	kg CH_4/animal/year	IPCC, 2006
Direct N_2O from manure storage	= N excretion in-house (kg/year) x 0.005 x 44/28	kg/year	IPCC, 2006
N volatilized from manure storage (N_{vol_MS})	= N excretion in-house (kg/animal/year)) x 0.26	kg/year	EEA, 2019
Indirect N_2O emissions from manure storage	= (N_{vol_MS} x 0.01) x 44/28	kg /year	IPCC, 2006
N available at fertilized soils (no pasture) (N_{av_s})	= (N excretion in-house − N_{vol_MS} − direct N-N_2O manure storage)	kg/year	

N available at pasture (N_{av_p})	= N excretion at pasture	kg/year		
Direct N_2O emissions from fertilized soils and pasture	= (N_{av_s} x 0.01 + N_{av_p} x 0.02) × 44 / 28	kg /year	IPCC, 2006	
N volatilisation from fertilized soils and pasture (N_{vol_field})	= N_{av_s} x 0.2 + N_{av_p} x 0.2	kg /year	IPCC, 2006	
Indirect N_2O emissions from fertilized soils and pasture	= (N_{vol_field} x 0.01) x 44/28	kg/year	IPCC, 2006	
$CO_{2\text{-eq}}$ from CH_4	= CH_4 * 28	kg/year	IPCC, 2014	
$CO_{2\text{-eq}}$ form N_2O	= N_2O * 265	kg/year	IPCC, 2014	
$CO_{2\text{-eq}}$ straw	= kg straw x 0.58	kg /kg DM	Ecoinvent (2015)	Centre
$CO_{2\text{-eq}}$ alfalfa	= kg alfalfa x 0.27	kg /kg DM	Ecoinvent (2015)	Centre
$CO_{2\text{-eq}}$ silage	= kg silage x 0.17	kg /kg DM	Ecoinvent (2015)	Centre
$CO_{2\text{-eq}}$ barley	= kg barley x 0.38	kg /kg DM	Ecoinvent (2015)	Centre

$CO_{2\text{-eq}}$ hay	= kg hay x 0.3	kg /kg DM	Ecoinvent Centre (2015)
Acidification potential (AP)			
NH_3 from manure storage	= N_{vol_MS} × 17/14	kg/year	IPCC, 2006
NH_3 field (kg/year)	= N_{vol_field} × 17/14	kg/year	Guinée et al., 2002
SO_2-eq from NH_3	= NH_3 × 1.88	kg/year	IPCC, 2006
SO_2-eq straw	= kg straw × 0.006	kg /year	Ecoinvent Centre (2015)
SO_2-eq alfalfa	= kg alfalfa x 0.02	kg /year	Ecoinvent Centre (2015)
SO_2-eq silage	= kg silage x 0.0063	kg /year	Ecoinvent Centre (2015)
SO_2-eq barley	= kg barley x 0.01	kg /year	Ecoinvent Centre (2015)
SO_2-eq hay	= kg hay x 0.008	kg /year	Ecoinvent Centre (2015)
Efficiency production			

Gross energy conversion ratio (ECR)	ECR = GEI (MJ farm/year) / (BWG kg/farm) x 0.59 x 0.81 x 10.67)	Ertl et al., 2015 and Berton et al., 2017
Potentially human edible-gross conversion ratio (HeECR)	HeECR = HeE[12] (MJ farm/year)/ (BWG tot x 0.59 x 0.81 x 10.67)	Ertl et al., 2015 and Berton et al., 2017

[1] BW: Body Weight
[2] 0.025 for suckler cows and heifers, 0.028 for weaned calves for replacement or fattening and 0.032 for pre-weaning calves
[3] Cfi: Coefficient varying for each animal category (0.078 for suckler cows; 0.073 for pre-weaning calves, weaned calves for replacement or fattening and heifers)
[4] Ca: coefficient corresponding to animal feed situation (1 for suckler cows and heifers; 0 for pre-weaning calves, weaned calves for replacement and for fattening)
[6] Fat: 3.46%[6] Protein: 3.34%
[7] GEI: Gross Energy Intake
[8] γm: enteric methane yield based on diet
[9] GE: Gross Energy
[10] ASH: 0.08
[11] Bo(T): maximum methane producing capacity for manure producing capacity for manure produced (m3CH_4/kg VS)
[12] HeE: human edible fraction of animals' diet

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Table S4: Coefficients of the linear mixed models analyzing log-transformed data of productivity (Kg DM/ha) and manure load (Kg/ha) of parcels with the fixed effects of land use, irrigation, slope and their interaction, the willingness to change land use the random effect of farm.

	Productivity					Manure load				
	DF	Value	SE	T	P	DF	Value	SE	T	P
Intercept	57	8.518	0.394	21.62	<0.001	41	9.341	0.609	15.35	<0.001
Seminatural (SN) vs natural (N)	57	-0.595	0.568	-1.05	0.299	41	0.015	0.380	0.04	0.969
Temporary crop (TC) vs natural	57	-0.508	0.408	-1.24	0.218	41	0.212	0.331	0.64	0.526
Irrigation: yes (IY) vs no (IN)	57	-0.120	0.443	-0.27	0.788	41	0.612	0.312	1.96	0.057
Slope	57	-0.027	0.017	-1.61	0.112	41	-0.003	0.015	-0.19	0.851
Land use change: yes (LCY) vs no (LCN)	57	0.434	0.273	1.59	0.118	41	0.023	0.257	0.09	0.928
SN*IY vs N*IN	57	-0.847	0.815	-1.04	0.303	41	-1.040	0.528	-1.97	0.056
TC*IY vs N*IN	57	-0.024	0.798	-0.03	0.976	41	0.031	0.643	0.05	0.962
Slope: SN vs N	57	0.042	0.044	0.95	0.345	41	0.036	0.031	1.17	0.251
Slope: TC vs N	57	0.054	0.032	1.69	0.097	41	-0.009	0.047	-0.19	0.853

5.2 Paper II: relationships between local sheep breeds and mosaic landscape, strategies to conserve animal genetic resources and development of new territorial marketing strategies

Added Value of Local Sheep Breeds in Alpine Agroecosystems
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Added Value of Local Sheep Breeds in Alpine Agroecosystems

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Abstract: This study is part of a project (Sheep Al.L. Chain, RDP Veneto Region) aiming to improve the competitiveness of local sheep breed farms through valorization of their links with mountain agroecosystems. We considered two local sheep breeds of the eastern Italian Alps, "Alpagota" and "Lamon", which have a population of 400 and 3000 heads, respectively, and are used to produce lambs for typical products. A total of 35 farms (17 for Alpagota, with a total of 1652 heads; 18 for Lamon, with a total of 337 heads) were surveyed to collect data on farm organization, flock structure and management (farm questionnaire), land use management (GIS approach), and value chain organization (participatory processes). The link between the two local sheep breeds and mountain agroecosystems is very strong: land use is characterized by a large number of small patches of grasslands in marginal areas. Moving from the results of this study, a set of strategies aiming at improving the competitiveness of these systems have been proposed. Communication to the consumers and to the relevant stakeholders of the added value of local sheep breeds in marginal mountain agroecosystems can contribute to favor the resilience of small ruminant farms and the conservation of Alpine sheep breeds.

Keywords: mountain livestock systems; value chains; ovine biodiversity; genetic resources; typical lamb production

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1. Introduction

The Commission on Genetic Resources for Food and Agriculture recognized the contribution of animal genetic resources to food security for present and future generations and their benefits to the environment, humanity and to cultural heritage [1]. Indeed, local breeds guarantee not only provisioning Ecosystem Services (ES) (food, genes, fibers etc.) but also cultural services, such as traditions and cultural heritage maintenance [2,3]. However, in recent years there has been a significant loss of animal genetic resources, which has led to the development of new strategies to improve sustainable use and ensure their conservation [1]. For instance, in situ preservation should be preferred since it allows safeguarding of the characteristics of each breed [4], keeping the animals in their original area and valorization of the associated typical local products [5,6], which are also important from a cultural and traditional perspective. Local breeds are farm animals linked to a specific geographical area [7], often characterized by adaptability and resilience to extreme climatic conditions [8]. In the Alpine region, most local breeds are raised in grassland-based livestock farming systems which deliver multiple ES, especially cultural ES [9]. In the Italian Alps, specifically in Veneto and the Trentino Alto-Adige regions, several areas are characterized by the presence of local breeds [9]. The limited population size increases the risk of inbreeding [4,10], and new strategies are being developed for the sustainable use of genetic resources, such as breeding schemes [11], which allows selecting, for mating plans, the most genetically distant ram. In European Mediterranean regions, traditional grassland-based livestock systems are mostly located in mountainous areas and other unfavourable areas [12,13], and involve small ruminants which are able to manage marginal areas better with respect to other livestock systems [14,15], to maintain the biodiversity and fragmented landscape, to control the forest encroachment [16,17] and to improve the forage's quality [18,19].

Pasture-based livestock systems are considered low input systems, presenting a high feed self-sufficiency with low production costs [14,20,21]. Indeed, herbivores use natural resources that couldn't be directly consumed by humans, transforming it into food and non-food products, such as meat, milk and wool [20,22,23], as well as a series of services and public goods [24,25]. However, in the last decades, European mountain areas have been affected by a massive abandonment of livestock farming [26], mainly driven by increasing competition with other economic sectors, especially where the geographical and topographical conditions are less favorable [27,28], and by the lack of generational turnover [14,29]. The consequences of this abandonment, which has strongly affected marginal and harsh pastures and meadows [30], are loss of traditional landscape, cultural heritage and biodiversity [31,32] and an increase in natural hazards, e.g., forest fires in Mediterranean areas [30,33]. The European Union recognizes the important role of livestock farming systems to maintain pastures and meadows [34,35] and to manage High Nature Value Farmland (HNVF) [13,36] and, hence, provides financial aid to farmers.

Indeed, the implementation of new strategies to preserve animal genetic resources should integrate socio-economic aspects [37]. The added value of local sheep breeds can be sustained with different strategies; among these, the conversion to organic farming can represent a good opportunity for grassland-based farming systems. The European Commission, within 2030, aims to convert 25% of total Europe farmland into organic farming [38]. In the developed countries, consumer interest in organic products is rapidly growing, demonstrating a willingness to pay more from a perspective of food safety and health [39], with a consequent increase in the market value [40]. The European Union's financial aids also support new marketing opportunities, including sponsorship and communication instruments to promote campaigning and organic labelling [39]. Furthermore, the European Green Deal recognizes the importance of guiding consumers' choice, through a sustainability food labelling framework to move towards the development of new business strategies for farmers [38].

In this perspective, small ruminant farms are characterized by low income compared to other farm production sectors [41]; thus, new marketing strategies should be found to ensure fair remuneration for farmers [42]. The challenge is to create an added value in the sheep supply chain recognizing the importance of the role of sheep farming systems, which guarantee public goods and services [43,44]. These farms are characterized by low mechanization and strong links with the territory [41]; furthermore, the products represent a specific geographical area, including its cultural identity and heritage [45].

This study presents the results of Sheep Al.L. Chain's project (Sheep Alpagota Lamon Chain), funded by the European Agricultural Fund for Rural Development (EAFRD) (Rural Development Program of Veneto Region). The project aims at improving the competitiveness of local sheep breed farms through the valorisation of their links with mountain agroecosystems. Two local sheep breeds of the eastern Italian Alps were considered: Alpagota and Lamon, both located in Belluno province. In this area, pastoral activity and land management are strongly linked and land use is characterized by a large number of small patches, often with high slopes and reduced accessibility. One of the main goals is to promote cooperation between smallholders. Furthermore, moving from a local to a global perspective, the link between local genetic resources and mountain agroecosystems could be a factor in ensuring the resilience of traditional livestock systems.

Using an approach based on participatory processes, we surveyed a representative sample of farms with three specific goals. Firstly, we developed and implemented a smartphone application for the sustainable use of genetic resources with the purpose of limiting the risk of inbreeding and supporting cooperation between farmers. Specifically, the aim was to increase both the population size and the number of farmers involved and to preserve and valorise local genetic resources through an in vivo in situ conservation program. Secondly, we developed a "territorial marketing" strategy based on clear communication to the consumer of the farms' features and links with their mountain agroecosystems and landscape. Finally, through a SWOT analysis, we identified the strengths, opportunities, weaknesses and threats related to the potential conversion to organic farming for the Alpagota breed.

2. Materials and Methods

2.1. Study Area

The study area (Figure 1) is located in the province of Belluno (Veneto region, in the north of Italy, between 45°50′ N and 46°40′ N), which covers an area of 3610 km^2 [27]. It is predominantly a mountainous area, with an average altitude of 1276 m a.s.l. (ranging from 257 m a.s.l. to 3313 m a.s.l.) and is characterized by the presence of the Piave river, which is the main river [46]. Specifically, the study was conducted in the south-western (Lamon-Feltrino) and south-eastern (Alpago-Cansiglio) portions of the province. According to Geiger R. 1954 [47], the climate is classified as Cfb (Oceanic climate with mild summers and cool winters) with an annual average rainfall of 1869 mm (average values range between 64 mm in January and 229 mm in July) and an average temperature of 9.5 °C (ranging between −0.7 °C in January and 18.7 °C in July), and mean relative humidity of 78–82%. Forest (58%, from deciduous to mixed and to coniferous following elevation) dominates land cover, followed by grassland (17%, mostly permanent meadows and pastures under extensive management, with a high biodiversity value) and arable crops (8%, mostly maize), while unproductive land (rocky or bare land, water bodies, urban) accounts for the remaining 12% of the surface [48,49].

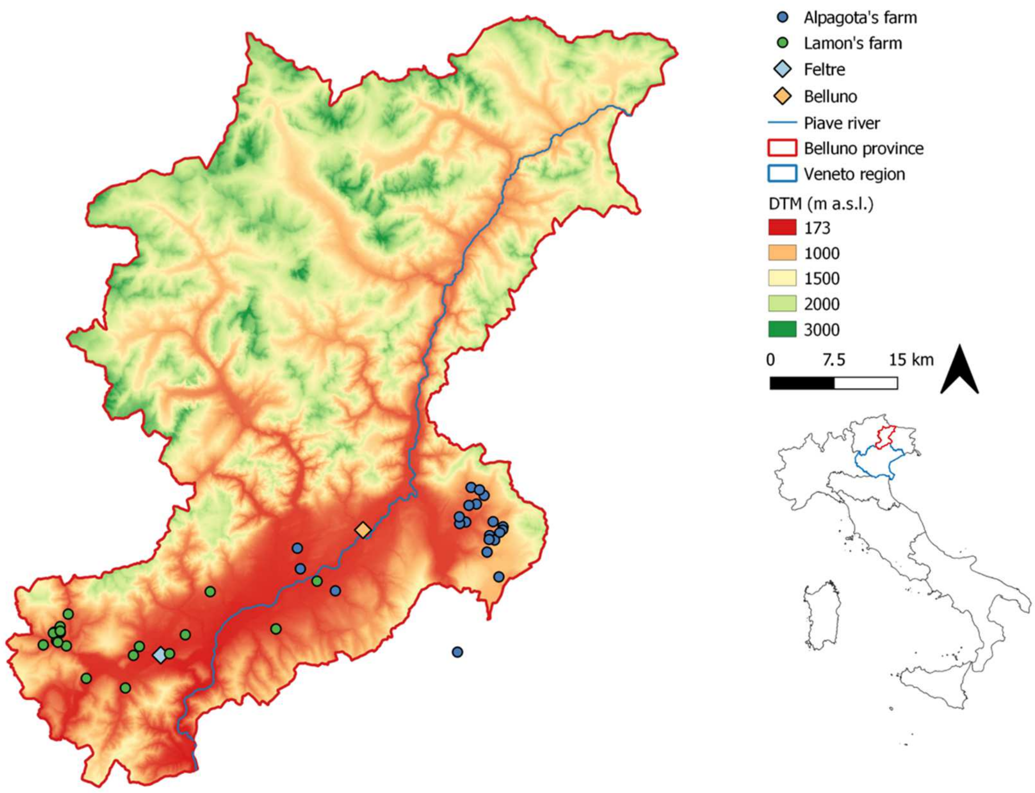

Figure 1. Study area. Blue dots indicate the Alpagota farms, located in the eastern part of Belluno province, while green dots indicate the Lamon farms, located in the western part of Belluno province.

Between 1982 and 2010, the area was affected by an abandonment of farming activity, with a reduction of 84% of cattle farms, 70% of sheep farms and 81% of goat farms. Cattle heads decreased by 48%, whereas sheep and goat heads were increased, respectively, by 71% and 34% (Table 1) [50–53].

Table 1. Number of farms and heads of cattle, sheep and goats in the Belluno province. Source: ISTAT, 1982, 1990, 2002, 2012. Data from the last general agricultural census, held in Italy in July 2021, are not yet available.

	Years			
	1982	**1990**	**2002**	**2012**
Cattle				
Farms	4763	2562	1137	717
Heads	35,830	27,161	20,606	18,293
Sheep				
Farms	431	316	342	127
Heads	4099	4638	5615	13,943
Goats				
Farms	399	211	244	74
Heads	1354	1795	2318	2069

2.2. The Alpagota and Lamon Breeds

The Alpagota (Figure 2a) is an autochthonous breed of the "Alpago-Cansiglio" area, located in the south-eastern portion of the Belluno province (Figure 1). In the past, it was used as a triple-purpose breed, whereas nowadays the main product that comes from the breed is meat (mostly obtained by lambs) [54]. Milk production is very low (0.8–1.2

kg/sheep/day) along with the production of wool (2.5–3 kg/head/year); prolificacy is about 1.46 lamb/sheep whereas the average live weight is about 50 kg [55]. The population size of the Alpagota breed is about 3000 heads (DAD-IS, www.fao.org/dad-is/en, accessed on 18 September 2021), divided into 59 herds, 41 of which are located in the Belluno province and the remaining in the western part of Friuli-Venezia Giulia Region (overall Pordenone's province) (BDN, www.vetinfo.it, accessed on 24 September 2021). The "Fardjma" association involves several breeders, who raise the Alpagota breed following strict rules established by the production's technical policy "Fardjma/Slow Food Presidium". The use of silage and animal feed is not allowed; feeding is mainly based on grazing (during the favorable season) and on in-house forage (during the winter).

The Lamon breed (Figure 2b) is an autochthonous population of the south-western part of the Belluno province (Figure 1). Like the Alpagota breed, the Lamon was a triple-purpose breed, although in this breed the main product is currently meat [54]. All the milk produced daily is used to feed the lambs, and wool production is about 4.5–5 kg/head/year; the prolificacy is about 1.5 lamb/sheep and the average live weight is 66 kg [55]. The population size of the Lamon breed is about 400 heads (DAD-IS, www.fao.org/dad-is/en, accessed on 18 September 2021), divided into 25 herds, 21 of which are located in the Belluno province and the few remaining in the Trento province (BDN, www.vetinfo.it, accessed on 24 September 2021). The "Fea de Lamon" association deals with the protection and valorization of the Lamon breed and related meat production. Specifically, the association involves several members (farmers, Lamon municipality, economic operators, etc.) and the main goal is to give an added value to the whole supply chain.

(**a**) (**b**)

Figure 2. On the left (**a**), the Alpagota breed; on the right (**b**), a Lamon sheep.

