LIFE PASTORALP

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Pastures vulnerability and adaptation strategies to climate change impacts in the Alps

Deliverable D.2

Report on actions for the evaluation of socio-economic impact on the local economy

March, 2023

Action D.2 Monitoring and evaluation of the project socio-economic impact on the local economy and population

Beneficiary responsible for implementation: INRAe

Responsibilities in case several beneficiaries are implicated: ARPA, IAR, PNGP and PNE will cooperate in reporting the results of the monitoring and evaluation

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1 Introduction

The purpose of action D.2 is to define and describe the methodology for assessing the socio-economic impact of the Pastoralp project on the local economy. The Pastoralp project focused on biophysical data (floristic census, models of pasture productivity, climate scenarios) and on studies of human behaviour (based on stakeholder perception and knowledge). The project main aim is to raise awareness about the potential impact of climate changes on local agropastoral systems and to devise appropriate management options able to facilitate the adaptation of the grazing system to expected changes in quality and quantity of grass biomass.

Measuring the impact of a project on the local economy has to deal with several issues. In the case of the Pastoralp project, two main aspects need to be considered: 'counter factual' and the time range over which the project may have socioeconomic impacts. The former refers to the possibility to actually link a measured impact on the territory (e.g. reduction of unemployment) with the project. That aspect requires assumptions about what would have happened without the project to be able to discern the impacts of the project from the impacts related to any other driver. The latter relates to the feasibility to measure impacts that very often accrue over several years following different pathways. To assess the project impact, an analytical framework was therefore developed to identify the main factors at play, the different drivers influencing the system, and the variables and features of the pastoral socioecological system that could be affected.

As a first step, a list of socio-economic indicators that could theoretically be used to assess impacts on pastoral areas was devised. The set of indicators was employed and adapted to the available data to perform a socio-economic monitoring test in the project area. The test was intended to provide an example of the development of feasible variables and indicators able to monitor relevant socioeconomic aspects. The Gran Paradiso National Park (PNGP) area was selected as a test area. The selection was based on the accessibility of data (e.g. the scale of the national census data), which is usually more limited in Italy than in France. The test of the monitoring procedure was therefore carried out to outline an approach that was as feasible as possible in both case study areas. Throughout the project, a stakeholder-based activity was also carried-out to identify the relevant factors driving to change of practices and management and in particular how the adaptation strategies suggested by the project could affect the local pastoral agroecosystem. The procedure provides an illustration and validation of a method, knowing that evaluating all impacts on all socio-economic domains is a formidable endeavour.

The report of deliverable D.2 is organised as follows. Section 2 summarises the state of the art on agropastoral systems as a socioecological system and outlines the rationale for the proposed socioeconomic monitoring approach. Section 3 describes the methodology and data collection process employed for testing the socioeconomic monitoring. Section 4 describes the results of the monitoring and Section 5 concludes the report.

2 State of the art: Mountain as a peculiar socio-ecological system

Mountain pastoral systems in the Alps have changed and adapted to the important socioeconomic dynamics that have affected alpine regions. Indeed, in the second half of the 20th century, economic development, technological innovations in the agricultural sector and the Common Agricultural Policy have all concurred to reduce the competitiveness of the agricultural sector in marginal areas compared to areas with intensive agriculture. On the other hand, alternative employment opportunities have been disclosed for mountain populations. These dynamics have led to an ageing population, emigration and/or shift from agriculture activities to industry or the tertiary sector (mainly tourism) and has had profound effects on the mountain socioecological systems. These effects have changed the structure of the landscape, and affected the culture, traditions and human capital in general in many mountain areas. These trends have been documented across Europe where the abandonment of grassland management has been linked to the general depopulation of marginal lands and the indirect effects of the Common Agricultural Policy, which has privileged agricultural activity on more fertile and accessible land (MacDonald et al. 2000). The impacts of the Pastoralp project, which aim at boosting the adaptation capacity of the pastoral systems to climate changes, cannot therefore be assessed without considering both biophysical and socioeconomic factors on the one hand, and quantitative and qualitative aspects on the other. Indeed, farmers' vulnerability depends not only on their exposure to increasing problematic climatic events, but also on the environmental and social characteristics that modulate the impact of anomalous weather events (Bhatt et al. 2021). The socioeconomic impacts of the Pastoralp project are therefore to be considered embracing the range of different dynamics affecting the mountain socioecological system to understand how and under which circumstances the project is able to enhance the adaptation capacity of the agricultural sector. In this context, recurrent questions that emerge regard the extent to which mountain farmers are prepared to adapt their farming practices, the factors affecting their vulnerability and the role that policy interventions play in helping, or harming, such adaptation capacities.