According to the Italian National Guidelines for the conservation of plant, animal and microbial biodiversity of agriculture, the Alpagota and Lamon breeds are included in the Anagraphic Registrer of autochthonous sheep and goats with limited population size [56]. The Anagraphic Register is managed by national breeders' associations or by a public institution operating in the sector, and includes information about breeding rams and their precursors, with the aim of avoiding inbreeding. The in situ conservation and productive use of the two breeds now depends on smallholders, with a large percentage of part-time farmers. There is also a program of ex situ, in vivo conservation, which is conducted by two public centers, Veneto Agricoltura (Villiago, province of Belluno) and the Agricultural High School "IIS Della Lucia" (Feltre, province of Belluno). These centres are able to preserve the functional and morphological characteristics of both breeds through mating plans which aim to counter the inbreeding within the population.

2.3. Project Description

The data collection, analysis or treatment, and the relative contribution of the information obtained to the achievement of the project's aims are shown in Figure 3. Data were collected by surveys between August 2019 and January 2020, and involved 35 farms which were representative of the study area production's context. Genomic mapping of rams was performed and the results used to assess a matrix of relationships between rams, which allowed the development of a smartphone application supporting the farmers in the choice of rams exchanged and the consequent mating plans. Farm surveys and the collection of cadastral and land cover maps were used to build a geodatabase of farm management and geographical features. The genetic information, as well as the information regarding farm management and geographical features, was integrated into the development of the smartphone application. Indeed, a description of each farm was used in QR code-based labelling of the products. Finally, the outputs of meeting with farmers and stakeholders (tourism operators, restaurateurs, representatives of the local association, local policy makers) were used in conducting a SWOT analysis to obtain a better insight into the feasibility of organic farming conversion of Alpagota farmers. This task was developed only for the Alpagota breed since the population size justified the interest towards organic farming and the relative costs with respect to the Lamon breed. This breed is characterized by a smaller population size and couldn't address the certification and traceability fees.

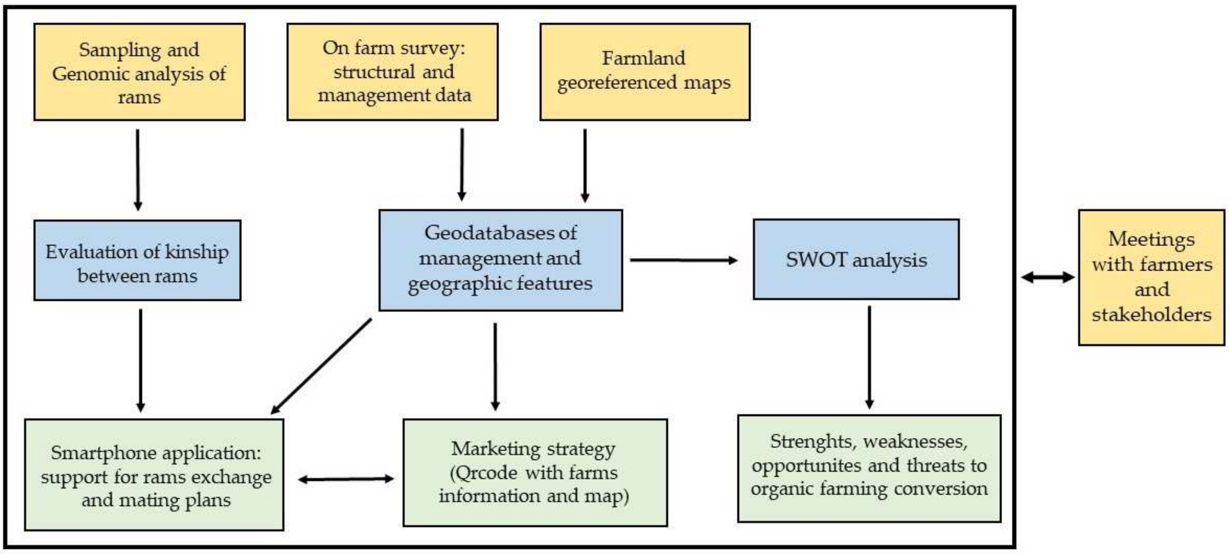

Figure 3. Description of the main steps of the project. Light blue panels relate to data collection and meetings; yellow panels relate to data analyses or (geo)database production; green panels indicate the three main goals and outputs of the project. The arrows indicate the flows of information.

2.4. Genetic Analysis of Rams

The blood samples were collected from all the breeding rams belonging to the 35 farms during the period of the survey (August 2019–January 2020). We collected data only from rams since the males represented the factor limiting genetic variability. In this way, we optimized the ratio between costs (few samples) and benefits (many offspring); in small ruminants, the collection of data from the whole female population is not convenient due to reduced economic income. Specifically, tubes with K3EDTA anti-coagulant were used to collect blood samples which had been preserved at a temperature of −20 °C. In May 2020, the extraction of genomic DNA from the blood samples was carried out following the SIGMA® protocol. A total of 81 rams (41 for Alpagota and 40 for Lamon) of the two local breeds (Alpagota and Lamon) were genotyped with the OvineSNP50 BeadChip (Illumina, San Diego, CA, USA). Autosomal markers presenting minor allele frequency (MAF) less than 0.10, significant deviations from the Hardy–Weinberg equilibrium ($p \leq 10^{-5}$) and with call rate less than 0.90 were removed, as well as samples with a call rate lower than 0.90. After quality control, 39,162 SNP markers remained in the genomic dataset. Population substructure was evaluated by performing a Principal Component Analysis (PCA) based on the genomic matrix using the ade4 R package [57]. The similarity between animals based on genomic information was assessed using a hierarchical cluster based on Ward's hierarchical clustering method with a Euclidian distance analysis.

The genomic inbreeding estimate was based on the genomic relationship matrix (F_{GRM}); the genomic relationship was obtained using the method described by VanRaden (2008) [58]. The genomic matrix was estimated as $G = ZZ'/2\sum p(1-p)$ where Z is the SNP marker matrix assuming 0, 1 and 2 for genotypes AA, AB and BB, respectively.

2.5. On Farm Survey and Farmland Mapping

The on-farm survey lasted about two hours per farm and was divided into three parts. It was based on a questionnaire defined and tested with the project partners (see Table S1 in supplementary materials). The first part dealt with general information (species and number of animals reared, land management, etc.) and farmers (age, other employments besides livestock activity, etc.). Secondly, specific data about sheep flocks and their management were collected, such as indoor and grazing periods, diet composition (amount of forages and concentrates used during the indoor period) and lambing seasonality. Farmers were also asked to mention the most critical issues for the management of the flock. Finally, we obtained from the Veneto Agency for Payments in Agriculture (AVEPA) and the Regional Centre for the Veterinarian Epidemiology (CREV) the cadastral and land cover maps (in two broad categories: grassland and cropland) of each surveyed farm and implemented them in QGIS [59]. We extracted the altitude and slope for each parcel from the DTM with a resolution of 10 m (https://www.regione.veneto.it/web/ambiente-e-territorio/ctr, accessed on 4 May 2021).

The data obtained by the on-farm survey and farmland mapping were organized into geodatabases that provided information for all three goals of the project.

We generated a QR code for each participating farm to link with, including all the information collected on the farm (surface and type of land use managed, number of animals, type of products, farm's location in Google Maps, etc.) in order to develop new territorial marketing strategies and to give added value to local sheep production.

2.6. Meeting with Farmers and Stakeholders and SWOT Analysis for Organic Farming Conversion

One of the aims defined with the project partners was to explore the potential added value generated by the certification for organic labelling. Based on organic farming systems regulations and on the information collected during the survey, a SWOT analysis was carried out to evaluate the potential for conversion to organic farming for Alpagota breed farmers. We focused on the Alpagota sheep breed because the farmers showed interest in applying for this certification, whereas for Lamon this opportunity needs to be further explored. Data on farm management were collected during the on-farm survey. The data were used to collect information on potential difficulties in the transition towards organic labelling for each single farm. The SWOT analysis allowed for identification and evaluation of internal factors (strengths and weaknesses) and external ones (opportunities and threats) in order to evaluate the opportunity of conversion to organic production systems.

3. Results

3.1. Genetic Analysis and Genomic Information

Principal Component (PC) analysis identified genetic stratification among Alpagota and Lamon breeds and the two PC explained 37.8% of the genetic variation across the breeds (Figure 4A,B). As expected, differences between Alpagota and Lamon were large, although Lamon exhibited more genetic similarity, whereas Alpagota showed more dissimilarity, indicating more variability within this population compared with Lamon. These results reflect directly on the relationship between animals in the population as observed by plotting the G matrix by the difference in the subgroups within the population, in which it is observed that Lamon had the highest proportion of closed related animals in comparison with the results observed in the Alpagota breed (Figure 5). Alpagota showed 10 subpopulations that are more related to each other; in Lamon, 8 groups were observed that are more related to each other (Figure 5).

This relationship indicated more animals with inbreeding rates higher than 0.01 for Lamon (n = 23); while, in Alpagota, only 10 animals showed values above the threshold of 0.01. Thus, the great variability observed for Alpagota occurred by an increase in heterozygosity within the evaluated population (Figure 6).

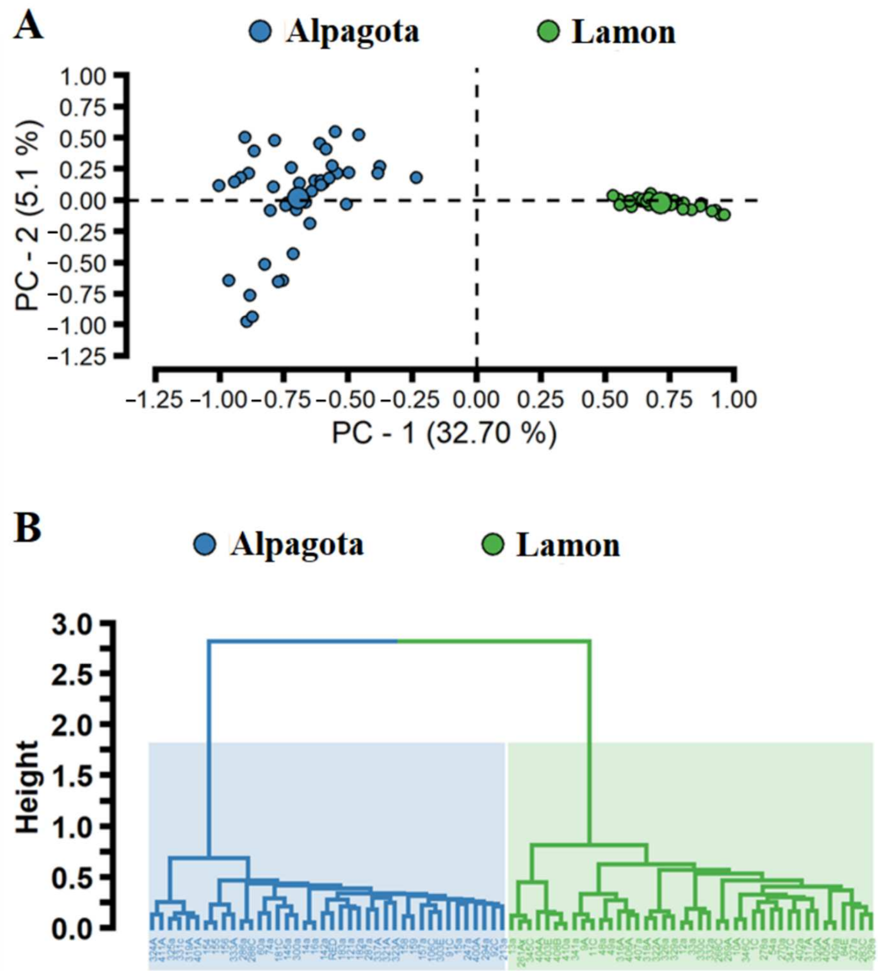

Figure 4. Alpagota and Lamon population structure based on genomic information. Above, (**A**) Principal Coordinate Analysis based on the genomic kinship coefficient. Below, (**B**) hierarchical cluster based on Ward's hierarchical method from genomic matrix, for Alpagota (n = 40) and Lamon (n = 41).

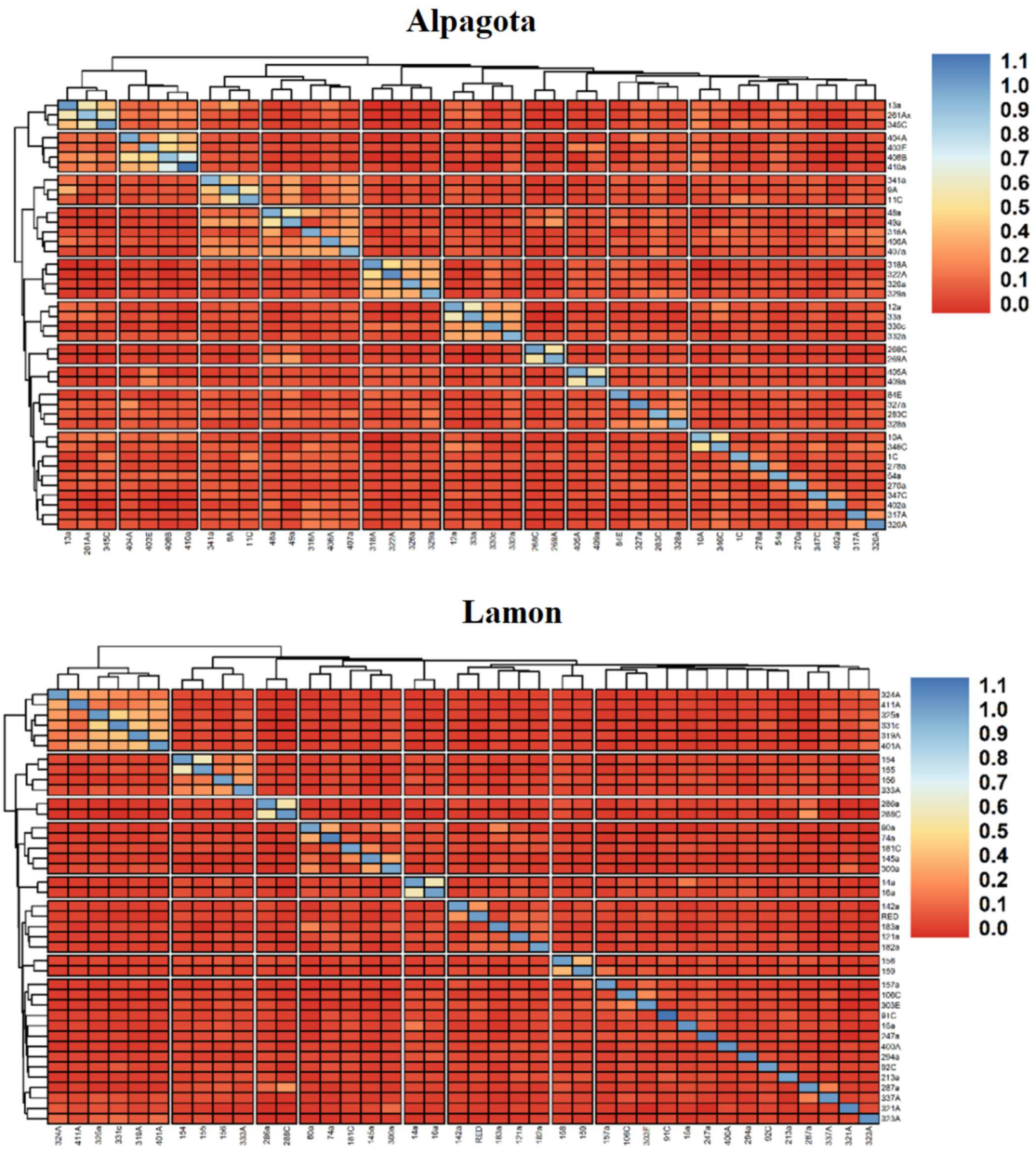

Figure 5. Relationship matrix based on genomic information. The genomic relationship matrix, built according to VanRaden (2008), both for Alpagota and Lamon.

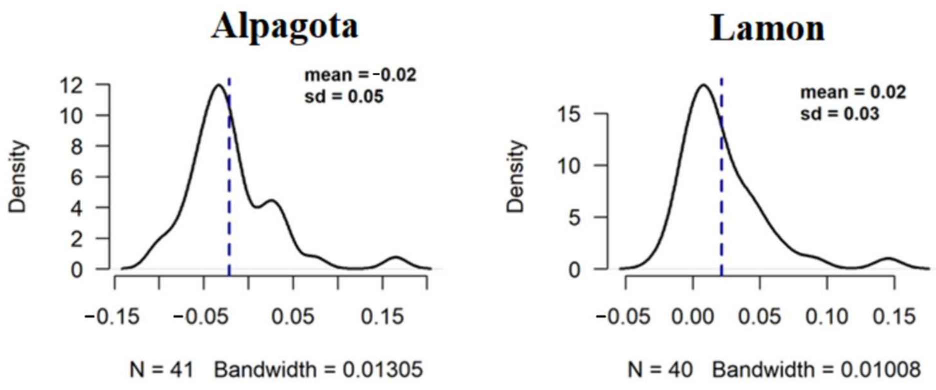

Figure 6. Inbreeding estimation based on diagonal of G matrix (A) for Alpagota and Lamon.

3.2. Farming Systems and Integration with Agroecosystems

Table 2 reports the descriptive statistics and farmer features. Data were collected in 17 farms with the Alpagota and 18 with the Lamon breed, managed by farmers of average age 47 ± 15 year, with a workforce of 1.8 ± 1.3 units, and little difference between the farms of the two breeds. The differences between the two breeds were tested with a one-way non-parametric ANOVA (Kruskal–Wallis test). In most cases, the farmers had other employment (72% for Lamon and 82% for Alpagota), and livestock farming was conducted part-time. Moving to flock sheep characteristics and management, the total number of heads surveyed was 1989 (337 of Lamon and 1652 of Alpagota breed, respectively). The Alpagota flocks were characterized by a small flock size (14.6 ± 18.6 LU/farm), and those of the Lamon breed by a very small flock size (2.8 ± 1.9 LU/farm), although the total LU/farm did not differ since other animals of different breeds and/or species, such as cattle and horses, were considered. The average amount of forage administered was 1.81 ± 0.5 kg DM/head/day, 88% of which was on-farm, indicating a high level of self-sufficiency. The average amount of concentrate administered per day was low and, in general, was produced off-farm. No statistically significant differences were found between Alpagota and Lamon breeds, except for the variable LU, according to the population size previously reported (DAD-IS, www.fao.org/dad-is/en, accessed on 18 September 2021). Lambings were mostly concentrated in winter, spring and autumn.

Table 2. Descriptive statistics of farms, LU, farmers' features and local sheep breed's features, management and feeding.

Variable	Unit	All Farms	Alpagota	Lamon
Farms	N	35	17	18
Farmers' features				
Worker units, mean	N	1.8 ± 1.3	1.8 ± 1.5	1.8 ± 1.1
Farmer age, mean	N	47 ± 15	49 ± 15	45 ± 15
Other employment	%	77	82	72
Local sheep breeds				
Number of sheep [1,2], total	N	1989	1652	337
LU [4] of local sheep breed/farm	N/farm	8.5	14.6 ** [3]	2.8 ** [3]

Total LU [4,5]/farm	LU/farm	21.8 ± 40.5	22.0 ± 26.7	21.6 ± 51.1
Forage, mean	kg DM [6]/head/day	1.81 ± 0.50	1.81± 0.54	1.80 ± 0.40
Forage self-sufficiency	%	88	91	84
Concentrate, mean	kg DM [6]/head/day	0.24 ± 0.22	0.19 ± 0.17	0.40 ± 0.24
Concentrate self-sufficiency	%	10	6	13

[1] The farms which raise only local sheep breeds are 15 in total (9 for Alpagota breed and 6 for Lamon breed). [2] Sheep included also rams; [3] ** p-value < 0.01; [4] LU: Livestock Unit; [5] The LU included all the animals raised in the farms: cattle, horses and sheep (including local and other breeds); [6] DM: Dry Matter.

Table 3 reports the data describing farmland management. On average, the farms managed 30.2 ha of Utilized Agricultural Area (UAA), with a great variation (SD = 34.3 ha). The farms managed 21.6 ± 26.7 ha of grassland followed by forest 7 ± 14.9 ha and by arable land 1.6 ± 2.5 ha; the average LU/UAA and LU/grassland were 0.7 and 1.0 unit/ha, with greater values in Lamon than in Alpagota farms. Regarding grassland, the patches were 3335 (mean value of 95 patches/farm) with an average surface of 0.2 ± 0.8 ha and an average altitude of 682 ± 292 m a.s.l. whereas the average slope was 11 ± 8°, without great differences between the regions considered (Figure 7).

Table 3. Geographic data, land use, land cover surface and land management features of the study area.

Variable	Unit	All Farms	Alpagota	Lamon
Farms, mean				
UAA [1]	ha	30.2 ± 34.3	40.2 ± 40.9	20.2 ± 1.6
Grassland [2]	ha	21.6 ± 26.7	27.4 ± 31.1	16.2 ± 21.4
Arable land	ha	1.6 ± 2.5	1.3 ± 2.7	1.6 ± 2.3
Forest	ha	7 ± 14.9	11.5 ± 19.5	1.9 ± 2.7
LU [3]/UAA	N/ha	0.7	0.6	0.9
LU/Grassland	N/ha	1.0	0.8	1.3
Patches of grassland				
Number	N	3335	2131	1204
Patches/farm		95	125	67
Surface, mean	ha	0.2 ± 0.8	0.2 ± 1.0	0.2 ± 0.4
Altitude, mean	m a.s.l.	682 ± 292	680 ± 255	684 ± 350
Slope, mean	°	11 ± 8	12 ± 7	11 ± 9

[1] UAA: Utilized Agricultural Area; [2] Grassland including pasture and meadows; [3] LU: Livestock Unit.

The georeferenced data were implemented in QGIS software to highlight the patches managed by these livestock systems. Figure 7 shows an example of the patches managed by a single farm, located in the Alpago region. Moving from the lake to highland pastures, following an altitudinal gradient, the patches with a red color were identified. As can be seen from the map, a single farm was able to manage a large number of small patches of grassland in the most marginal areas, with several ES linked to this traditional livestock system activity. The patches are characterized by important slopes and reduced accessibility, which only small ruminants were able to graze.

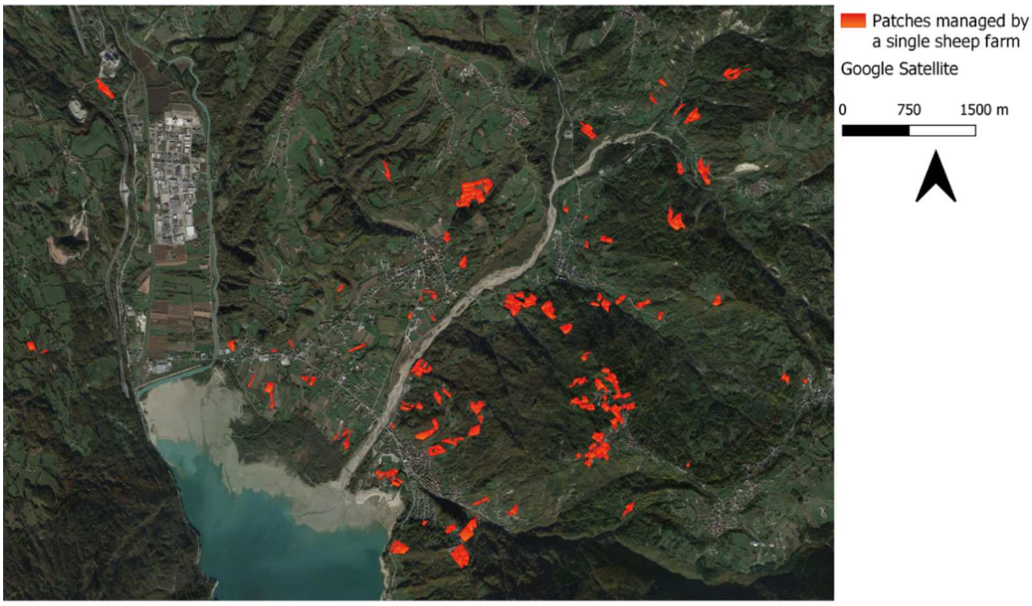

Figure 7. Patches managed by a single farm involved in this study.

3.2.1 Smartphone Application: Development and Implementation

The smartphone application provides three functionalities. The first concerns the registry of rams and ewes: farmers can report all information regarding the code of rams and ewes, date of lambing, number of ram and ewe lambs born and their weight. Information about the slaughtering (slaughterhouse code, number of heads slaughtered, carcass weight) and other deaths or culling and their causes are reported and can be modified and updated by farmers. The second feature deals with the ram evaluation, which allows farmers to calculate the offspring's inbreeding risk of using a given ram from another flock in their flock. This kind of communication between farmers allows them to favor the use of rams with less kindship with respect to the flock, reducing the risk of inbreeding and promoting the conservation and the sustainable use of genetic resources. The last functionality regards marketing: a QR code for each farm was implemented to enable consumers to obtain information regarding environmental markers (pasture, meadows, arable land surfaces), type of products (overall meat), and presence of agritourism. It even allows for notification as to whether the farms have joined the associations of Fardjma (Alpagota breed) or Fea de Lamon (Lamon breed) and location of the farm in Google Maps. Data can be modified and updated by farmers.

3.3. Conversion to Organic Farming and SWOT Analysis

The results of the survey performed to explore the potential of Alpagota sheep farms to conversion to organic labelling are reported in Figure 8, with a SWOT analysis approach. The strengths are mainly related to the strong link between livestock farming systems and grasslands (including pasture and meadows) and local breeds and their link to local traditions, mountain landscape and marginal areas. Another strength is the cooperation between smallholders. Organic regulation for ruminants requires the use of pastures, a high level of self-sufficiency and promotes the use of local genetic resources. In this sense, Alpagota sheep farms have all the characteristics to be converted to organic production, with the added value of cooperation, which can help to overcome the technical problems for smallholders. The opportunities regard the positive implications related to the commercialization of organic products and the link with eco-green tourism. In fact, consumers and tourists show favorable attitudes towards this kind of production [60]. Moving to the negative aspects, we identified as weak aspects burdens and costs related to the certification and traceability needs, since their management is expensive and complicated for smallholders. The main threats are lack of infrastructure, services and plants for wool valorization. Moreover, the land available is very fragmented and harsh. In recent years, there were also several wolf predations and the sheep sector is very marginal with respect to other livestock (agri-food) chains.

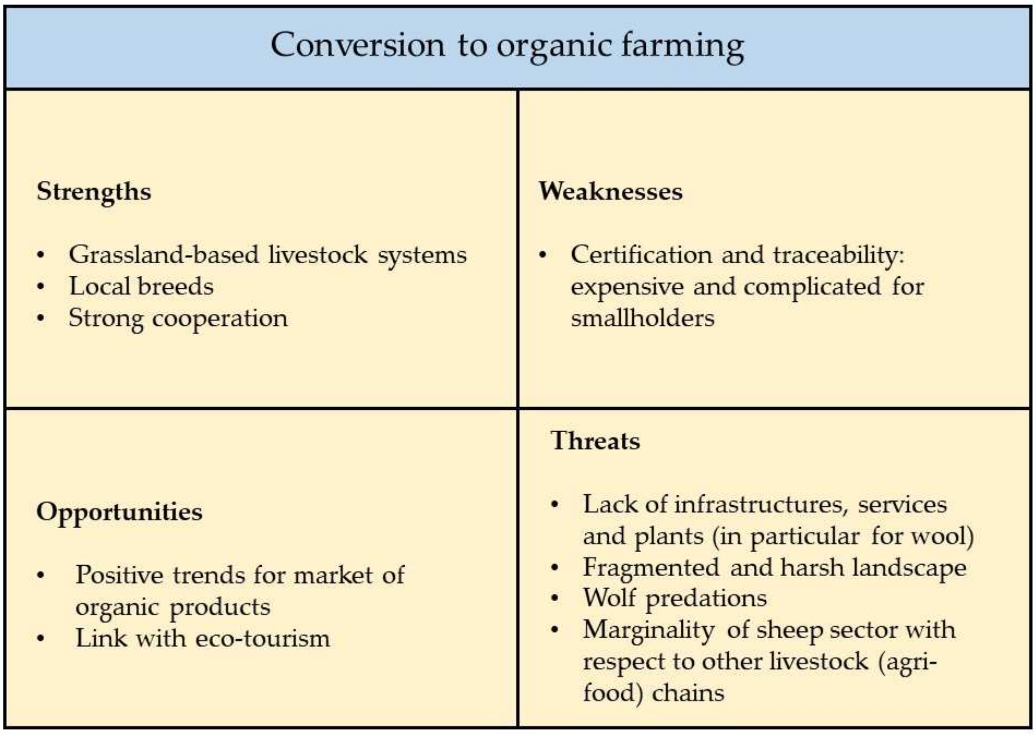

Figure 8. Chart illustrating the strengths, weaknesses, opportunities and threats identified by SWOT analysis.

4. Discussion

Alpagota and Lamon are local breeds typical of Alpago and Lamon-Feltrino areas, both located in the south of Belluno province [55]. All the farms considered in this study demonstrated a strong link with the territory, maintaining a mosaic landscape and providing high quality products.

Both breeds are classified as "at risk" [61] in the Farm Animals Diversity Information System (DAD-IS, www.fao.org/dad-is/en, accessed on 18 September 2021), mainly because of the low number of animals, especially for the Lamon breed. The genomic analysis showed a low level of inbreeding and a good genetic variability between the sampled rams, which belonged to the two populations of Alpagota and Lamon. The Alpagota rams had generally null relationships with the Lamon rams, with testimony as to the absence of recent genetic exchange between the two populations and testimony also to the genetic individuality of the two populations. On the other side, it is worth noting that the two breeds are also phenotypically different, especially in terms of size and external conformation. The Lamon is a large-size, long-legged sheep breed used in the past in large transhumance flocks, whereas Alpagota is a medium size sheep breed reared in the past especially in small mountain farms [54]. As reported in the results, the genetic variability is due to correct management of mating plans which allow for reducing the risk of genetic erosion [1,62]. In the Global Plan of Action, published by FAO in 2007 [1], the importance of animal genetic resources is recognized as a basic human need of food and livelihoods and their conservation is essential to ensure global and food security [37]. In addition, Leroy et al. [8] highlighted the important role of local breeds to provide ES. For this reason, in Alpago-Cansiglio and Lamon-Feltrino areas, an in situ conservation project was adopted in order to promote sustainable use of genetic resources, to preserve all the features typical of each breed and to valorize their products [5,55]. The development and the implementation of a smartphone application, provided by the project "Sheep Al.L. chain", aimed to further support the farmers in order to monitor the inbreeding and to increase the population size of sheep breeds as well as the number of farmers involved. Data can be constantly updated by farmers, who could report in the application the changes in the numbers of animals (births, deaths, animals sold or culled for various reasons, etc.). Moreover, in the ram function, in addition to the genealogical data, they can add all the genetic characteristics of the rams with the aim of favoring specific mating plans in order to maintain genetic distance and variability by involving other farms. The application will be further developed, and it can facilitate not only communication but also cooperation between smallholders.

Regarding the farm features and management, the results showed that, on average, LU/farm (including all the species raised in the farms) was similar in the two areas, but lower if compared with studies focused on different regions, e.g., Sturaro et al. [63] and Riedel et al. [64]. The majority of farmers worked part-time, since livestock activity alone was not sufficient for their livelihood, with a consequent employment in other sectors, such as services and industry [27]. The purchases of external feeds mostly resulted in concentrates with low off-farm inputs of forage, which indicated high self-sufficiency, according to other studies conducted in Mediterranean areas by Ripoll-Bosch et al. [20] and de Rancourt et al. [41]. The results show that the patches are characterized by small areas of reduced accessibility and are located in marginal areas, which only small ruminants are able to graze. The managed surfaces were mostly grassland (including pasture and meadows), whereas the areas covered by arable land were smaller, as they are extensive livestock farms based mainly on the use of meadows and pastures. Results regarding the georeferenced data show that the sampled farms were able to manage a large number of patches with respect to mountain dairy farms, e.g., Sturaro et al. [65]. Small ruminants were able to graze pasture and meadows located in marginal areas with limited forage resources [66] and the majority of small ruminants were represented by local breeds. As can be seen in Figure 7, sheep, belonging to a single farm, could graze patches with high slopes and reduced accessibility, guaranteeing not only the maintenance of a certain type of landscape, but even a series of ES. Several studies demonstrated that a fragmented landscape prevents forest fire and protects natural habitat, plant and fauna species [33,67,68], such as the conservation of dung beetle diversity [69]. Therefore, this type of livestock system, on the one hand, conserves the genetic resources of local breeds and, on the other, maintains a mosaic landscape, as well as a high level of biodiversity, these giving added value to the system.

Finally, according with that stated above, a SWOT analysis was conducted to assess the possibilities of conversion to organic farming of the Alpagota breed. This type of analysis is a valuable tool for understanding potential marketing strategies to give added value to the whole supply chain. The opportunities identified by SWOT analysis pointed out positive trends in the marketing of organic products and links with eco-tourism. New marketing strategies should be found, considering that consumers had different perceptions of local and sustainable products [70,71], with a consequent willingness to pay more for organic products [39]. Nevertheless, the main weaknesses highlighted by SWOT analysis were the costs of traceability and certification. According to Escribano et al. [72], financial aid should be provided to support farmers since they were not able to sell their products at a price which allowed for coverage of production costs. A threat emerging during the analysis was the marginality of the sheep sector compared to other livestock farming systems; thus, new strategies to create added value to the local sheep supply chain should be found. The challenge was to combine economic and ecological performance by implementing management practices respecting agro-ecological principles [10,73]. In agreement with Cabo P. et al. [74], a collaboration between educational and research institutions and between associations of farmers and local stakeholders could be considered to valorize local production. The diversification of farms' income (e.g., agritourism and the direct sales of products) and the management of HNVF should be evaluated to create added value [75]. In France, label and territory imagery were used to give added value to local production and consumers demonstrated a willingness to pay for high quality local products [76]. Moreover, the main restrictions linked to their production were due to the lack of infrastructure and services, as estimated by SWOT analysis, and by the decline in native sheep herds [74]. For this reason, the Farm to Fork strategy, established in 2020 by the European Commission, provides new tax incentives to support pasture-based livestock systems located in marginal areas, the conversion to organic farming and the promotion of organic products.

5. Conclusions

Results from this case study involving local sheep breeds reared in the eastern Italian Alps highlighted a strong link between traditional sheep farming systems and mountain agroecosystems. Alpagota and Lamon are local breeds associated to a specific geographical area (Alpago and Lamon-Feltrino, respectively) and their products are strictly related to the local tradition and the cultural heritage.

This type of livestock system provides a series of contributions to society and the environment (production of high quality food, such as lamb and sheep meat, maintenance of biodiversity, conservation of genetic resources, etc.) that give added value to the whole supply chain of the Alpagota and Lamon breeds. Moreover, the smartphone application showed a good potential in application and acceptance for farmers, who can update and upload farm information at any time and promote their products and activities such as agritourism, creating new territorial marketing strategies. Indeed, the application is not only a support tool during mating plans to avoid inbreeding, but also a means of communication to convey information about the areas managed by the farms and grazed by the animals and the relative contributions to the environment and to society related to this type of management (such as the ES mentioned above).

Regarding the SWOT analysis related to the potential conversion to organic farming of the Alpagota breed, results show a strong cooperation between farmers as well as a link between local sheep breeds and mountain agroecosystems. However, certification and traceability for organic products can be complicated and expensive for smallholders, while also lack of infrastructure and the marginality of the sheep sector were considered as threats. The positive and negative aspects detected suggest that financial aid to support farms should be provided; the conversion to organic farming can create added value to the supply chain, valorising the typical local products and links with eco-green tourism.

In according with the Farm to Fork strategy, conversion to organic farming could be an opportunity to generate added value to farms involved in these projects, in terms of food safety also.

The results of this project represent an initial step in favoring the competitiveness of local breed sheep chains. There is a fundamental need to guarantee the sustainability of the tools and networks developed throughout the project. In this perspective, the participatory process will be further developed to involve policy makers and other relevant stakeholders (advisory services, producers, tourist operators, consumers, etc.), with the aim of generating added value for these farming systems.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Table S1: Information collected during the survey about farm characteristics and products, herd size and composition of local sheep breed, herd size and composition of other species, land use and surface.

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Supplementary material

Table S2: Information collected during the survey about farm characteristics and products, herd size and composition of local sheep breed, herd size and composition of other species, land use and surface

Variable	Description	Unit	Standardization
Age of farmer		years	
Worker units	How many people work in the farm	Number	
Other employment	Owner employed in other job besides the farm management	%	
Municipality			
Herd size and composition of local sheep breed			
Number of sheep		Number	Livestock Unit (LU)=0.15
Number of rams		Number	Livestock Unit (LU)=0.15
Season of lambing		Months	
Forage intake[1]		kg/Dry Matter (DM)/year	
Off-farm purchased forage		%	
Concentrate intake[1]		kg/Dry Matter (DM)/year	
Off-farm purchased concentrate		%	

Herd size and composition of other species			
Number of sheep (other breed)		Number	Livestock Unit (LU)=0.15
Number of cattle		Number	Livestock Unit (LU)=1
Number of horses		Number	Livestock Unit (LU)=0.74
Number of goat		Number	Livestock Unit (LU)=0.15
Others[2,3]		Number	
Surface and use			
Utilized Agricultural Area (UAA)		ha	
Pasture		ha	
Meadows		ha	
Forest		ha	
Arable land		ha	
Chain of farm products	Each farmer was asked about the supply chain of products on the farm (overall lambs), i.e. who they are sold to, whether they are used at farm level, etc.		
Membership of local association (with reference to which one)	Each farmer was asked if he/she join to some local association in order to market and/or enhance their products		

[1] Forage and concentrate used during the indoor period; [2] Each farmer was asked to indicate the species in order to perform the correct standardization in Livestock Unit (LU); [3]No species besides sheep, cattle, horses and goats were raised

5.3 *Paper III: Evaluating the feasibility of an emergent initiative analysing the interest of the local stakeholders involved as well as the exchange of information and trust level among them*

Participatory approaches to analyse the feasibility related to the development of a beef quality brand in the Aragonese Pyrenees

The paper will be submitted in a scientific journal (probably Agricultural Systems) as soon as we have collected all the revisions from all the authors involved

Participatory approaches to analyse the feasibility related to the development of a beef quality brand in the Aragonese Pyrenees

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ABSTRACT

CONTEXT

Mostly extensive livestock systems, based on pastures and meadows with low off-farm inputs, are localized in mountainous regions. However, these are characterized by low income because: i) they are located in disadvantages areas which not allowed to create a wider market; ii) they suffer high competition with industry and intensive farming systems located in lowland areas. In Ansó and Hecho valleys (Aragonese Pyrenees) an emergent initiative concerning the development of a beef quality brand is taking place. The aim is to differentiate the local beef production in order to: i) create added value to the whole supply chain; ii) contribute to the local development.