Mountain social-ecological systems in the Mediterranean region are complex due to their high biological and cultural diversity, as well as interlinkages with other downstream social-ecological systems (Debolini et al., 2018). The complexity of these ecosystems refers to both constraining features such as accessibility, marginality and fragility, and enabling features such as diversity, niche and human adaptive capacity (Jodha 1992). Taking into account such complexity, approaches to understanding and measuring the nature and magnitude of expected impacts of climate changes are commonly framed as vulnerability analyses. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which a system is susceptible to adverse effects of climate variability and extremes (Smit and Wandel, 2006). As informed by Ribot (2009), the IPCC framework for vulnerability analysis builds on both the risk factor approach and the livelihood approaches. The former focuses more on examining the biophysical impacts of a climatic event, whereas the latter situates vulnerability in the broader context of the socioeconomic fabric. The vulnerability of socio-ecological systems is thus a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity to such changes, and its adaptive capacity (Brodnig and Prasad, 2010). Exposure is defined as "the nature and degree to which a system is exposed to significant climatic variations" and sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (Adger, 2006). Adaptive capacity concerns the ability of a socio-ecological system to moderate potential impacts related to climate changes (including climate variability and extremes) and the aptitude to adjust to take advantage of opportunities, or to cope with the consequences. Accordingly, climate changes events are expected to affect a range of socio-economic and environmental aspects that characterise an agricultural system, calling for the consideration of different socio-ecological aspects in the assessment of farmers' vulnerability (Eakin et al. 2011). These aspects include the impacts of climate changes on productivity and revenue, but also effects concerning the role of agri-environmental policies and technical support, the ability to adapt practices to contingencies, and farmers' perception and awareness.

A wide range of issues may concur to exacerbate or reduce the sensitivity of the pastoral system (Huber et al. 2013). For instance, the vulnerability of pastoral systems is often related to their rate of dependence on climate-sensitive resources such as semi-natural grassland resources. Thus, alpine grazing systems are expected to be more strongly affected compared to systems based on external inputs (Marshall et al. 2014). However, strong links to semi-natural resources also imply more indirect effects on experience, awareness and tradition to adapt to the fluctuation of forage resources, which increases long-term adaptive capacity (Maru et al. 2014). In this context, local environmental knowledge is considered a keystone of adaptation strategies, as it improves farmers' efficiency abilities to act within a known environment and respond to environmental feedbacks (Berkes, Colding and Folke 2000).

It becomes obvious that grassland conditions play an important role in affecting mountain pastures, as they are strictly connected with changes in pastoral management (Dibari et al. 2016). Climate changes are expected to be a relevant driver of pastoral resources and their management, but these impacts overlap with the range of land-use modifications associated to depopulation and the development of other economic activities described above. Nevertheless, recent research has shown that dynamics in the Alps are far more nuanced and that the simple isolation-abandonment relation does not help to design more effective agricultural policies (Hinojosa et al. 2016a). Studies on the vulnerability of agriculture in mountain regions have tried to capture the complexity of mountain social-ecological systems (e.g. Adger 2006, Petit et al. 2015). Several approaches and methods have been implemented to identify and estimate indicators of vulnerability and adaptive capacity, either based on case-study approaches or using models applied to the national scale (see, for instance, Polsky et al. 2003, Brooks et al. 2005). However, despite all the progress made, there is still wide room/need to find the right fit in applying frameworks and methods to specific regions (Acosta-Michlik 2008, Eakin and Patt 2011). Vulnerability is a feature of social-ecological systems that is complicated to assess with an objective "yardstick" and requires the development of a methodology able to include qualitative and quantitative data in a common analytical framework (Metzger et al. 2006). Some authors even argue that vulnerability, in principle, cannot actually be measured (Hinkel, 2011). Over the last decade, advancements have been made in understanding the vulnerability and response of social-ecological systems in the face of climate changes and natural phenomena. However, assessing whether the delivery of tools able to support the adaptation capacity of local resource-based systems is able to counterbalance their higher sensitivity remains a practical challenge (Berrouet, Machado and Villegas-Palacio, 2018). Such an analysis requires a methodological framework that explicitly addresses the range of feed-back and feed-forward processes that are potentially triggered by the range of drivers affecting a pastoral system. In other words, a methodological approach capable to embrace the complexity of socio-ecological systems is necessary (Norberg and Cumming, 2008). This complexity is mainly due to the assessment of how some socio-economic characteristics drive the ability of farmers to buffer shocks, to adapt by introducing novelty without changing the production system, or to transform the system through implementing radical changes (among which the abandonment of pastoral activities) (Tuvendal & Elmqvist, 2012). Reliable monitoring of Pastoralp's impacts thus relies on the development of a methodological approach based on an analytical framework that is able to describe the current dynamics and, at the same time, to support hypotheses about the future impacts of the project on the territory.

3 Methodology

The project Pastoralp focuses on mountain pastures in two protected areas: the Gran Paradiso National Park in Italy and the Écrins National Park in France. These parks were chosen because they are representative of western Alpine environments and because the possible impacts of climate change on pastoralism have already been partially studied in these areas. In addition, these parks are considered "open laboratories" because they allow for the testing of land-use planning and sustainability strategies. However, from an impact assessment perspective, the diversity of systems covered by these two parks is huge: in the PNGP, it is a dairy cattle system on private property, with arrangements for livestock management, processing of raw materials and accommodation of breeders, while in the PNE it is a sheep and meat on communal properties with little development. More specifically, in the PNE, the dominant system is sheep, even if there are some cattle, goats and horses. Pastures represent 40% of the park's surface and are widely used by breeders. The pastures are used by farmers of the park, but also by farmers from the plains who will have the possibility to rent the use of the pastures during the summer season. In the PNGP, the dairy cattle system and private property dominate the pastoral system. The mountain pastures are developed and eventually irrigated so as not to run out of resources throughout the seasons. Thus, the types of livestock are not similar between the two areas and the management of spaces and herds is different.

3.1 Defining a set of potential socioeconomic indicators

Impact monitoring is usually based on indicators related to quantitative or qualitative parameters. Indicators are commonly used to inform decision-making by providing insights and identifying trends on matters that are not immediately detectable. Besides the identification of indicators, the possibility to predict the impact of a project on a socioeconomic system also requires data availability regarding different aspects attaining to economy, social and cultural assets at an appropriate scale of analysis. Indeed, indicators are usually used in combination to cover the full range of dimensions of the agricultural socio-ecological system and several methodological frameworks have been proposed, for instance, as stand-alone tools for the assessment of agricultural sustainability along its three dimension: environmental, social and economic. The possibility to reach a comprehensive view based on a common set of indicators is, however, debatable in mountain systems, as these are characterized by a wide range of features (e.g. high agro-biodiversity, traditional products) compared to other more homogenous regions. That entails the necessity to enlarge the scope of the analysis to identify as wide a range as possible different indicators that may fit into monitoring and to select on that basis indicators that can reasonably be employed according to data availability.

The first step has focused on reviewing socio-economic indicators developed for agriculture in peer-reviewed publications in English or French. The general objective was to define a set of indicators targeting farm socio-economic features. The search was performed in the Scopus database (keywords: "agricultur*" AND "mediterran*" AND "indicator*"; November 2015) in "Article Title, Abstract, Keywords" in the data range "all years to present" and the "Life Sciences" subject area. After screening the titles and abstracts of the documents, 76 documents have been selected. The selection of documents was based on the presence of a specific reference to the social and/or economic aspect of sustainability. The output of the review (Table 1) is a list of indicators attributed to one of 11 specific "themes" that integrate different classification of indicators, as reported in a review on livestock systems (Lebacq et al., 2013). The list of papers employed in the review is attached to the report.

Table 1. List of potential socio-economic indicators for mountain agricultural systems based on the literature review.