OBJECTIVE

The aim of this study was to adopt two participatory approaches as tools to analyse the interest and the feasibility concerning the development of the beef quality brand in Ansó and Hecho valleys.

METHODS

Since the success of collective action depended on exchange of advice among actors as well as on the trust level among them, we adopted a participatory approach methodology to test the feasibility of the initiative. We organized 3 focus groups according to the stakeholders' labour sectors. We participated to the discussion as observers or mediators to investigate the viability as well as the interest in the initiative of the participants. Concerning the SNA, we surveyed 32 local stakeholders. Through the data collected, we were able to: i) build advice network including surveyed and no-surveyed actors; ii) build a trust network, including only the surveyed actors highlighting their level of confidence; iii) analysing the factors which contribute to shape the trust network.

RESULTS AND CONCLUSIONS

Our results showed that, despite it being an emergent initiative, the possibilities of successful of the initiative is good since: i) stakeholders were interest in the development of the beef quality brand; ii) both advice network and trust network as well as the statistical analysis revealed good levels of interactions among stakeholders involved and good level of confidence. Stakeholders are willing to contribute to development of the beef quality brand but none are willing to assume the role of

coordinator, i.e. managing stakeholders and resources involved. In general, we founded a lack of resources which inhibit the development of the initiative.

SIGNIFICANCE

Both participatory approaches resulted to be useful tools to investigate the feasibility of an emergent initiative; further investigations should be implemented but, observing this preliminary results, it seems to be a good methodology.

1. Introduction

Collective action is as a voluntary process of cooperation involving different stakeholders with shared interests (Barnaud et al., 2018; Scott and Marshall, 2009) and aiming to achieve common objectives. Cooperation and collaboration between different stakeholders enable the exchange of knowledge and resources to find common solutions (Tengö et al., 2014; Lazega, 2006; Ostrom, 2009) and develop common initiatives (Copena et al., 2022).

Information sharing among stakeholders strongly depend on trust (Ostrom, 1990) which is a central element for the success of collective action and a key element for collaboration (Stern and Coleman, 2015; Crespo et al., 2014). Indeed, trust in collaborative process is fundamental to achieve common objectives and to understand other stakeholders' interests and positions (Emerson and Nabatchi, 2015). Furthermore, participation of stakeholders in common initiatives is favoured if they trust each other (Young et al., 2016); common projects as well as collective actions are based on trust and mutual understanding among participants (Zaga-Mendez et al., 2021; Coleman et al., 1994). Trust is created, maintained and developed through the interactions between stakeholders and the groups they belong to (Stern and Coleman, 2015); indeed, if stakeholders trust each other, there is not only greater participation in collective action but also fewer conflicts (Young et al., 2016) which may limit or enhance common projects (Baland and Platteu, 1998). The results of interactions, cooperation, trust and exchange of knowledge between stakeholders and the networks generated by these interrelations is defined as social capital (Díez-Vial and Montoro-Sánchez, 2014; Inkpen and Tsang, 2005). A solid social capital means strong relationships between stakeholders which is fundamental for the achievement of collective actions (Borgatti et al., 1998; Burt, 2000).

Social Network Analysis (SNA) methodology is valuable tool for understanding the relationships between stakeholders in a collaborative process (Mandarano and Meenar, 2015; Connick and Innes, 2003). It enables quantitatively measuring the exchange of information and resources between stakeholders and institutions, revealing the level of collaboration (Lazega, 2014; Bodin and Crona, 2009); this approach also allows to analyse the link between collective action and social capital (Siegel, 2009; Bodin and Prell, 2011)

In mountainous regions, promoting collective projects is recommended to protect natural areas and maintain Ecosystem Services (ES) provision (Ernstson. et al., 2008; Rac et al., 2020; Vialatte et al., 2019). The majority of ES in mountain areas are delivered by livestock activities (Bernués et al., 2005) and their provision can be improved by the collaboration between local stakeholders (e.g., farmers, tourism operators, restaurateurs, etc.). Indeed, the engagement of the local communities who live and work in a specific mountain area could improve the delivery of benefits to human well-being, both at local land global level, since people can share their knowledge and their perceptions of ES (Schripke et al., 2021). Geographical proximity allows strengthening social capital, which is the basis for the success of collective action, for example the development of a new quality brand (Houdart et al., 2011; Pachoud et al., 2020).

In mountain and remote areas, the existence of geological barriers and the lack of infrastructure usually produce isolation and hamper collaboration. Regional proximity enables the exchange of feedback and could enhance interactions and collaborations between local stakeholders (Torre and Wallet, 2014; Lynch and Maggio, 2000). Indeed, personal relations allow to share individual perceptions between actors, which is essential to promote and to valorise local products (Furtschegger and Schermer, 2013). In addition, community projects involving large number of farms improve environmental benefits, social capital and co-working more than individual farms' projects (Keenleysyde et al., 2009; Swales, 2009; Pachoud et al., 2020; Orchard et al., 2020). Furthermore, the capability of stakeholders to act collectively allow to valorise the territory and its resources (Vollet and Torre, 2016), giving added value to local products. For example, Edelmann et al. (2020) showed how participatory processes and collective strategies help to increase awareness of local products, highlighting their link to a specific geographical area, including its cultural identity and heritage (Fusté-Forné, 2020). Finally, according to Schröter et al. (2018), SNA could also be an instrument to support inclusive processes in order to create cooperation for the development of new projects.

This study aims to analyse, through a participatory approach methodology, the feasibility related to an emergent initiative, i.e. the development of a beef quality brand in Ansó and Hecho valleys (Aragonese Pyrenees). The initiative was promoted by local and regional rural development and public institutions. Specifically, we found a gap in the literature related to participatory approaches as methodology to test as well as to analyse the viability and the exchange of information among stakeholders involved in an emergent initiative in mountainous regions. The specific objectives were:

i) to test the interest of the development of the beef quality brand collecting local stakeholders' opinions and perceptions;
ii) to build an advice network including all the local stakeholders involved and potentially interested in the development of the beef quality brand analysing the relationships between them and their role in the initiative
iii) to build a trust network including only the surveyed local stakeholders analysing the level of trust between them and their role in the initiative
iv) to identify if there were differentiated local stakeholders' groups regarding their contribution to the quality brand development and the factor that contribute to their formation.

2. Material and methods

2.0 Study area

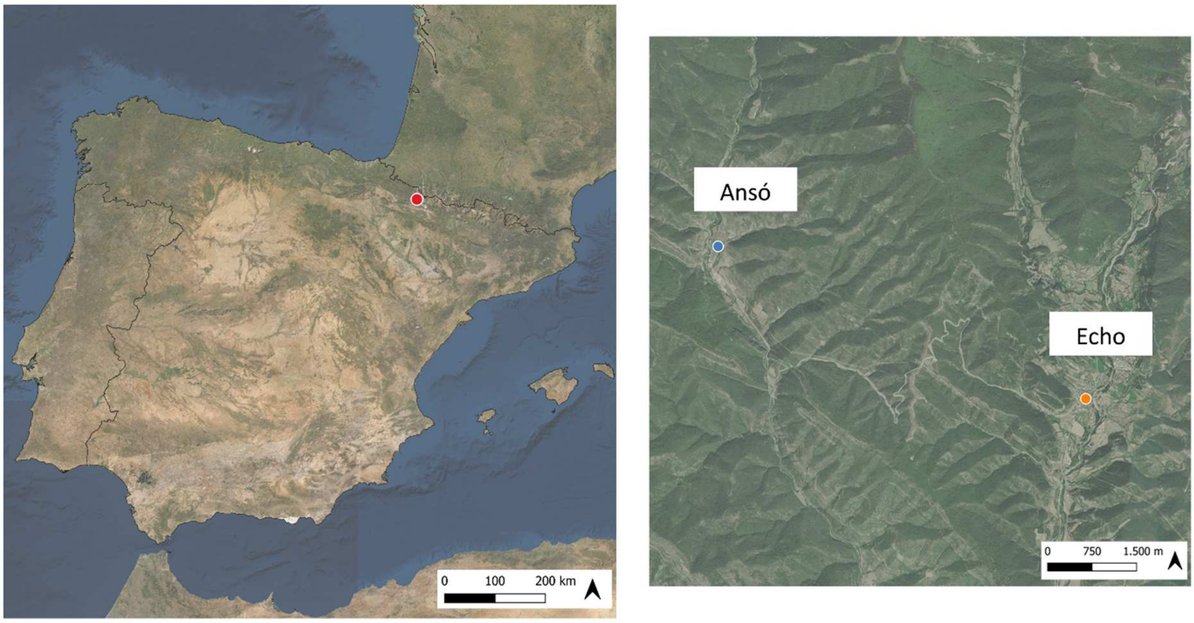

Figure 3: Study area. The blue and the orange point indicate the Ansó and the Hecho villages, respectively, and the related valleys.

The study was conducted in Hecho and Ansó valleys, belonging to Jacetania *comarca* (county) located in the west side of the Aragonese Pyrenees (province of Huesca, North of Spain, between 41°00'N and 0° 45' W) (Figure 1). The two valleys cover a surface of 435.9 km^2 with an average altitude of 1244 m a.s.l. (ranging approximately from 500 m a.s.l. and 2500 m a.s.l.) and are characterized by the presence of the Aragón Subordan river (in Hecho valley) and by the Veral river (in Ansó valley). According to Köppen-Geiger R. (1954), the climate is classified as Cfb (Oceanic climate with mild summers and cool winters) with an annual average rainfall of 1361 mm (the average values range between 74 mm in July and 148 mm in November) and an average temperature of 10.3°C (ranging from 2.4 °C in January to 19.3°C in July) and mean relative humidity of 71-73%. The surface is mostly covered by forest (53.5%) followed by pasture (36%), unproductive land (9%), arable land (1.3%) and urban area (0.2%). (Gómez et al., 2020). Currently, communal pastures cover a surface around 27520 ha with approximately the same area in each of the valleys. In Ansó valley, the communal pastures occupy more than 50% of its total surface. During the last century, the area was affected by a strong population abandonment due to rural-urban migration processes. This depopulation produced a sharp decrease of the number of farms and an increase of herds size, which has continued to date. Indeed, according to Instituto Aragonés de Estadistica (IAEST), between 2010 and 2021 the number of heads increased by 29% (in 2010 the number of heads were 2080 while in

2021 they were 3949) whereas the number of farms remained almost equal (42 in 2010 and 41 in 2021, respectively).

As opposed to neighbouring valleys such as Broto and Benasque, Hecho and Ansó valleys have been characterized by modest tourism development which has allowed to maintain agricultural and livestock activities; this has been due to the lack of labour alternatives and to the reduce competition with the other economic activities. Currently 18% of the local population still works in the primary sector. In 2006, these valleys were designated as part of the *Valles Occidentales* Natural Park according to the law 51/2006, which cover a total surface of 27073 ha including other neighbouring valleys, with the specific aim to recognize the important natural value of these territories.

2.1 Initiative of quality brand and participant selection

Local and regional rural development and public institutions have considered the opportunity to develop a quality brand of beef production in Hecho and Ansó valleys. In the two valleys, there has been a growing demand for local high-quality products both from tourists and residents. The idea of above mentioned institutions is to start a bottom-up initiative involving local stakeholders with different profiles and belonging to different labour sectors (accommodation, restoration, touristic, administrative, rural development etc.). Indeed, local stakeholders are the main actors which could contribute to the development as well as to the success of the beef quality brand. The main goal was to study the feasibility of creating a differentiated quality brand in order to give added value to local beef production.

2.2 Data collection and analysis

Data were collected using participatory approaches, i.e. focus groups and surveys, including a part of the local stakeholders involved in the initiative. Specifically, through the focus groups methodology, we wanted to test the feasibility and the opportunities related to the development of the beef quality brand collecting local stakeholders' opinions and perceptions. This also allowed us to test the interest in the initiative of the participants. Regarding the surveys, the aim was to collect data to build both the advice (which include surveyed and non-surveyed actors involved in the initiative) and the trust network (which involved only the surveyed actor) analysing the relationships between local stakeholders and their role, e.g. contribution, in the development of the beef quality brand.

With trust network we even analysed the level of confidence, e.g. trust, between the surveyed local stakeholders.

2.2.1 Focus group

The focus group is a methodology where a researcher moderates a group of 4 to 12 people to discuss a specific topic (O. Nyumba et al., 2018). The aim of the focus group methodology is to share knowledge, opinions and ideas, paying attention to the interactions and the discussion between the participants (Stewart and Shamdasani, 2014), whose opportunity to participate in the discussion and to express their opinion has to be ensured (Elliott et al., 2005).

In October 2021, the same institutions, in collaboration with the *Centro de Investigación y Tecnología Agroalimentaría de Aragón* (CITA), organized three focus groups with the aim to: i) analyse the feasibility and the opportunities related to the development of the beef quality brand; ii) to test the willingness of local stakeholders to take part to the initiative; iii) to identify the synergies between the local stakeholders belonging to different labour sectors.

The three focus groups, organized in collaboration with the local and regional rural development and public institutions, took place in October 2021 with the aims to: i) analyse the feasibility and the opportunities related to the development of the beef quality brand; ii) to test the willingness of local stakeholders to take part to the initiative; iii) to identify the synergies between the local stakeholders belonging to different labour sectors. We performed three different focus groups to divide the local stakeholders according to common interests and similar labour sector: i) administrative and technician stakeholders, employed in public and private sector (8 participants); ii) stakeholders working in the tourism, commerce, restaurant and accommodation sector (4 participants); iii) farmers (6 participants).

The focus group lasted on average an hour and a half and started with a short introduction of the initiative and it was explained the reason why they were invited to participate. A common design for the three focus groups was established with some differences for each focus group (Table S1). With the participants' permission, discussions were recorded. Besides, two assistants took notes during the discussion.

2.2.2 Social Network Analysis

The Social Network Analysis (SNA) is used to study the relations among local stakeholders focusing on the pattern of relationships (network structure) and the interactions between them (Vaughan, 2005; Stokman, 2001). SNA methodology allows to understand the role of each local stakeholders in the network and their position within the social structure (Crona et al., 2012; Pachoud et al., 2019). Social networks are commonly represented by graphs, in which nodes represent actor whereas links represent the relations that connect the nodes (actor) (Bodin and Crona, 2009).

We used the roster method to collect data and to build the social network which consists in asking participant to indicate the name of the persons with whom they have discussed about the initiative, , i.e. the question utilized during the surveys "*to whom of the people of the list did you discussed about the initiative concerning the development of a beef quality brand in Ansó and Hecho valleys?*"

We surveyed 32 actors including 18 farmers and 14 other stakeholders (tourist operators, restaurateurs, technician, administrative agents etc.). During the focus groups, we asked participants for their contact details and their availability to participate in surveys, between November 2021 and January 2022, in order to collect data to carry out a SNA. The local and regional rural development and public institutions which promoted the initiative also provided us, respectively, a list of other stakeholders and missing farmers, who did not attend to the focus groups but could potentially had an interest in the development of the quality brand since they belong to the valleys and work actively there. During the survey, we asked to participant, for the other stakeholders' missing contacts. From an initial list of 47 local stakeholders, only 32 were available to take part in the survey (18 farmers and 14 other stakeholders which included tourist operators, restaurateurs, technician, administrative stakeholders, etc.). Indeed, part of them did not respond and others did not want to participate in the survey since they were not interested in the initiative; furthermore, in some cases, the farm was owned by more than one person present in the list (e.g., other family members) but managed by only one of them.

Since not everyone was willing to take part to the survey, to carry out the SNA, we focused only on local stakeholders interested in the initiative. From a methodological perspective, some studies underlines that the lack of data should not be ignored (Huang et al., 2019; Huisman, 2009). However, since our objective was to explore the possibility of cooperation among local stakeholders in the study area, the results concerning the SNA should be considered as an example of application as well as a preliminary step to analyse the exchange of information and opinions among local stakeholders. Indeed, currently, this type of analysis can be performed only with local stakeholders who showed interest and therefore took part in the surveys; some studies showing that missing data due to no-response surveys could be balance out by reciprocal nominations or by the presence of common exchange partners (Kossinets, 2006; Robins et al., 2004; Jorgensen et al., 2018). Future studies will involve a larger sample of local stakeholders since further meetings are planned to promote the initiative in the two valleys.

First of all, each participant was asked to sign a declaration of consent to the processing of data in respect of privacy, specifying that the data provided would not be associated with the personal name.

Specifically, we designed the survey in three parts: the first one regards general information about the participant: name, age, labour sector, place of residence; the second one regarding general information about the quality brand (number of meetings to which they took part regarding this initiative, from whom they first heard about the initiative, whether they think it will create added value in the Hecho and Ansó valleys). Later, to build the advice network, we presented a list of people involved in the development of the beef quality brand and we asked for each participant to with whom of the people of the list had discussed as well as exchange opinions and information concerning the development of the beef quality brand. Finally, to assess the level of confidence and to build the trust network, we asked to each respondent to indicate for each person named in the list and with whom they had discussed about the initiative, on a scale from 0 (very low) to 10 (very high), how much they relied on that person's opinions and ideas as contribution to the development of the brand. (see Table S2 for a survey's details). To design the question concerning the trust we based on methods adopted in other studies founded in the literature, i.e. Pachoud et al. (2020); Hahn et al. (2006); Crespo et al. (2014). However, we are aware that our data could be subjected by judgments and, as stated above, it represented an example of application as well as a preliminary step to analyse the trust between some of the stakeholders involved in the initiative since it is an emergent project and the quality brand is still to be developed. We analysed two networks: the first one regarded the advice network, also including the non-surveyed actors and the second one regarded the trust network, including only the actors surveyed. Indeed, since all the data were available only for the surveyed actors, i.e. data collected through the surveys, the trust network was built only for surveyed local stakeholders to avoid biased results. Specifically, the aim of the advice network was to show the exchange of information between the local stakeholders potentially involved in the initiative as well as their contribution to the development of the beef quality brand. Instead, the aim of the trust network was to highlight the level of confidence between actors since the trust is a key factor to develop new initiative without neglecting the contribution of each actor in the network.