Theme	Socio-economic variable	Brief definition
Autonomy	Subsidies	Farm reliance on subsidies
	Agricultural input	Farm reliance on external inputs
	Indebtedness	Farm solvency
	Personal control (room for manoeuvre)	Farmer control of decisions and room for manoeuvre
	Global/local dependency	Reduced reliance on global inputs and valorisation of the local different and complementary (human, technical, financial) resources
Durability	Succession	Relations between generations and knowledge passing to new generations
	Age	Age of the decision maker, farm age structure
	Viability	Economic durability of the farm enterprise
	Local dynamics (e.g. Land grabbing and urban sprawl)	Assessment of external dynamics that may hamper farm viability (competition for land, economic marginalisation of agriculture, out-migration) or favour it (e.g. in-migration of new rurals, investments in "land")
Entrepreneurship	Entrepreneurship	Entrepreneurial capacity
Equity	Resource access	Resource and rights of production are guaranteed
	Decision making	Decision making follows ethic rules
	Gender	Gender issues

	Corruption	Corruption level and concerns
	Property and use rights	Assessment of local institutions and public resource use rights (e.g. water, grazing lands)
	Conflict management	Presence of conflicts and their management (e.g. water access)
Knowledge	Information access	Access to media
	Education	School education level
	Experience	Experience of the decision maker
	"Life-long learning"	Access and frequency of trainings and advisory/extension services
	Educational/science collaborations	Farmer participation to educational/scientific programmes
	Traditional & environmental knowledge	Mixing traditional cultivation techniques with modern knowledge. System functions as much as possible within the means of the bio-regionally available natural resource base and ecosystem services. Investment in improvement of natural production potential (e.g. Shelterbelts). Working "with" (not against) environmental potential. Work based on observation and conservation of environmental potential
Local competitiveness	Social	Accounting for and awareness of farm impacts on local social development

	Cultural	Accounting for and awareness of farm impacts on local cultural development
	Economic	Accounting for and awareness of farm impacts on local economic development
Networking	Networking	Farmer level of participation to local organisations and local flow of information
Profitability	Income variability	Farm income variability
	Income level	Farm income level
	Irrigation/rainfed cropping	Linked to intensity but extremely relevant for S. Med
	Productivity/intensity	Output and intensity (including mechanization) are often considered tightly linked
	Water efficiency	Efficiency of irrigation (extremely relevant for S. Med)
	Efficiency	Efficiency of production factors
	Assets	Value of farm assets

Quality	Life quality	Wellbeing and welfare of farmer and farm workers
	Work quality	Quality of working conditions
	Food safety	Health safety of production
	Food quality	Food quality
	Production process	Quality of the production system meets citizen expectations
Vulnerability & diversification	Food security	E.g. livelihood strategies
	Risks	Risk perception and exposure, risk management strategies (e.g. insurances)
	Adaptation constraints	Restrictions to adaption and change, for instance distortionary subsidies
	Market and input diversification	Stable business relationships are maintained with a sufficient and alternative number of market channels
	Labour diversification	Availability of a large pool of working skills locally or in the farm
	Agricultural system integration	E.g. crop + livestock, agroforestry, lower specialization
	Culture diversification	Presence of different cultural features (e.g. traditions and innovations)
	Income diversification and multi-activity	Balance between in-farm and off-farm income, including remittances. Search for social security

		(e.g. army enrolment or public servant)
	Multifunctionality	Farm delivers a range of services besides agricultural production (e.g. education, tradition and culture, bio-energy)
Structure	Farm size	Size allows viable production
	Land tenure	Property of the farm
	Land fragmentation	Risk of fragmentations e.g. For succession rules, land accessibility
	Access to market	A favourable market position of the farm (e.g. not far from major urban centres)

The activities of this action go hand-in-hand with Pastoralp actions C.3 and C.4 with the definition of indicators and the help of local stakeholders (see also action E.2). The selection was also supported by a questionnaire (as delivered in action A.2) in the two study areas (PNE and PNGP). The set of indicators was then compared with available statistical databases to identify relevant data to be selected. An in-depth focus on the available indicators for the socio-economic monitoring of the Gran Paradiso case study area is presented.

3.3 Implementing the indicator set for the case study areas: The example of Gran Paradiso National Park

For the implementation of the indicators in the case study area, a database was developed to list the available socio-economic data for the municipalities of the two parks. We worked on the Italian and the French parts at national and regional levels, and then at municipal level. The aim of the research at the national level was to provide a basis for comparison. Indeed, the Italian territory accounts for very different types of agriculture at various scales. For the municipalities to be studied, we chose to focus only on the core municipalities of the parks:

For PNE:

- Isère: Besse, Clavans en Haut, Entraigues, Lavaldens, Le Bourg d’Oisans, Mizoën, Oris en Rattier

- Hautes-Alpes: Ancelle, Aspres-lès-Corps, Buissard, Chabottes, Champcella, Champoléon, Châteauroux les Alpes, Crots, Embrun, Freissinières, L'argentière la Bessée, La Chapelle en Valgaudémar, La Grave, La motte en Champsaur, Le Monêtier les bains, Les Vigneaux, Orcières

For PNGP:

- Aosta Valley: Aymavilles, Cogne, Introd, Rhêmes-Saint-Georges, Rhêmes-Notre-Dame, Villeneuve, Valsavarenche
- Piedmont: Ceresole Reale, Locana, Noasca, Ribordone, Ronco Canavese, Valprato Soana

For the PNGP (Italian side), most of the data were available for the years 2010/2011, and then from 2015 to 2019. For the PNE (French side), agricultural data are available from national censuses. A high heterogeneity was evident between data availability in the two countries. For instance, in Italy, each region compiles agricultural statistics independently from the others, especially Aosta Valley because as it is an autonomous region. In general, data availability at municipal scale in Italy is scarce compared to France. Data for the socioeconomic monitoring should be homogenous as far as possible. For that reason, to outline an exemplary socioeconomic monitoring of the project, the report focuses on the Gran Paradiso National Park.

Table 2 below reports the data gathered for the development of the database.

Table 2. Data sources for the development of the socioeconomic monitoring in the Gran Paradiso case study area.

Type	Indicators	Categories	State	Source
Demography	Age structure	0-14	Sometimes found as is but often calculated (%)	ISTAT
		15-64	Sometimes found as is but often calculated (%)	ISTAT
		'+' 65	Sometimes found as is but often calculated (%)	ISTAT
		Total	Found as is	ISTAT and Annuario Regionale Aosta Valley
	Birth rate		Found as is	Piedmont STAtistica e B.D.D.E. + Annuario Statistico Regionale Aosta Valley

	Old age index		Found as is	Piedmont STAtistica e B.D.D.E. + Annuario Statistico Regionale Aosta Valley
	Death rate		Found as is	Piedmont STAtistica e B.D.D.E. + Annuario Statistico Regionale Aosta Valley
Land	Total agricultural area		Found as is	Anagrafe Agricola Unica
	UAA		Found as is	Anagrafe Agricola Unica + Assessorato Agricoltura e risorse naturali
	% UAA/TAA		Calculated	
	Agricultural land price	Pastures	Found as is	Dati Pronunciamento Commissione Provinciale – Agenzia entrate
	Pastures areas	Fertile Pastures	Found as is	Assessorato al turismo, sport, commercio, agricoltura e beni culturali
		Meager pastures	Found as is	Assessorato al turismo, sport, commercio, agricoltura e beni culturali
		Permanent meadows	Found as is	Assessorato al turismo, sport, commercio, agricoltura e beni culturali
	Number of mountain huts		Calculated	PNGP internet site
Farm structure	Number of farms	Total	Found as is	Anagrafe Agricola Unica
		with cattle	Found as is	Anagrafe Agricola Unica
		with pastures	Found as is	Anagrafe Agricola Unica
	Average size of farms (UAA)		Calculated	
Livestock for grasslands	Nb of livestock	Cattle	Found as is	Anagrafe Agricola Unica + Assessorato Agricoltura e risorse naturali
		Sheep	Found as is	Anagrafe Agricola Unica + Assessorato Agricoltura e risorse naturali e corpo forestale
		Goats	Found as is	

				Anagrafe Agricola Unica + Assessorato Agricoltura e risorse naturali
Organic farming	Number of farms	Total	Found as is	Anagrafe Agricola Unica
		with UAA	Found as is	Anagrafe Agricola Unica
		with cattle	Found as is	Anagrafe Agricola Unica
Tourism	Number of hotels		Found as is	ISTAT
	Number of beds		Found as is	ISTAT

Not all indicators were used for interpretations. In cases where data were only found for a single year and when data were not available at municipal level, we removed them from the final list because they were not considered relevant (Chaumien, 2021a, 2021b). The final set of indicators included in the report is as follows (Table 3):

Table 3. Socioeconomic indicators employed in the monitoring of the Gran Paradiso case study area.

Age structure
Average size of farms
Average number of head of cattle per holding
Birth rate
Death rate
Number of farms
Old age index
Pasture presence
Total numbers of cattle, sheep, goats
UAA (Utilized Agricultural Area)

3.2 Land-use mapping

Corine Land Cover and the Copernicus platform were used to map land uses. The aim was to determine the distribution of land use in the municipalities used and to notice any changes in land use. The primary objective was to see the distribution of grazing land in order to understand variations in NDVI (Normalised Difference Vegetation Index) thereafter. However, this indicator also allowed to assess the distribution of pastures at municipal level.