To analyse both the advice network and the trust network we used two approaches: structural approach and positional approach. However, within the positional approach, the Louvian's communities were identified only for the trust network due to the lack of data for non-surveyed actor. Furthermore, to analyse the trust network we used even a third approach, namely Exponential Random Graph Model (ERGM). The analysis was carried out in R 4.1.3 (R Core Team, 2013) using the packages igraph (Csardi and Nepusz, 2006), qgraph (Epskamp et al., 2012) and ergm (Hunter et al., 2008).

The structural approach, allowed to analyse the relations between the local stakeholders, e.g. how much they are interconnected, the presence of more or lesser individual isolated. Structural indicators are important to highlight the sharing of knowledge as well as the exchange of information. For this reason, we estimated the density and the reciprocity and we identified, for the trust network, the existing actor groups (communities hereafter) using the Louvian algorithm. Density estimates the ratio of links present in the network to the total number possible links. Density allows to understand the level of interaction among actors. Reciprocity measures the members mutually cited since it determines the presence of mutual exchange of advice, i.e. help between local stakeholders involved in the network (Jana et al., 2013). The Louvian's algorithm allows to identify, using the modularity parameters, the communities partition between the actors involved in the initiative. The communities were identified for the trust network, since only for them we had all the information, gathered through interviews, to describe each community. Indeed, the Louvian algorithm identified the communities basing on the actors' characteristics. To compute the Louvian's alghoritm in R, we had to change the network from directed to undirected. We also computed a permutation test for one-way ANOVA, to identify which factors were significant in forming Louvian's communities.

Moving to the positional approach, we identified which actors have a central role in the network by estimate the in-degree centrality and the betweenness centrality parameters. The in-degree centrality measures the number of edges (links) that point inward a node (Hansen et al., 2020). In-degree centrality, therefore, reveals the prestigious actor since measures the number of advice request counting the number of times that an individual is nominated by others (Baek et al., 2022; Wasserman and Faust, 1994). Betweenness centrality measures *'the extent to which a certain vertex lies on the shortest paths between other vertex'* (Hansen et al., 2020). Betweenness centrality reveals which actor is in the brokerage position, i.e., who contribute to the information flow and to network cohesion (Everett and Valente, 2016).

Finally, regarding the ERGM, we tested if network was shaped randomly and which factors contribute to define it; specifically, we analysed which internal and/or external attributes most influence the exchange of advice therefore the structure of the network. We estimated both endogenous and exogenous attributes in order to identify which factors contributed to form the social networks. The ERGM was applied on the trust network since to compute them in R the dataset should not have Not Available (NA) data. First of all, we tested if relations between members were established randomly or are derived by internal (endogenous) or external (exogenous) attribute of the nodes. Specifically, we analysed three internal attributes: i) density of edges defined as the number of links present in the network divided by the number of possible links; ii) reciprocity defined as mutual advice relationships; iii) the probability of two actors which had a relationship with a third one to share an advice ties. For this purpose, we estimated the Geometrically-Weighted Edgewise Shared Partnerships (GWESP): two nodes i and r have a shared partner when they are connected to each other and both i and r are also connected to a third individual k.

Regarding external attribute, we considered age, labour sector, and education level. We treated age as a continuous variable whereas labour sector as well as education level as factor. First we tested the presence of homophily for each attribute. No homophily was found in any of the factors. Then we build the model testing the attributes in order to find the best solution with the lowest Akaike Information Criterion (AIC) testing all the different combinations with the attributes (Table S3 in Supplementary Material).

3 Results

3.0 Focus group

Figure 2 reported the opinions and perceptions of the actors participating to the focus group, concerning the beef quality brand. All participants were interested in the initiative since they perceive an increasing demand for local products, including beef. Specifically, the administrative and technician agents recognized the importance of livestock activity in maintaining landscape characterized by a high nature value both from a natural and cultural perspective. During the discussion they proposed some strategies to give added value to local beef: i) fattening the calves with local concentrate feed; ii) commercialize the beef in local shops as well as in local restaurants, iii) preferring high quality cuts; iv) to find synergies and cooperation with other initiatives, both located in the same valleys or in other neighbouring valleys. During the focus group which involved the touristic and commercial agents (including restaurateurs and accommodation providers), it emerged their willingness to buy local products in order to commercialize them in local shops or in restaurants. They had also suggested to find synergies and collaboration with the neighbouring villages, e.g. Jaca, to create a wider market for local products. Finally, as a weakness, they found out the seasonality of the demand which not guarantee a constant income during all the year. Finally, concerning the focus group of farmers, they agreed with touristic and commercial agents to collaborate with local shops located in Jaca, which is the largest neighbouring town, to contrast the demand's seasonality. Furthermore, they are reluctant to invest more time without the guarantee of more revenue. For this reason, they proposed to start with few calves to test the feasibility of the initiative. The 6 participants agreed that the main difficulties are related to scarce availability of local concentrate feed as well as the slaughterhouses which are located far from the valleys. Unlike the other local stakeholders, farmers did not recognize the importance of livestock activity in maintaining landscape from both cultural and environmental perspective.

It emerged during the three focus groups that no one is willing to coordinate the project and thus to manage the resources and the local stakeholders involved.

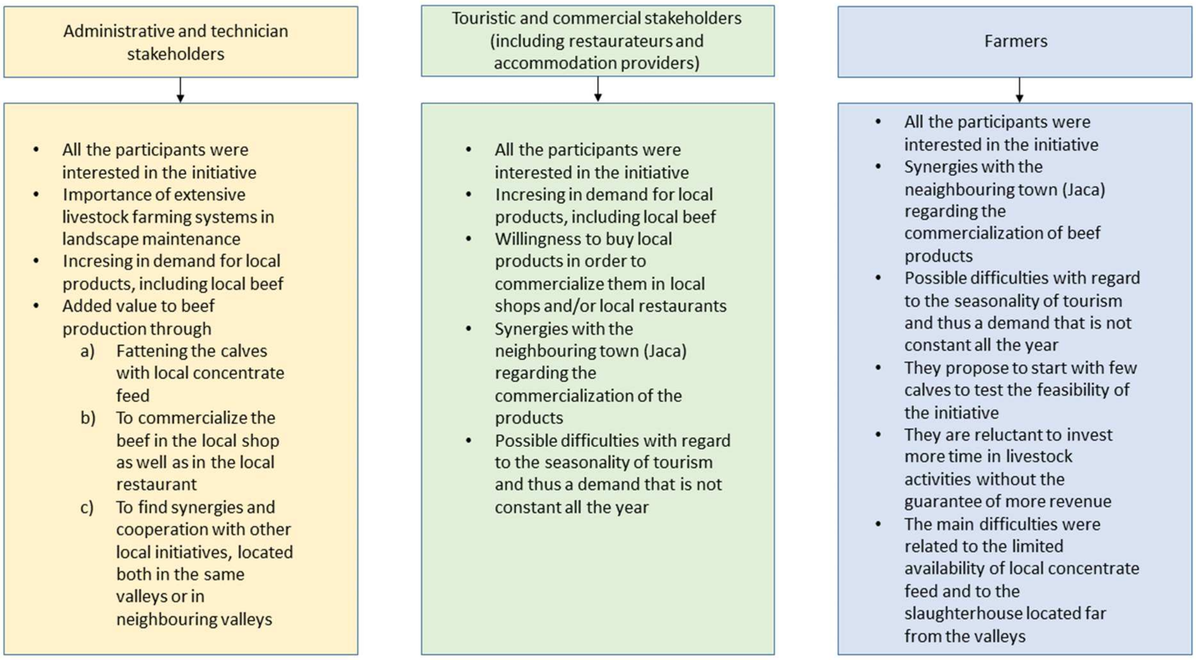

Figure 4: main results emerged during the three focus group.

3.1 Main features of actors surveyed and main characteristics of farms and farmers' involved in the initiative

Table 1 shows the main features of the actors who participated in the interviews. We surveyed 18 farmers and 14 no-farmers (7 tourist and commercial stakeholders, 5 administrative and technician stakeholders and 2 stakeholders belonged to other labour sectors). The average age of the people surveyed was of 44±12.5 years. Concerning the education level, results showed that the administrative and technician stakeholders as well as the other stakeholders had an education level higher with respect to farmers; indeed, most of them (11 farmers) interrupted their studies after the secondary school whereas the remaining 7 attended the high school (3 farmers) and did a professional training course (5 farmers). Concerning the tourist and commercial stakeholders, 4 of them got a university degree or a professional training certificate whereas within the remaining 3, 2 attended the high school and 1 interrupted their studies after the secondary school.

Table 1: main features of the actors surveyed

Variable	Unit	All actors	Farmer	Tourist and Commercial stakeholders[1]	Administrative and Technician stakeholders	Other stakeholders
Actor surveyed	N of actors	32	18	7	5	2
Age	Mean	44±12.5	44±12.7	48±10.7	44±12.9	34±9.9
Education level						
Primary school	N of actors	7	7	0	0	0
Secondary school	N of actors	4	3	1	0	0
High school	N of actors	5	3	2	0	0
Professional training	N of actors	8	5	2	1	0
University	N of actors	8	0	2	4	2

Table 2 reports general information about farmers and their livestock activity. Most farmers declared to be full-time employed in farm activities. A small but relevant group of them had other employments in addition to farming (22% of farmers).

The average herd size was 145.6±87.8 LU/farm.Regarding the calves sold, results showed that in the two valleys were sold 29.6±16.7 LU/year/farm. The grazing length was of 7.5±2.4 months (referring to the whole study area). Concerning the surface managed by these livestock systems, results showed that the majority were communal pastures with an average surface of 355.5±628.6 ha followed by the rented land (including pastures, meadows and crop land) with an average surface of 79.1±238.9 ha. Results showed a great variability because: i) some farmers have access to a large area since they shared the pasture with other farmers; ii) they keep the herd on pasture all the year. Finally, regarding the owned land, results showed that farmers owned very few hectares (8.6±8.0 ha).

Variable	Unit	All farms
Famer, total	N	18
Other employment	%	22
Farmer age, mean	year	42.5±13.3
LU[1,2]/farm	LU/farm	145.6±87.8
LU[1] of calves sold /year	N	29.6±16.7
Grazing length, months	months	7.5±2.4
Owned land, mean	ha	8.6±8.0
Rented land, mean	ha	79.1±238.9
Communal pastures, mean	ha	355.5±628.6

1 LU: Livestock Unit; 2 LU included cattle and calves

3.2 Social network analysis

In this section we reported the results concerning the advice network and the trust network, the communities identified by the Louvian's algorithm within the trust network and finally the results regarding the ERGM.

3.2.1 Advice network and trust network

Figure 3 represented the advice network between the stakeholders involved in the initiative, including also the non-surveyed actors whereas figure 4a and 4brepresented the trust network, including only the surveyed actors. Specifically, the nodes' size of figure 4a referred to the in-degree value of each actor whereas the nodes' size of figure 4b referred to the trust mean values of each actor given by the other stakeholders involved in the network. Results regarding positional and structural indicators were reported in table 3 as well as the number of nodes and the number of links. The advice network involved 44 actors (nodes) and counted 196 links whereas trust network counted 26 actors (nodes) and 131 links. The density of advice network was 10%, lower than the trust network, which had a density of 20%; both values indicated that the actors are quite connected. Concerning the reciprocity, this was high for both network: the advice network showed a reciprocity of 53% whereas the reciprocity of trust network was 58%. These values of reciprocity indicated that more than 50% of stakeholders were mutually linked. Regarding the structural indicators, in the advice network the most cited actor was an administrative member of the Hecho's village city hall with 17 advice request (highest indegree centrality) (Figure 3). During the survey, we discovered that the same actor was the initiative's promoter. The other actors most cited, with 12 advice request, were actor 24 (a rural development agent as well as the one who organized the first meeting and the focus groups) and actor 32 (the veterinary). Actor 6 (an agent employed in the touristic services) and actor 22 (a farmer) received 9 advice request. Regarding the trust network, actor 24 had the highest indegree centrality (Figure 4a) with 24 advice request followed by actor 8 and by actor 6 with 23 and 19 advice request, respectively. Compared to the advice network, the veterinary and farmer 22 were not the most cited actors since actor 2 (the president of the famers' association of Hecho valley) and actor 3 (a rural development agent) received more advice request showing indegree centrality's values of 16 and 15, respectively. Finally, concerning the betweenness centrality, the advice network showed that actor 24 was in the brokerage position with a value of betweenness centrality of 283.5 followed by actor 8 with a value of 268.6. As reported in the table, the actors 2, 6 and 22 showed lower betweenness centrality's. Even in the trust network, actor 24 was the one which contributes most to the information flow and to the network cohesion, with a betweenness centrality's value of 112.5 followed by the president of the farmers' association of Hecho valley which showed a betweenness centrality of 88.7. Actor 8, 6 and 22 had lower betweenness centralities with values of 77.7, 60.5 and 50.8, respectively. For both advice and trust network, the differences between actors in terms of betweenness's centrality values were wide.

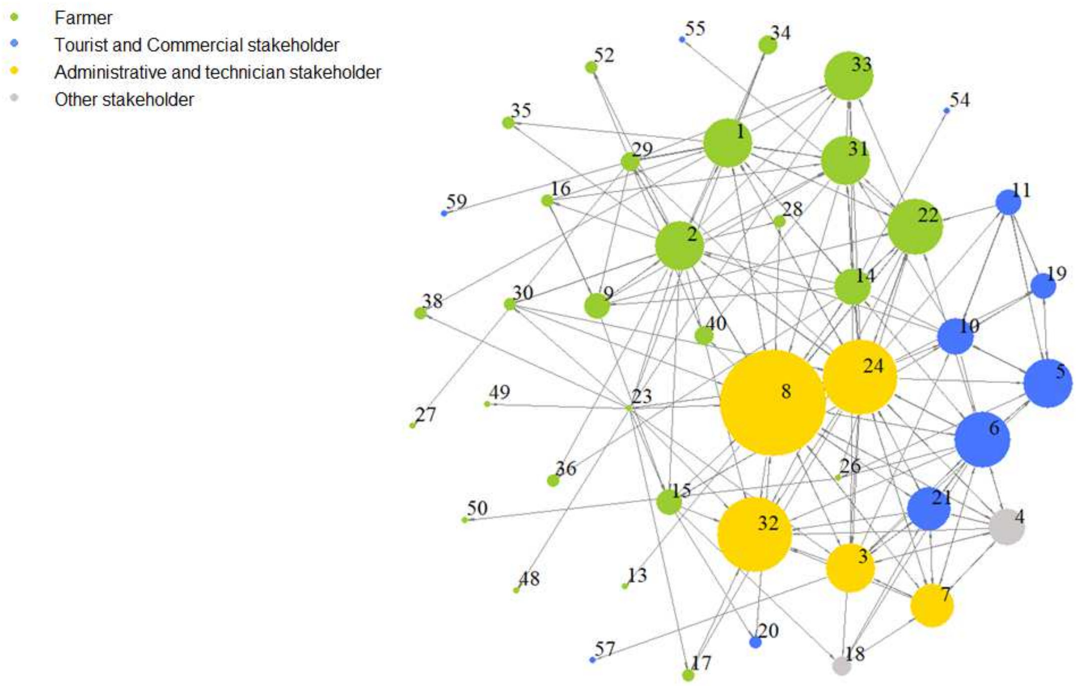

Figure 5: advice SNA included all the actors (even those not surveyed) involved in the development of the quality brand. The graph represents the exchange of advice between the actors; the nodes represent the actors and the links (edges) represent the connections between the actors. The size of each node depend on the in-degree value of each actor. The graph is directed since the links which connected the nodes are represented by directed arrow. The colours of the nodes highlight the different labour sectors (44 nodes; 196 links).

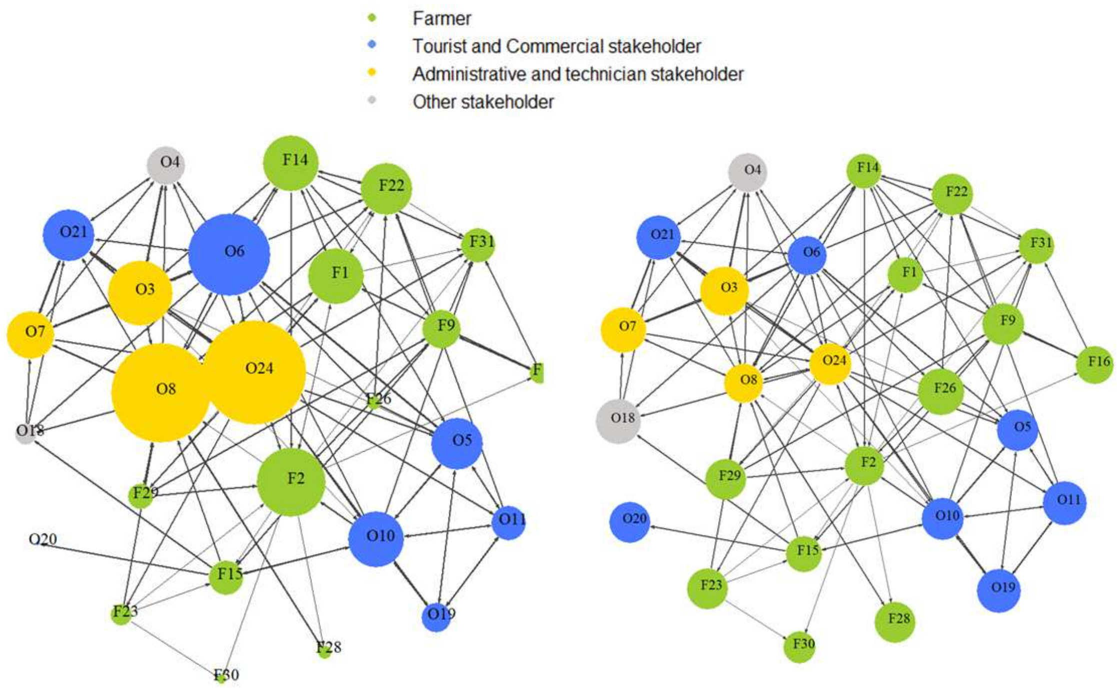

Figure 6: SNA related to the trust between the actors surveyed. The F which precedes the number indicates if the actor was a farmer and the O indicates if the actor was non-farmer. The nodes size of figure 4a depended by the in-degree values whereas the nodes size of figure 4b depended by the average trust values given by the other actors involved in the network. he colours of the nodes highlight the different labour sector. The edges are thicker or thinner according to the average value of trust given by the actors during the survey (26 nodes; 131 links).

Table 2: node, links, structural indicators and positional indicators for both advice and trust SNA.