For both case study areas, georeferenced data on grassland evolution assessed by means of the NDVI were used to support the interpretation of socio-economic data. The NDVI correlates to terrestrial vegetation dynamics thanks to its estimation of biomass and leaf area index and is therefore commonly used as an indicator for the assessment of grassland vegetation states and trends (Nemani et al. 2003). NDVI is a dimensionless index describing the difference between the visible and near infrared reflectance of vegetation cover and can be used to estimate the density of greenery on an area of land (Weier et al. 2000). They were used to study the dynamics of vegetation in the studied area and thus to look for signs of plot use. The data were calculated from Landsat images with a resolution of 30 m. Thermal sums and NDVI calculations were then carried out. NDVI values were available for 2006 and 2013. The 2006/2013 NDVI difference data were converted from vector to raster point to more easily visualise territorial changes. We used the vector data to calculate the average NDVI change for each municipality, also retrieving the minimum, maximum, median and standard deviation of these variations. It was possible to assess grassland changes by comparing the NDVI values of the two periods.

3.2 Assessing potential long-term impacts of the project

The Pastoralp project focused on the climate sensitivity and adaptive capacity of grassland systems. To assess the project's expected impacts, the socioeconomic modelling exercise (actions C.3 and C.5) was used as a reference to outline how the project's adaptation strategies could affect socioeconomic vulnerability. That approach helps to i) understand the drivers and their impacts on vulnerability; ii) identify the "concurrent" environmental and economic policy factors that enable or constrain the effectiveness of such practices. As outlined in the reports E.2 and C.5, the approach includes the construction of a participatory Fuzzy Cognitive Mapping (FCM) (Özesmi and Özesmi, 2004) to identify factors and feedback relations between climate change-related variables and drivers of farming systems (Jasper & Kok, 2014). The FCM assesses the relationships between drivers and potential adaptation strategies in the case study regions. In doing so, the expected impacts of the Pastoralp are outlined.

4. Results

4.1 Socioeconomic indicators: the case of PNGP

In Gran Paradiso, dairy cattle is the main livestock system. The socio-economic context of pastoralism is quite different between in the two regions of Gran Paradiso (Aosta Valley vs. Piedmont). In particular, the agricultural dynamics are opposite. Overall, Aosta Valley residents are more linked to traditional practices while the farmers and operators of Piedmont are more focused on optimisation of CAP incentives. Between 2006 and 2013, there was an increase in NDVI is reported on 42.15% of the total area of the PNGP. That might reflect a reduction in pastoral activity and/or the abandonment of some pastures.

In Aosta Valley, the number of farms is constant between 2011 and 2019. We can confirm these data because by dividing the number of farms by the number of inhabitants per municipality (Fig. 1 and Fig. 2), the result remains constant over the years.

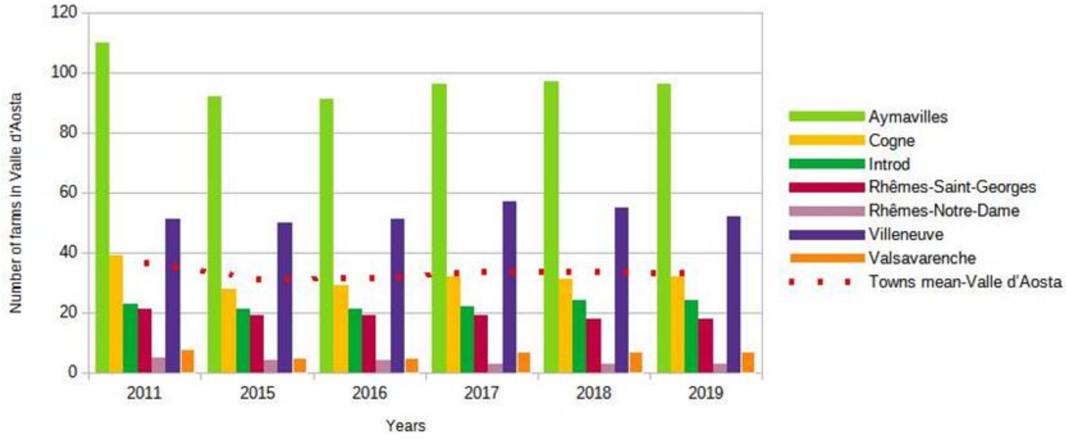


Fig. 1: Evolution of the number of farms for the municipalities of Aosta Valley

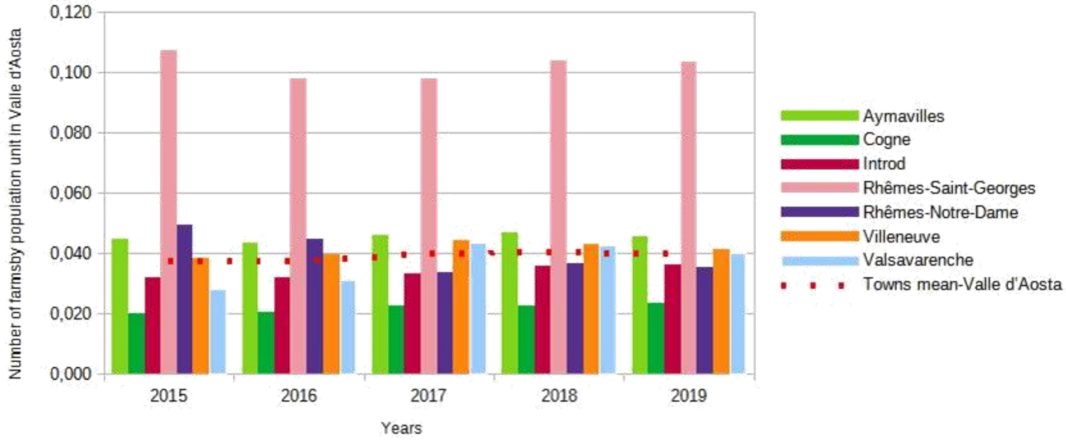


Fig. 2: Evolution of the number of farms per unit of population for the municipalities of Aosta Valley

In Piedmont, the number of farms has doubled in ten years if we compare only 2010 with 2015/2019, as figures between 2010 and 2015 are not available (Fig. 3). However, when this number is related to the number of inhabitants, it is constant (Fig. 4). This trend is explained by the transition from lowland farms to pastures, due to the change in pasture subsidies with the 2015 CAP. The headquarters of some farms in Piedmont have been moved to mountainous regions in order to receive more direct payments.

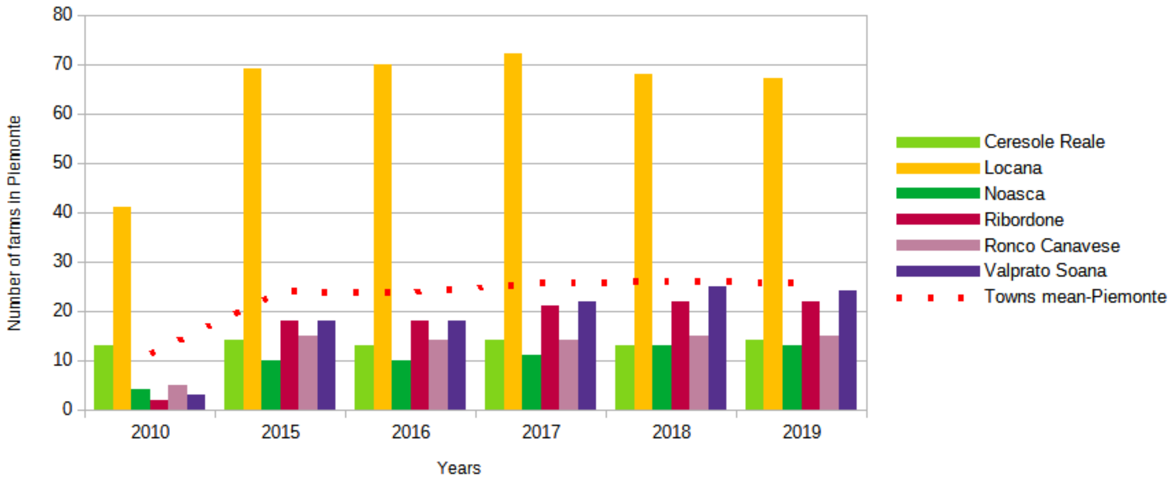


Fig. 3: Evolution of the number of farms for the municipalities of Piedmont.