Advice SNA		Trust SNA	
Variable	Results	Variable	Results
Nodes	44	Nodes	26
Links	196	Links	131
Structural indicators		*Structural indicators*	
Density	10%	Density	20%
Reciprocity	53%	Reciprocity	58%
Positional indicators		*Positional indicators*	
Indegree centrality		Indegree centrality	
Actor 8, administrative stakeholder	17	Actor 24, rural development stakeholders	24
Actor 24, rural development stakeholder	12	Actor 8, administrative stakeholder	23
Actor 32, veterinary	12	Actor 6, touristic sector's stakeholder	19
Actor 6, touristic sector's stakeholder	9	Actor 2, farmer	16
Actor 22, farmer	9	Actor 3, rural development stakeholder	15
Betweenness centrality		Betweenness centrality	
Actor 24, rural development stakeholder	283.5	Actor 24, rural development stakeholder	112.5
Actor 8, administrative stakeholder	268.6	Actor 2, farmer	88.7

Actor 2, farmer	127.6	Actor 8, administrative stakeholder	77.7
Actor 6, touristic sector's stakeholder	115.4	Actor 6, touristic sector's stakeholder	60.5
Actor 22, farmer	96.2	Actor 22, farmer	58.2

3.2.2 Louvian communities within the trust network

Figure 4 shows the 4 communities identified by the Louvian's algorithm, within the trust network, whereas their main characteristics are reported in table 4. The number of members belonged to each community ranged between 4 and 8. The algorithm assigned to community A only farmers with an average age of 30±8.7 years; most of them came from the Hecho valley and got a professional training certificate. Community B included 8 members, mostly non-farmer's agents, with an average age of 46±13.5 years. The majority of them got a university degree and were employed in touristic, commercial, technical or administrative sectors. Louvian algorithm's assigned to community C mainly touristic and commercial agents, with an average age of 46.0±10.8 years; mostly of them came from Ansó valley. Community D included 4 actors, mostly farmers located in Hecho valley, with an average age of 44±9.9 years. Comparing community A to community D, which both included mostly farmers, results showed that the education level of the former was higher with respect to the latter. Probably this was due to the lower average age of actors belonged to community A.

Table 3: main features of each Louvian's communities identified

	A	B	C	D
Number of members	7	8	7	4
Age, mean years	30±8.7	46±13.5	46±10.8	44±9.9
Labour sector				
Farmer, %	100	13	29	75
Tourist and commercial agents, % of agents	0	25	57	25
Administrative and technician agents, % of agents	0	37	14	0
Others, % of agents	0	25	0	0
Education level				
Primary school, % of agents	0	13	29	25
Secondary school, % agents	14	0	0	50
High school, % of agents	29	13	14	0
Professional training course, % of agents	57	13	29	25
University, % of agents	0	63	29	0

Table 5 reported the results regarding the permutation test for one-way ANOVA in forming Louvian's communities. According to the figure 4, the factor which mostly contributed to the communities' formation was the labour sector. Also education level resulted to be significant in forming Louvian communities since may be partly associated with the labour sector. Indeed, previous results showed that most of the non-farmer's agents got a university degree whereas most of the farmers interrupted their studies after secondary school or they attended a professional training course.

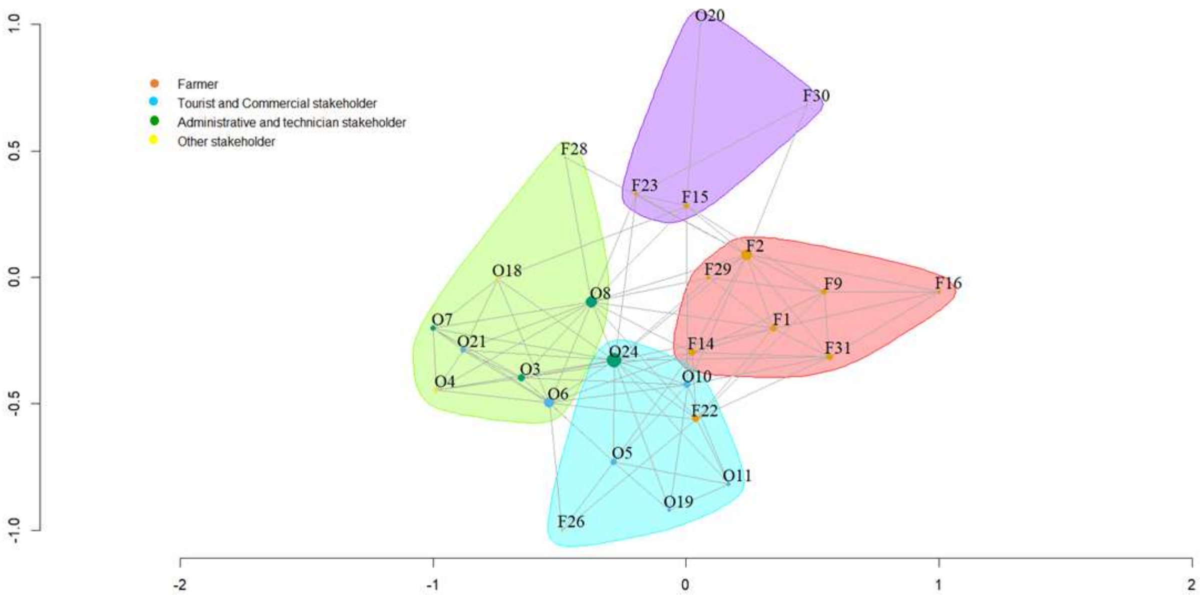

Figure 7: communities, referring to the trust network, identified by Louvian's algorithm. The four communities were identified with different colours: community A: red; community B: green; community C: blue; community D: purple; the different colours of the nodes highlight the different labour sector (modularity: 0.272).

Table 4: results of permutation test for one-way ANOVA in forming Louvian community.

Attribute	Df	R Sum Sq	R Mean Sq	Iter	Pr(Prob)	Significance
Labour sector						
Cluster	3	109.183	36.394	5000	< 2.2e-16	***
Residuals	26	87.784	3.376			
Education level						
Cluster	3	25.132	8.3772	5000	0.007	**
Residuals	26	39.168	1.5065			

3.2.3 ERGM

Table 6 reports the results of the final exponential random graph model (ERGM) concerning trust network. Indeed, the dataset created to build the advice network had NA data because it also included non-surveyed actors. Regarding the endogenous attributes, the statistical analysis showed that all of them shape the structure of the network. Indeed, all these factors were significant: density (edges), reciprocity (mutual) and GWESP showed a significance of $p<0.001$. The positive and significant values of reciprocity and GWESP showed as trust influence the network's structure as well as the presence of common exchange partners. Concerning the exogenous attributes, results showed that the labour sector 3 (which included the city hall and the rural development agents), the education level 4 (referred to high school), education level 5 (professional training course) and education level 6 (university)were positive and significant; these attributes influenced the network's structure. Indeed, the education levels 4, 5 and 6 as well as the labour sector 3 play an important role in shape trust network, e.g. the request of advice depending on confidence's level between local stakeholders. However, the significance for education level 4 and education level 6 was not so high ($p<0.01$ for education level 4 and $p<0.1$ for education level 6). Comparing endogenous and exogenous attributes, it is possible to point out that very external attributes influenced the exchange of advice between local stakeholders. The goodness of fit parameters, for both endogenous and exogenous attributes, of the model as well as the other models tested with the relative AIC were reported in Supplementary Material (Table S3, Figures S1 and Figure S2).

Table 5: estimate coefficients and standard error for the both endogenous and exogenous attributes referred to the final exponential random graph model.

	Estimate	St. Error	Significance
Endogenous attributes			
edges	-3.4642	0.2814	***
mutual	2.0841	0.3396	***
GWESP[1]	1.0879	0.2293	***
AIC[2]		566.0	
Exogenous attributes			
edges	-3.70217	0.35331	***
mutual	2.48034	0.30851	***
Education level 3[3]	0.29465	0.27862	
Education level 4[4]	0.74098	0.22689	**
Education level 5[5]	0.78245	0.21415	***
Education level 6[6]	0.6294	0.26354	*
Labour sector 2[7]	0.0876	0.1504	
Labour sector 3[8]	0.76397	0.20542	***
Labour sector 4[9]	-0.08281	0.30443	
AIC[2]	702.1		

1: GWESP: Geometrically-Weighted Edgewise Shared Partnerships; 2 AIC: Akaike Information Criterion; 3 Education level 3 referred to secondary school; 4 Education level 4 referred to high school; 5 Education level 5 referred to professional training course; 6 Education level 6 referred to university; 7 Labour sector 2 included touristic and commercial agents (even restaurateurs and accommodation providers); 7 Labour sector 3 included city hall and rural development agents; 8 Labour sector 4 included agents belonged to other work field.

4.0 Discussion

Our study aims to analyse the feasibility and the interest concerning the development of a beef quality brand in Hecho and Ansó valleys (Aragonese Pyrenees) through two participatory approaches: focus groups and SNA. Results showed that stakeholders were interested in the initiative since it could give an added value to the whole study area and it could create local development. The main outputs of

SNA evidenced that stakeholders were mutually linked and they trust each other which is fundamental for the success of collective action.

The focus groups revealed that all the local stakeholders were interested in the initiative with some similarities and dissimilarities between the three groups. Administrative and Technician stakeholders had a high perception concerning the role of livestock activity in maintaining high nature value landscape both from environmental and cultural perspective. Indeed, studies concerning people's perception of ES provided by mountain livestock activity, demonstrated that residents and non-residents in mountainous regions had a high consideration of landscape maintenance (Bernués et al., 2013; Leroy et al., 2018; Pachoud et al., 2020; Zoderer et al., 2019). However, during the discussion with farmers, which are the actors mainly engaged in livestock activity, they didn't mention the landscape maintenance as benefit provided by livestock activity as well as they had a scarce consideration regarding the beef production. Indeed, farmers thought that beef production in Hecho and Ansó valleys had not an added value with respect to neighbouring valleys or to beef production localized in the lowland areas. This was due to: i) use of concentrate feed produced in other valleys and/or regions; ii) slaughterhouse localized far from the valleys and usually in other regions, i.e. Navarra. Administrative and Technician stakeholders as well as Touristic and Commercial stakeholders agreed with farmers in using local concentrate feed. Indeed, extensive livestock systems are characterized by few off-farm inputs and by a local and a short supply chain, providing a series of associated products featured by high-quality and cultural identity. These characteristics increase the products' market value; several studies demonstrated the willingness of consumers to pay more for high-quality and healthy products (Mazzocchi et al., 2021; Ali and Ali, 2020; Meemken and Qaim, 2018; Profeta and Hamm, 2019). Indeed, the positive externalities provided by the mountain livestock farming systems increased the consumers' interest towards sustainable products (Mazzocchi and Sali, 2022) and the label framework is fundamental to inform consumers concerning quality and traceability of products (Stampa et al., 2020). The recent Farm to Fork Strategy (EU, 2020) established by the EU, is moving towards the consumer's awareness of high-quality and healthy products. Furthermore, a food labelling framework give added value to local products and contributes to the local development (Bentivoglio et al., 2019; McMorran et al., 2015). Since the initiative involved different local stakeholders and they were willing to collaborate with the neighbouring valleys, the development of collective brand should be taken into consideration. However, to accomplish this goal, it is important to proceed in certain steps, such as: i) to analyse the consumers' preferences as well as their consumption behaviour (Moran and Blair, 2021; Tabacco et al., 2021); ii) to highlight the strong relationships among livestock farming systems and mountain agroecosystems, focusing on environmental and cultural benefits provided (Santini et al., 2013; Sarti et al., 2018).

Finally, it is fundamental the collaboration and the cooperation among local stakeholders, which strongly depend on trustness (Perlik and Membretti, 2018; Pagliacci et al., 2022). For this reason, the development of the quality brand to differentiate the beef production of Ansó and Hecho valleys should be accompanied by a structured labelling framework which increase the consumer awareness. During the farmers' focus group emerged that they were reluctant in investing more time in livestock activity without the assurance of more revenue; indeed, Muñoz-Ulecia et al. (2021) showed that farmers were not willing to invest in livestock activity for long-medium income. For this reason, farmers proposed to start with few calves to test the feasibility and the success of the initiative.

Concerning the main features of the stakeholders' involved, results showed that actors who were employed in the administrative and/or technical sector, e.g., veterinary, or those who were employed in rural development sector as well as in commercial and touristic sector had a higher education level compared to farmers. However, the community A identified by Louvian's algorithm (figure 5), showed that mostly younger farmers did a professional training course. This was due probably to a greater opportunity to attend schools. Indeed, during the surveys, especially farmers, declared that the majority of high schools and universities are localized far from valleys and the lack of infrastructures, e.g. roads and transports, makes difficult to attend them; students have to move to the villages, towns or cities where schools are localized. Furthermore, the majority of stakeholders who had a higher level of education were used to live in cities, e.g. Zaragoza or Barcelona, and moved to the valleys.

Moving to farmers' features, we found that the average age was lower compared to other studies conducted in the neighbouring valleys (García-Martinéz et al., 2009; Muñoz-Ulecia et al., 2020); looking at Louvian's communities (figure 5) (which we will discuss better below), the 7 farmers belonged to community A, had a lower average age because: i) they moved from lowland areas, i.e. cities, and decided to start with livestock activity; ii) due to generational turnover issues. According to other studies, Teston et al. (2022) and Cocca et al. (2012), farmers had other employment in other sectors, such as services, industry or local shops since livestock activity didn't supply to their sustainment. Concerning the herd size and the grazing length we found, the former larger and the latter similar, compared to other studies conducted in Spanish Pyrenees, e.g. Aragonese and Catalan Pyrenees (Muñoz-Ulecia et al., 2021; Teston et al., 2020). Indeed, these type of livestock systems were mainly based on the use of communal pasture, shared by more than one farmer, i.e. collective pasture. Results reported in table 2 showed that the surface managed by the farms involved in this study referred mostly to communal pastures; farmers adopted extensive farming practices with the transhumance to highland pastures, i.e. communal pastures, during the favourable season (Fernández-Giménez and Ritten, 2020). During the surveys, farmers declared that they based their livestock activity mainly on communal pastures since they accessed to European subsidies. EU provides financial aids to farmers to maintain highland pastures since they are characterized by high nature value and deliver a series of benefits to human well-being, namely as ES (Liechti et al., 2018: Bernués et al., 2011).

Regarding the SNA, results showed that density, for both advice and trust network, had lower value compared to other studies concerning exchange of advice related to livestock activities and natural resources management (Angst et al., 2018; Wood et al., 2014) whereas reciprocity showed higher values with respect to other studies (Pachoud et al., 2019; Pachoud et al.,2020). Higher levels of reciprocity demonstrated that stakeholders trust each other and are mutually linked; indeed, figure 3 and Figures 4a and 4b showed no isolated nodes. This means that all the stakeholders were connected to each other and it is fundamental for the success of collective action, such as the development of the beef quality brand. Furthermore, reciprocity and density' values of trust network were higher with respect to advice network meaning that stakeholders surveyed had a clearer idea about the initiative; indeed, during the surveys, they stated that the quality brand could generate added value to local beef production and to the Ansó and Hecho valleys. Looking at Figures 4a and 4b, stakeholders were more connected: we noticed that the exchange of information were higher compared to advice network. This was probably because: i) stakeholders who accepted to do the survey had a clearer idea about the initiative since they took part to the focus groups and/or to other meeting concerning the initiative. For this reason, they considered the beef quality brand as an opportunity to create local development; ii) the trust network highlighted not only the exchange of information concerning the beef quality brand among the stakeholders surveyed but also the level of confidence among them.

Concerning the positional indicators, advice network and trust network differed for the in-degree centrality values: in the former, the prestigious member was the initiative promoter and in the latter the prestigious member was actor 24, i.e. a stakeholder working on rural development sector who organized the focus groups and the first meeting to introduce the initiative to stakeholders involved. However, concerning betwenness centrality, actor 24 was also in brokerage position in both advice in trust network; the local stakeholders her important role in managing the information flow concerning the initiative. Indeed, actor 24 was the rural development stakeholders who organized the first meeting and the focus group with the local stakeholders. The difference found for the prestigious actor was probably because: i) the advice network highlight only exchange of information concerning the initiative for both surveyed and no-surveyed actors; ii) trust network was based on exchange of information as well as on confidence's level. Indeed, looking at the trust level, the incoming edges (links) to actor 24, was thicker compared to incoming edges to actor 8; during the surveys, mostly stakeholders recognized actor 8 as idea's owner but they thought that the major contribution came from actor 24 because she was employed in rural development sector. Moreover, even actor 3 and actor 7 were characterized by high trust level: they were agents employed in administrative and technician sectors as well (the former in rural development sector and the latter in the Ansó city hall. Within the positional indicators, Louvian's algorithm identifies 4 communities within the trust network, grouping stakeholders with similar profile in terms of labour sector and education. Indeed, the permutation test for one-way ANOVA found these factors significant in forming Louvian's communities. People with similar interest and characteristics tend to form groups and/or to belong to the same community (Little, 2016; Wang et al., 2013). However, some studies, showed how interactions among stakeholders having different profiles favour the share of knowledge which is fundamental for the trust building and for the success of collective action (García-Nieto et al., 2019; Jungsberg et al., 2020). This means that although the algorithm had identified 4 communities, the level of interaction between individuals, despite having different characteristics and interests, was favourable to the development of the quality brand.

Finally, concerning the ERGM, endogenous attributes resulted to be significant; this means that the exchange of information as well as the trust among stakeholders played a central role in shaping the trust network. According to Cvetkovich and Winter (2003), the sharing of values and knowledge allow to build relationships thus the level of confidence among stakeholders. Young et al. (2016) found that trust is fundamental for actors' participation in collective action. Results regarding endogenous attributes showed that surveyed stakeholders, which were the actors mostly involved in the initiative, trust each other and this is decisive for the development of the beef quality brand. Regarding the external attributes, i.e. exogenous attributes, our analysis found out age, labour sector and education level as factors significant in affecting the trust network's structure. Except for the age, labour sector and education level were consistent with results of the one-way permutation test of ANOVA. Age, labour sector and education level influenced the exchange of information between stakeholders; however, education level could be considered as part of labour sector since descriptive data showed how actors, belonged to similar labour sector, tended to have even a similar education level. Anyway, results showed good levels of interactions and confidence among stakeholders within communities, which is decisive for the successful of an emergent initiative, especially in mountainous regions (Gretter et al., 2019). Endogenous attributes may be a good instrument to exchange of knowledge and ideas between different stakeholders, which could promote the initiative even among no-surveyed actors.

In general, we found out that the initiative had a great probability of success since stakeholders were interested in developing the beef quality brand. Moreover, both network as well as the statistical analysis showed that the level of confidence was good, meaning a positive developmental beginning.

However, it is missing a stakeholder who is able to coordinate the actors and the resources, which we found to be very few, involved in the initiative.

5.0 Conclusion

Our study revealed that a methodology based on participatory approaches, specifically focus groups and SNA, is useful to investigate the feasibility as well as the interest of local stakeholders concerning an emergent initiative, i.e. a quality brand to differentiate the beef products from Ansó and Hecho valleys. Moreover, through SNA we have been able to analyse the exchange of information as well as the level of confidence among the local stakeholders involved in the development of the initiative. During the focus groups, participants demonstrated interest in the initiative and they discussed concerning ideas and strategies to differentiate and to create a wider market for local beef production as well as to create added value to the whole supply chain. The focus groups were useful to investigate the real interest of the participants and thus the feasibility of the quality brand development.

Results concerning the SNA showed a good exchange of knowledge and/or information concerning the initiative as well as a good level of confidence among the stakeholders surveyed. SNA revealed that stakeholders belonged to the similar labour sectors and having a similar education level tended to relate more to each other. However, we found that trust and the presence of mutual relationships w, were the factors more affecting the trust network. Moreover, the communities found within the SNA were formed by local stakeholders belonging to different labour sectors and having different backgrounds. However, the level of interactions within communities were high promoting an exchange of knowledge among local stakeholders having different profiles, i.e. farmers, tourist and commercial stakeholders and administrative and technician stakeholders. the level of interactions between stakeholders were high within Louvian's communities, meaning an exchange of knowledge even between stakeholders belonged to different labour sector and having different backgrounds. This allowed to share ideas and information which could contribute to the development of the beef quality brand creating added value to the whole supply chain. Moreover, since we analysed even the advice network involving surveyed and no-surveyed actors, the stakeholders more engaged in the initiative could help in the involvement of the stakeholders lesser interested, i.e. who didn't participate in the interview.

However, we found two key limiting factors for the development of the brand. Firstly, that individual actors do not seem to be willing to compromise any private economic resources to the development of the brand, especially the farmers. Indeed, they have no assurance that the initiative will bring them more revenue, they are reluctant as they think they will have to spend more money and time on it but not obtain a higher profit. Secondly, that is no one playing a coordination role for the development of the initiative and no actor seem to be willing to play that role. This is a real handicap for the development of the brand as missing someone which manage the human, the economic and the bureaucratic resources. A possibility could be to apply for European and/or national funding, within the framework of rural development, to receive subsidies to support the local stakeholders, especially the farmers, in the resources involvement as well as to designate a coordinator, who can receive remuneration for his activities.

The focus groups as well as SNA revealed to be useful tools to assess the feasibility of an emergent initiative as well as to test the viability of its success. Indeed, despite the initiative is still to be develop, the discussions of the three focus groups detected the interest of the participants concerning the initiative. Moreover, the SNA showed good level of interactions, exchange of information and trust among local stakeholders which is fundamental for success of collective action, i.e. the development of the beef quality brand.

Our study represents an initial step for the development of the beef quality brand in Ansó and Hecho valleys; participatory processes, since they including different stakeholders, which are the main actors of local initiatives and local supply chains, should be further implemented to promote this initiative, enlarging the participation of relevant stakeholders and supporting them in their activities.

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Table S6:guidelines (including questions and aims) utilized to conduct the three focus group.

Focus group 1-city hall and rural development agents		
	Introduction	**Aims**
First part 10 minutes	To ask to each participants to sign a declaration of permission to take photos, to record the discussion and to sign the statement on respect for privacy. Brief presentation of the initiative and of the participants (including the moderator and the assistants). To ask to each participants the main positive features of the Valleys.	To create a relaxed atmosphere where everyone feels ease.
	Beef quality brand' development	**Aims**
Second part 20 minutes	What does beef quality mean for you? Which features differentiate the beef production in Hecho and Ansó valleys with respect to the other production systems located in other regions or in neighbouring valleys located in the Pyrenees? Which kind of benefits could provide the development of a beef quality brand? And which local stakeholders could benefit from such brand?	To identify the perception of the participants regarding the extensive beef production systems and the main features which differentiate it in the Hecho and Ansó valleys To know possible synergies related to the development of the beef quality brand related to the extensive traditional farming systems in the Hecho and Ansó valleys.
	Key factors contributing to the development of the beef quality brand	**Aims**
Third part-50 minutes	Do you know other similar initiatives? In the past, did you take part to other similar initiatives? For you, what were the main issues related to these past failure experiences? Do you think that farmers will be sufficiently organized and interested in the development of the beef quality brand?	To identify the main issues related to past failure experiences To identify the possible synergies between actors involved and possible strategies useful for the development of the quality brand To identify the main labour sectors and actors that could contribute

	Do you think that the restaurateurs and the accommodation providers as well as the touristic and the commercial agents could be interested in the development of the beef quality brand? Which kind of strategies could be adopting in the development of the beef quality brand? Which actors and labour sectors should actively take part in the development of the beef quality brand?	more to the development of the beef quality brand
Forth part-25 minutes	**Synergies and competitiveness of beef quality brand with other quality brand**	**Aims**
	Do you know the touristic label "Los Valles Tranquillos"? Which kinf of feauteres do you relate to this label? Do you think could be synergies between the development of the beef quality brand and the label "Los Valles Tranquillos"? Do you think could be create synergies between the development of the beef quality brand and the local breed Parda and Pirenaica? Do you think that the development of the beef quality brand could generate competitiveness with other beef quality brands of the Pyrenees?	To identify the main benefits and beneficiaries. related to the beef quality brand.
Fourth part-duration 5 minutes	Thank you for participating and ask if there are any topics that were not covered that should have been covered	To summarize the opinions collected during the discussions and conclude the discussion
Focus group 2-touristic and commercial agents (including restaurateurs and accommodation providers)		
First part 10 minutes	**Introduction**	**Aims**
	To ask to each participants to sign a declaration of permission	To create a relaxed atmosphere where everyone feels ease.

	to take photos, to record the discussion and to sign the statement on respect for privacy. Brief presentation of the initiative and of the participants (including the moderator and the assistants). To ask to each participants the main positive features of the Valleys.	
Second part 30 minutes	**Demand and consumption of local beef in the restaurants**	**Aims**
	Which features differentiate the beef production in Hecho and Ansó valleys with respect to other production systems located in other regions or in neighbouring valleys in the Pyrenees? Is there costumers' demand and consumption of local beef in the Hecho and Ansó valleys? What are the main common features of the costumers demanding for local products?	To identify the perception of the participants regarding the extensive beef production systems and the main features that differentiate this kind of production systems compared to other production systems located in the neighbouring valleys. To know if there is costumers' demand and consumption of local beef in Hecho and Ansó valleys. To know the general profile of costumers demanding local products
Third part-30 minutes	**Interest in the commercialization of beef quality brand**	**Aims**
	What potential could there be to market through bars, hotels, and restaurants local beef products of the valleys with a differentiated quality brand? Is there interest on the part of local shops to market local beef products with a differentiated quality brand? Which kind of products could have more interest for costumer?	To identify the main benefits given by the development of the quality brand for the touristic and commercial sectors (including restaurant and accommodations). To identify the costumers' local products demand (whether there is demand for local beef products, which type of beef products etc.)
Forth part-40 minutes	**Market chain for the beef quality brand**	**Aims**

	What kind of features should have the quality brand to be more competitive in the market? Do you think that the development of the beef quality brand could generate competitiveness with other beef quality brands of the Pyrenees? How the touristic and commercial sector (including restaurants and accommodations) could increase the market value of the beef quality brand? Which actors and labour sectors should actively take part in the development of the beef quality brand?	To identify the market chain of the beef quality brand To identify the main weaknesses and strengths related to the beef quality brand To identify the seasonality of the costumer's demand of local products To identify strategies to promote the beef quality brand
Fourth part-duration 5 minutes	Thank you for participating and ask if there are any topics that were not covered that should have been covered	To summarize the opinions collected during the discussions and conclude the discussion
Focus group 3-Farmers		
First part 10 minutes	**Introduction**	**Aims**
	To ask to each participants to sign a declaration of permission to take photos, to record the discussion and to sign the statement on respect for privacy. Brief presentation of the initiative and of the participants (including the moderator and the assistants). To ask to each participants the main positive features of the Valleys.	To create a relaxed atmosphere where everyone feels ease.
Second part 30 minutes	**Main characteristics of the management of the extensive farming systems in the Hecho and Ansó valleys**	**Aims**

	What does beef quality mean for you? How do you manage your farms and herds? What are the main characteristics related to the extensive livestock systems in Hecho and Ansó valleys? Which features differentiate the beef production in Hecho and Ansó valleys with respect to the other production systems located on other regions or in neighbouring valleys located in the Pyrenees?	To identify the main characteristics related to the management of the extensive beef farming systems in Hecho and Ansó valleys and the market chain related to the beef production. To identify the main features which differentiate the beef production in the Hecho and Ansó valleys.
Third part-20 minutes	**Benefits provided by the development of the quality brand and main characteristics related to the brand**	**Aims**
	Before this initiative, have you ever considered to develop a beef quality brand to differentiate the local products of Hecho and Ansó valleys? In your opinion, which kind of benefits might lead the development of a beef quality brand? What kind of features should have the quality brand to be more competitive in the market?	To identify the interest of farmer in developing the beef quality brand To identify the expectations of farmers related to the development of the beef quality brand
Forth part-60 minutes	**Main elements and factor which are needed to develop the brand**	**Aims**
	Do you think that the development of the beef quality brand requires a change in the production systems? Do you think that any issues could arise in the farmers' organization? Do you think that other local stakeholders should be included	To identify the main issues related to the development of the beef quality brand with reference to farmer's organization and in involving other local stakeholders To identify the possible change in the production systems related to the development of the beef quality brand

	in the development of the beef quality brand? Do you think that any issues could arise in including other local stakeholders? Do you think that any issues could arise in the commercialization of the beef quality brand? Do you think that some kind of technical, commercial and institutional support should be provided to be the brand more successful?	To identify the main issues related to the commercialization of the quality brand
Fourth part-duration 5 minutes	Thank you for participating and ask if there are any topics that were not covered that should have been covered	To summarize the opinions collected during the discussions and conclude the discussion

Table S7: information collected during the survey concerning the main features of actors and the relationships as well as the trust between actors to build the network. We also collected some general data regarding the main features of farms and surface managed.

Variable	Description	Unit	Standardization
Age		years	
Labour sector	Each actor was asked to which of the following labour sector they belonged: livestock activity, restaurants, accommodation, touristic, commerce, technician/veterinary service, administrative/public sector, other		To analyse the data, we associate to each labour sector a code
Education level	Each actor was asked to indicate what was the last level of education completed (no completed studies, primary school, secondary school, professional training course, university, other)		To analyse the data, we associate a code to each labour sector
Municipality of residence	Each actor was asked to indicate the municipality of residence		
Municipality of workplace and	Each actor was asked to indicate where the	km	

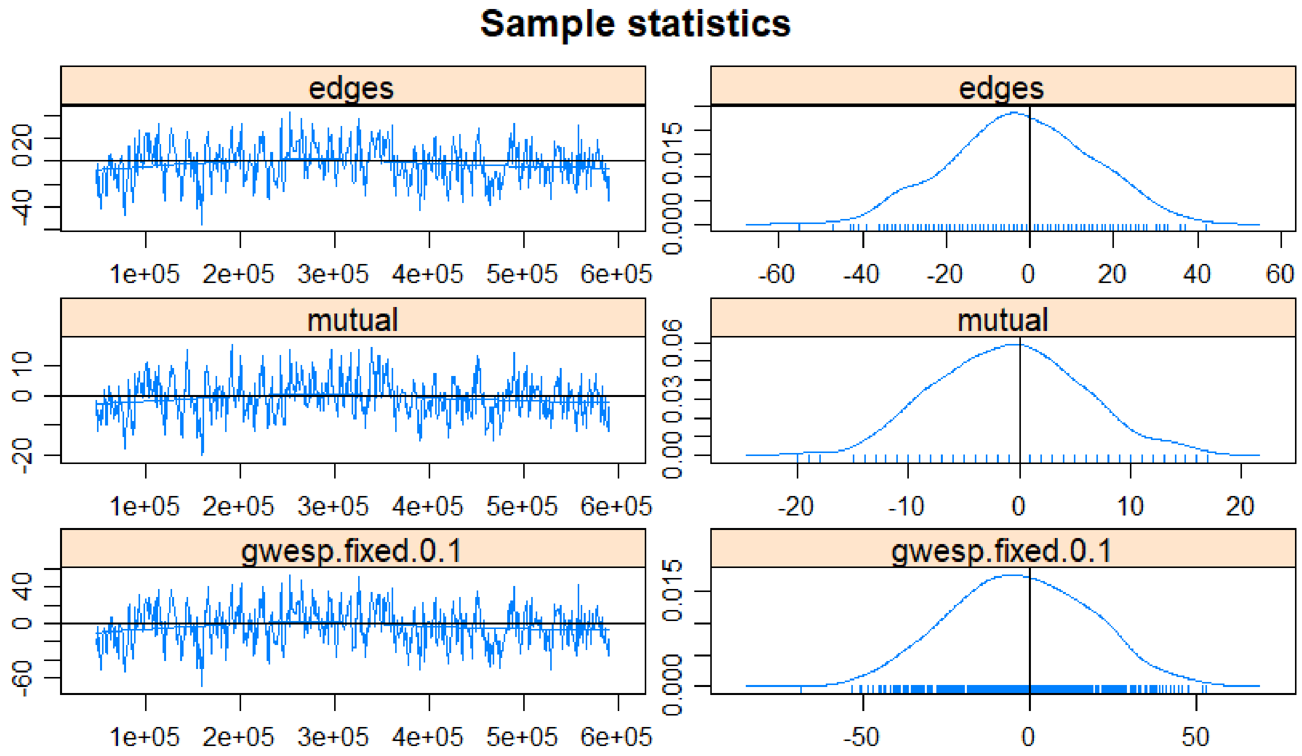
distance between the municipality of residence and the municipality of workplace	workplace is located and how far the workplace is from one’s residence		
Meeting attended concerning the beef quality brand	Each actor was asked to indicate the number of meeting attended in relation to the quality brand		
Data collection about the relationships between actors involved in the initiative	Each actor was asked to indicate to with whom of the list of actors we presented through the survey, they discussed about the initiative		To analyse the data and for privacy reasons, to each actor we assigned a code (for both surveyed actors and non-surveyed actors)
Data collection about the trust among actors surveyed	Each actors was asked to evaluate, on a scale from 0 (very low) to 10 (very high), how much each actor (with whom they discussed concerning the initiative) could contribute to the development of the beef quality brand.		To analyse the data and for privacy reasons, to each actor we assigned a code (for both actors surveyed and non-surveyed)
Considerations about possible conflicts between actors	Each actors was asked whether the development of the beef quality brand could bring to conflicts between actors involved and which type of conflicts might arise		
Only for farmers			
Variable	Description	Unit	Standardization
Other employment	Other employment besides the livestock activities	%	
Number of cattle		Number of heads	Livestock Unit (LU)=1
Number of calves sold		Number of heads	Livestock Unit (LU)=0.4
Grazing length		Months	
Owned land	Including pastures, meadows and crop land	ha	
Rented land	Including pastures, meadows and crop land	ha	
Communal pastures	Municipal pastures, mostly grazed during the summer and shared with other farmers	ha	

Table S8: models carried out in order to select the best final model with lowest Akaike Information Criterion (AIC).

		Estimate	St. Error	Significance
Model 1- exogenous attributes included education level and labour sector (best final model)	Edges	-3.70217	0.35331	***
	Mutual	2.48034	0.30851	***
	Education level 3[1]	0.29465	0.27862	
	Education level 4[2]	0.74098	0.22689	**
	Education level 5[3]	0.78245	0.21415	***
	Education level 6[4]	0.6294	0.26354	*
	Labour sector 2[5]	0.0876	0.1504	
	Labour sector 3[6]	0.76397	0.20542	***
	Labour sector 4[7]	-0.08281	0.30443	
	AIC[8]	702.1		
Model 2-exogenous attributes included education level, labour sector and age	Edges	-3.567713	0.791372	***
	Mutual	2.483205	0.315063	***
	Education level 3[1]	0.294004	0.296132	
	Education level 4[2]	0.723151	0.265426	**
	Education level 5[3]	0.751708	0.269001	**
	Education level 6[4]	0.599268	0.329694	.
	Labour sector 2[5]	0.112347	0.189509	
	Labour sector 3[6]	0.776864	0.24019	**
	Labour sector 4[7]	-0.051388	0.317116	
	Age	-0.00145	0.006489	
	AIC[8]	703.3		
Model 3-exogenous attributes included labour sector and age	Edges	-1.2450	0.3016	***
	Mutual	2.48145	0.31742	***
	Labour sector 2[5]	0.545048	0.17278	**
	Labour sector 3[6]	-0.3114	0.4359	
	Labour sector 4[7]	-0.4536	0.2857	
	Age	-0.3563	0.2489	
	AIC[8]	648.6		
Model 4-exogenous attributes included valley and labour sector	Edges	-4.361357	0.675984	***
	Mutual	2.599917	0.298806	***
	Education level 3[1]	0.401806	0.260843	
	Education level 4[2]	0.834494	0.231727	***
	Education level 5[3]	1.006538	0.223996	***
	Education level 6[4]	1.089974	0.209225	***
	Age	0.00605	0.005214	
	AIC[8]	719.7		

1 Education level 3 referred to secondary school; 2 Education level 4 referred to high school; 3 Education level 5 referred to professional training course; 4 Education level 6 referred to university; 5 Labour sector 2 included touristic and commercial agents (even restaurateurs and accommodation providers); 6 Labour sector 3 included city hall and rural development agents; 7 Labour sector 4 included agents belonged to other work field; 8 AIC: Akaike Information Criterion;

Figure S8a and S1b: sample statistics related and goodness of fit model, related to the endogenous attributes, for edges, mutual and Geometrically-Weighted Edgewise Shared Partnerships (GWESP).



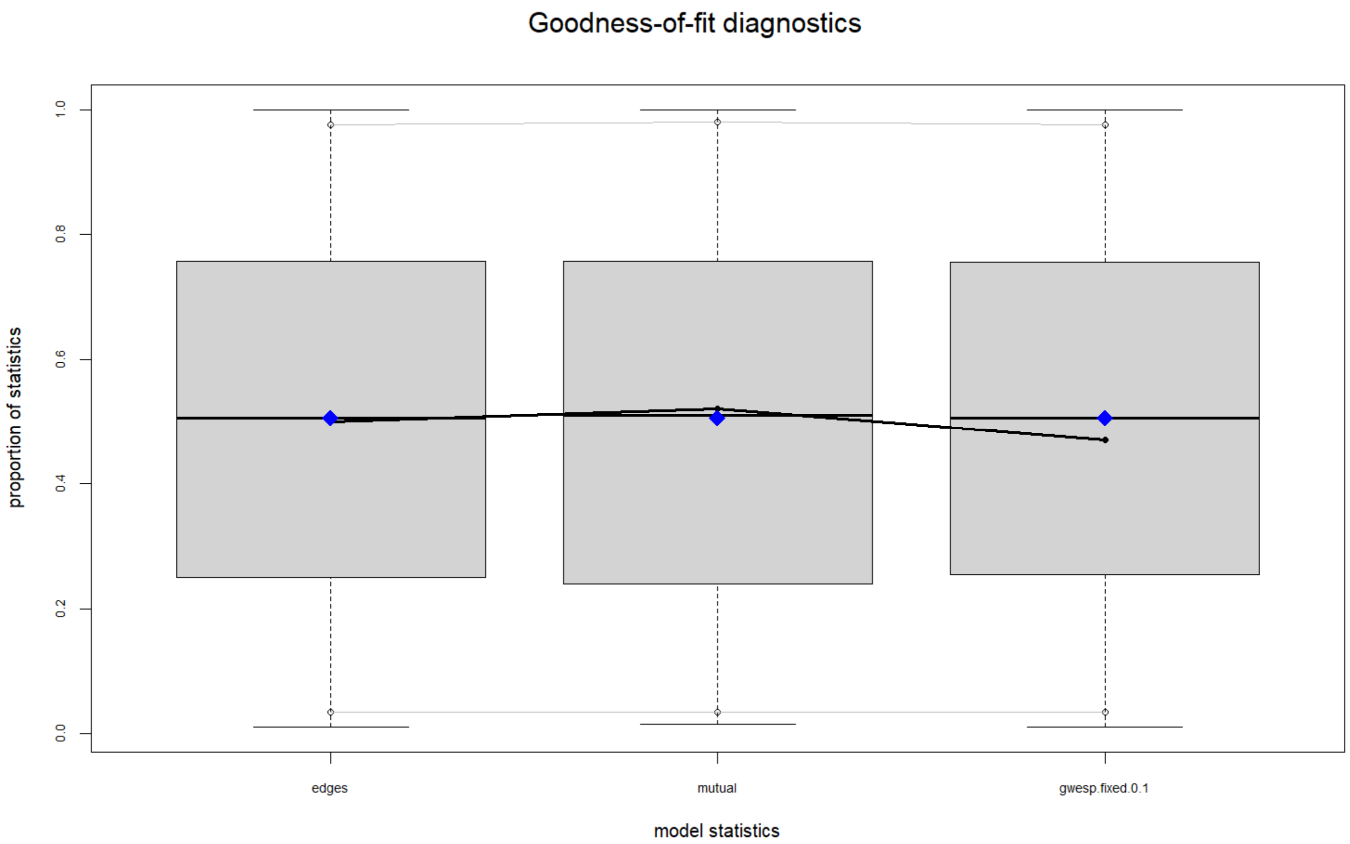
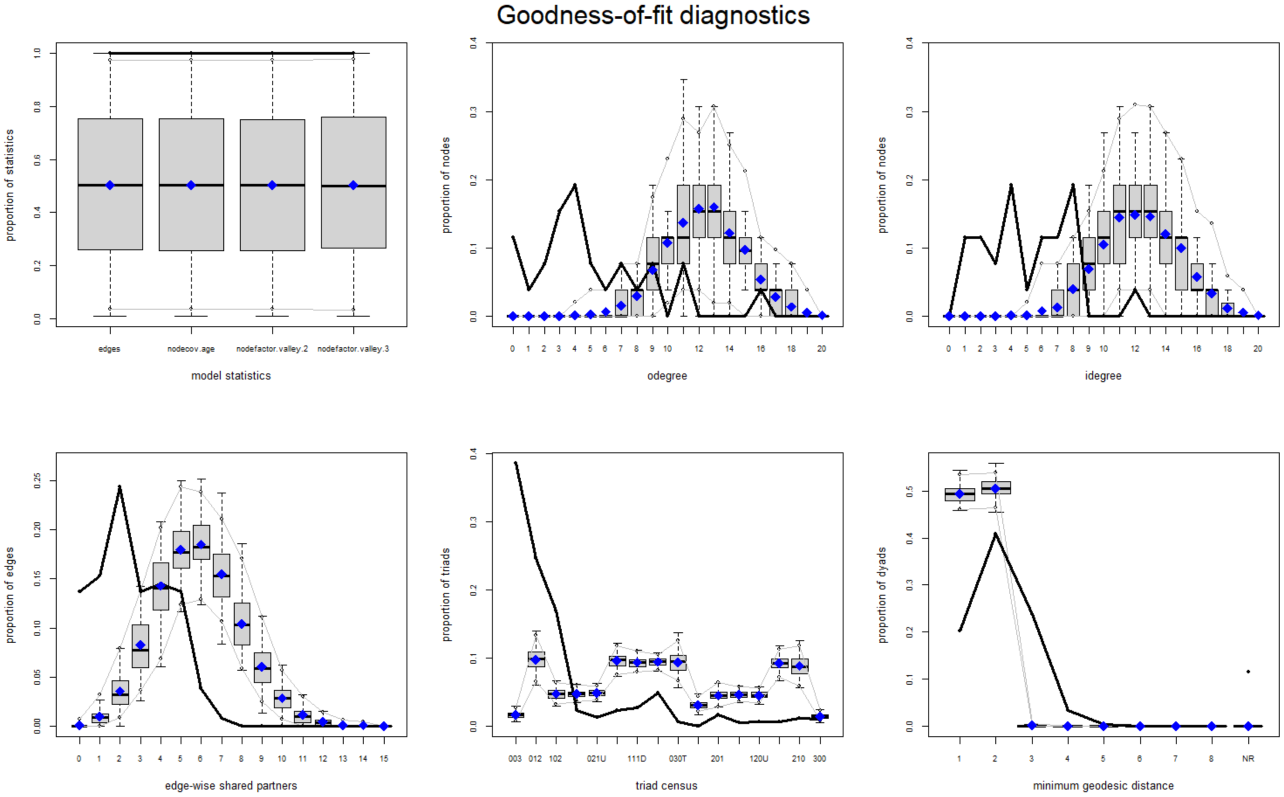


Figure S9: Goodness of fit of the final statistical model, related to exogenous attributes, for indegree, outdegree, edgewise shared partners, triad census and minimum geodesic distance parameters of the directed trust network among the actors surveyed and involved in the initiatives (farmers and non-farmers). AIC=702.1



6 General discussion

The aim of this thesis was to analyse different strategies to create added value to mountain livestock farming systems in order to contrast their abandonment and the associated rural depopulation. Three different mountain regions were considered: the Catalan Pyrenees, the Italian Eastern Alps and the Aragonese Pyrenees. Specifically, the first contribution highlighted the strong relationships between extensive beef production and mountain agroecosystems in the Catalan Pyrenees. Moreover, results showed that the livestock systems analysed were characterized by very few off-farm inputs and by low feed-food competition. Concerning the second contribution, results showed that farmers contributed to local sheep breed conservation. Indeed, through a correct management of mating plans and collaboration among smallholders, they contrast the risk of inbreeding of endangered local sheep breeds. Moreover, the contribution underlined the important role of small ruminants in maintaining mosaic landscape. Finally, the third contribution aimed to test the feasibility concerning the development of an emergent initiative, i.e. a beef quality brand, through a methodological approach based on participatory processes. Results showed that the initiative had good probability of success since local stakeholders have shown interest. Moreover, both advice and trust network showed that there were a good exchange of opinions and information among stakeholders as well a good level confidence.

6.1 Participatory approach methodology as tool to create added value to mountain LFS

The three contribution reported in this thesis adopted participatory processes approach. Farmers are the main actors involved in LFS and their contribution is fundamental to create added value to their activities and, more in general, to mountainous regions. Whereas for the first and the second contributions only farmers were surveyed, for the third one other local stakeholders were involved.
Specifically, the first contribution underlined the positive externalities provided at farms levels considering both the surface managed and environmental impacts. As the title suggested, including only organic beef farms, the aim was to highlight the strong link between them and the mountain agroecosystems. Even for the second contribution, only farmers were surveyed, focusing on: i) the role of small ruminants and of the associated farming activity in maintaining a mosaic landscape; ii) the role of farmers in conserving endangered local sheep breeds. However, the project concerning paper II even provided a SWOT analysis and meetings with farmers and other stakeholders with the specific aims to favour the collaboration between them and to create a wider market for local products.
Finally, the participatory approaches adopted for the third contribution concerned focus groups and surveys, with the specific aim to test the feasibility as well as the interest related to an emergent initiative in the Aragonese Pyrenees. Focus groups as well as surveys involved local stakeholders with different profiles: farmers, administrative and technician stakeholders, rural development stakeholders, commercial and touristic stakeholders.
Some studies, i.e. García-Nieto et al. (2019) and Jungsberg et al. (2020), showed how initiatives involving stakeholders with different backgrounds could enhance the development of common projects, i.e. the development of a beef quality brand in the Aragonese Pyrenees, as well as could contribute to better management of natural resources, i.e. the conservation of local sheep breed in Italian Eastern Alps.

6.2 The strategies founded to create added value to mountain LFS

Paper I focused on the positive externalities related to organic beef production in the Catalan Pyrenees. The study underlined that the farms involved in the study were able to manage a large surface of pastures and meadows, overall highlands pasture, mostly of them are classified as HNVF. Animals' grazing as well as farming activity allowed to maintain pastures and meadows, delivering a series of ES to residents and no-residents (Schirpke et al., 2019; Rodríguez-Ortega et al., 2018). Indeed, results showed that farms adopted mainly extensive farming practices, based on use of local natural resources, with very few external inputs; these allowed to maintain the HNVF, the associated biodiversity and a cultural landscape (Bernués et al., 2011; Varela et al., 2022). Even the assessment of environmental impacts showed that there was a balance between beef production and mountain agroecosystems resources. Indeed, results showed that the GWP and AP emissions were mainly related to on-farm stages; this means that farmers mostly used local natural resources. Farms involved in this research were self-sufficient demonstrating an almost close cycle between off-farm and on-farm inputs. The evaluation of energy efficiency showed a very low feed-food competition: the animals were able to transform the no-human edible feeds into high-quality beef products. Results suggested that the added value of these LFS was their multifunctional nature: i) the environmental impacts were more related to on-farms stages, with very off-farms inputs, showing a balance between beef production and mountain agroecosystems resources; ii) the farms showed a low feed-food competition; iii) extensive farming practices as well as the animals' grazing allowed to maintain pastures and meadows and the associated ES, contributing to human well-being.

Moving to paper II, results underlined the important role of small ruminants in maintaining a mosaic landscape, which are important both from an environmental and cultural perspective. According to the research conducted in the Catalan Pyrenees (paper I) and to other studies conducted in other countries (Faccioni et al., 2019; Zuliani et al., 2021; Negi et al., 2018), mountain LFS are featured by a strong relationship with mountain agroecosystems, which can be considered as bi-directional. Indeed, mountain agroecosystems provided food, i.e. forage resources of pasture and meadows, to animals; on the other hand, mountain agroecosystems and the related ES are maintained by livestock activities and by animals' grazing. However, the main differences among paper I and paper II were related to the mountain agroecosystems managed: the former were characterized by larger surface and accessibility compared to the latter. Indeed, while paper I involved cattle and calves, paper II concerned small ruminants, which are able to graze pastures located in marginal and steep areas characterized by reduced accessibility, small areas, high slope and limited forage resources (Hutchinson, 2019). The project Sheep Al.L. Chain (contribution II), underlined not only the important role of local sheep breeds in maintaining a mosaic landscape but even the important role of farmers' activity in conserve endangered local sheep breeds. Results of paper II showed a great genetic variability due to a correct management of mating plans by farmers involved; according to Gicquel et al. (2019) and to Pilling et al. (2020), farmers play an important role in conserve endangered local breeds. Perucho et al. (2020) showed that breeding schemes could be an important tool for farmers to contrast the inbreeding since they contribute to genetic diversity. Within the project Sheep Al.L. Chain, a smartphone application was developed with the specific aim to further support farmers during the mating plans favouring the collaboration between them. Indeed, since each farmer could report the main information and characteristics about their herds, including the code of rams, during the mating plans they could select the most genetically distant ram. Moreover, the smartphone application was developed even to increase the value of this farms and the associated products recognising the important benefits that they provided. Each farmer could update farm's characteristics and information, such as their products, other activities, e.g. agritourism, surfaces managed etc. According to the Farm to Fork Strategy (EU, 2020), a sustainable labelling framework, covering not only nutritional values but even environmental aspects, should be adopted to increase the consumer's awareness for healthy and high-quality products. Moreover, as suggested by Poux and Pointereau (2014), a label framework supported by territory images could increase products' value. As reported in the paper, within the project, a SWOT analysis was also carried out involving different local stakeholders; this analysis was useful to: i) assess the main positive and negative aspects related to the potential conversion to organic farming of Alpagota breed; ii) find new potential marketing strategies. Indeed, Stampa et al. (2020) found that a large group of consumers' showed a high perception concerning the environmental benefits derived from pasture-based LFS and a willingness to pay more for the associated products.

Finally, concerning the contribution III, a participatory approach methodology was adopted to analyse the feasibility as well as the interest related to an emergent initiative in the Aragonese Pyrenees. The initiative regarded the development of a beef quality brand which aims to differentiate the beef production in two mountain valleys, Hecho and Ansó, both located in province of Huesca. While the paper II aimed to find different marketing strategies to give added value to the whole supply chain of two local breeds, the initiative of paper III aimed to find strategies to differentiate the beef production in Ansó and Hecho valleys in order develop a quality brand. Both focus groups and SNA have proven to be good methodological approaches to analyse the feasibility and to estimate the possibilities of success related to the beef's quality brand development. The focus groups revealed that local stakeholders participating in the discussion were interested in the initiative. Indeed, they focused not only on the difficulties related to the beef production and on the potential threats concerning the development of the quality brand but even they found out strategies to differentiate the beef production in Hecho and Ansó valleys. Results regarding the SNA showed, both for advice and trust network, high values of reciprocity, meaning that the stakeholders involved in the initiative trust each other and are mutually linked. Even the statistical analysis of the trust network, i.e. ERGM, proved significant and positive values of the endogenous attributes; edges (density), mutual (reciprocity) and GWESP were the main factors shaping the network' structure. Trust and the presence of common exchange partners played an important role in information exchange among stakeholders, which influenced the network's structure. Several studies demonstrated that the success of collective action and common projects, such as natural resources management and/or collaborative and inclusive projects, strongly depend on trust and on the presence of mutual exchange advice (Koch et al., 2022; Reed et al., 2014; Fischer et al., 2019; Nohrstedt and Bodin, 2020). Concerning exogenous attributes, the factors affecting the information exchange were labour sector, education level and age. However, their significances were lower with respect to exogenous attributes. Finally, moving to communities identified by Louvian's algorithm within the trust network, results showed that stakeholders tended to belong to the same group according to their labour sector and to education level. The latter could be considered part of the former; indeed, descriptive data showed that mostly of the stakeholders employed in similar working fields had the same education level. Anyway, despite the communities identified, information's exchange within communities was good, which allowed an exchange of knowledge between actors having different background and belonging to different labour sector. According to García-Nieto et al. (2019) the share of knowledge among stakeholders with different profiles is fundamental to the success of collective action.

6.3 Research limitations and how to improve future studies

In this section the limitations of the methodological approaches are discussed.
Results of paper I assessed indirectly the contribution of sustainability of the farms involved in the study; we considered 8 farms, which were representative of the study area. A larger sample of farms could improve the results concerning the sustainability as well as could provide a wider perspective of their benefits. However, our results can be considered as guidelines for further investigations or can serve as indications even for conventional mountain LFS.
Results of paper II represented an initial step to improve the competitiveness of local sheep breed. Indeed, the SWOT analysis was conducted to analyse the positive and negative aspects deriving from the potential conversion to organic farming only for Alpagota breed. The project included only Alpagota and Lamon breeds: a new project, Sheep Up, started in 2020, which could be considered as a continuum of Sheep Al.L. Chain project, involve even Foza and Brogna breeds, classified as endangered in the Farm Animals Diversity Information System (DAD-IS, http://www.fao.org/dad-is/en). The Sheep Up project aimed even to implement the smartphone application, developed within the Sheep Al.L. Chain project, including farms' information raising Foza and Brogna breeds as well as their genetic information. Moreover, Sheep Up project provide other participatory approaches, such us focus group, involving local stakeholders having different profiles, with the objective to find strategies to create innovative economic models.
Concerning paper III, the results, especially those related to the SNA, represented an example of application concerning participatory approaches as methodology to test the feasibility as well as to analyse the possibility of success related to the development of an emergent initiative. The main limitations of this study were due to: i) Not Available (NA) data related to the no-surveyed actors; ii) the question to assess the trust among surveyed actors which could be subjected by judgments. Indeed, since we found a gap in literature related to participatory approaches as methodology to analyse the viability of an emergent initiative, we cannot directly compare our results with other studies. However, since the initiative is still to be developed, the advice network and the trust network should be considered as preliminary steps to analyse respectively: i) the exchange of information and opinions among local stakeholders concerning the beef quality brand; ii) the level of confidence among a part of them (surveyed local stakeholders). Since collective actions depend on interactions among actors as well as on the trust among them, our results can be considered as an initial support tool for the beef quality brand development, filling any gaps and looking for strategies to involve the less interested stakeholders.

7 Conclusions

This thesis provided new insights concerning strategies to generate added value to mountain LFS. Using a methodology based on participatory processes, local initiatives were analysed to generate added value to local supply chains that would otherwise be marginalised. Specifically, farmers and other stakeholders were involved to identify strategies to create added value as well as local development. From the results related to the three studies, the following findings can be drawn:

a) Mountain LFS and mountain agroecosystems are featured by a strong relationship, which could be considered as bi-directional. Indeed, the extensive farming practices and animal's grazing allowed to maintain pasture and meadows and the associated ES; on the other hand, mountain agroecosystems provided food and fibres for animals. The ES concerned mainly the forest-fire prevention, nutrient cycle, water regulation, food, raw materials and fibres production etc. Moreover, since mountain LFS are mainly based on traditional extensive farming practices, they even allowed to preserve cultural heritage, traditions and mosaic landscape, overall those involved small ruminants.
b) he farmers play a fundamental role in conserving endangered local breeds and local resources. The cooperation is fundamental to strength this role
c) The collaboration and cooperation between different local stakeholders enables the exchange of opinions and ideas in order to find synergies and strategies to develop new initiatives such as the beef quality brand in Aragonese Pyrenees. Indeed, a methodology based on participatory approaches seems to be a valuable tool to test the feasibility as well as the probability of success of an emergent initiative.

The positive externalities identified should be considered as strategies to generate added value to mountain LFS. Since they are characterized by high multifuncionality, a diversification of farming activities as well as initiatives involving different local stakeholders could be valuable solutions to contrast the rural depopulation, providing new opportunities to young people, both from employment and recreational perspectives.

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Dissemination activities apart from journal contributions

1. Teston M., Benedetti Del Rio E., Cei L., Gatto P., Defrancesco E., Sturaro E. Sheep farming systems in Italian Eastern Alps and their relationships with agroecosystems. In: *Book of Abstracts of the 72nd Annual Meeting of the European Federation of Animal Science.* Davos (Switzerland), 30th August 2021-3rd September 2021.
2. Teston M., Karatzia M.A., Ligda C., Tsiokos D., Santos L., Sturaro E. From local to global perspective: an integrated approach to analyse initiatives for sustainable development of livestock farming systems in mountain areas. In: IMC Congress, oral communication. Accepted. Despite the congress has already taken place, the Book of Abstract has not been puslished yet. Innsbruck 11th September-15th September 2022.
3. Benedetti Del Rio E., Teston M., Cei L., Defrancesco E., Gatto P. Sustainable use of local sheep breeds in Eastern Alps. In: ASPA 24th Congress Book of Abstract. Padova (Italy), 21st-24th September 2021.
4. Benedetti del Rio, E., Teston, M., Ramanzin, M., Sturaro, E. (2022). Fatty acid profile of meat and milk of local sheep breeds in Italian Eastern Alps. In: *Book of Abstracts of the 73rd Annual Meeting of the European Federation of Animal Science.* Porto, Portugal, 5-9 September 2022
5. Sturaro E., Pachoud C., Teston M., Taufer W. Relazioni tra servizi ecosistemici legati agli alpeggi estivi e prodotti di malga. Un processo partecipato per il coinvolgimento degli stakeholder e per la valutazione della percezione dei turisti**"** in *"Quaderni del Parco 17-SmartAlp: un progetto per valorizzare il sistema alpicolturale"* book. Ente Parco Paneveggio Pale di San Martino, 2022.