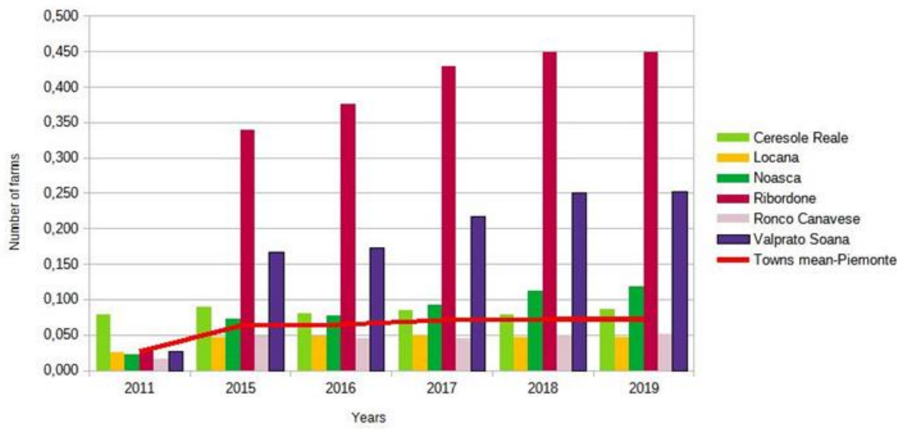


Fig. 4: Evolution of the number of farms per unit of population for the municipalities of Piedmont.

To compare the two sides of the park, the number of farms in the municipalities of Aosta Valley is slightly higher than that of Piedmont (the average number of farms per municipality is 32.6 in Aosta Valley and 25.1 in Piedmont). For the park in general, between 2010 and 2018 there was a steady but slight increase in the number of farms (325 farms in 2010, 363 farms in 2016 and 391 farms in 2018).

With the same number of farms, the average size of farms is almost constant for the municipalities of Aosta Valley (Fig. 5). Only Rhêmes-Saint-Georges and Valsavarenche have undergone a decrease between 2016 and 2017. This can confirm the fact that in Aosta Valley the quality supply chains allows maintaining the historical structures and the distribution of surfaces.

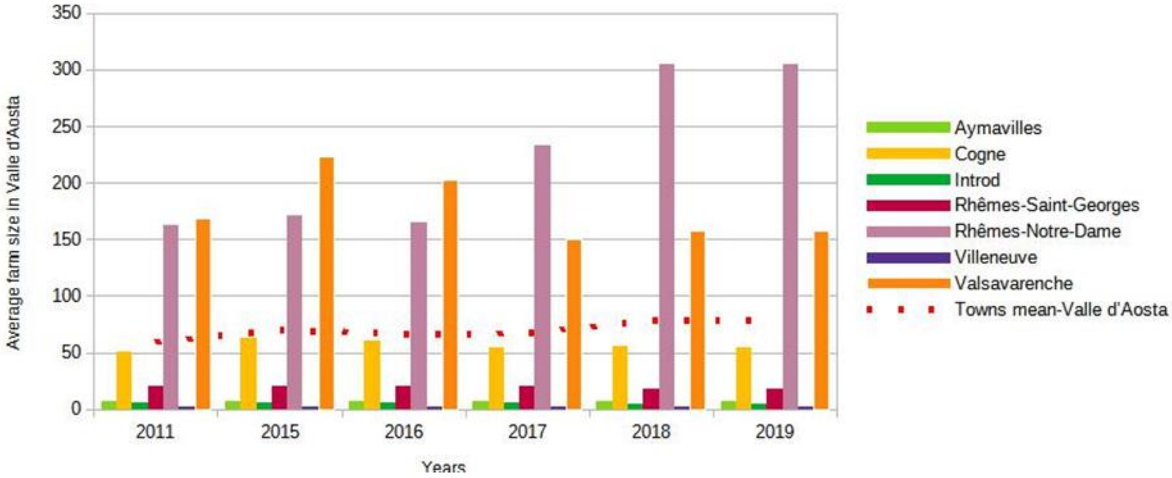


Fig. 5: Evolution of the average size of farms for Aosta Valley.

In Piedmont, there are two different dynamics (Fig. 6). For Ceresole Reale, Noasca and Valprato Soana, there has been an increase in the size of farms and these surfaces have at least tripled. Conversely, for Ronco Canavese and Ribordone there has been a decrease over the years. According to the same interpretation as before, the declaration of agricultural areas such as pastures was pushed by the increase in financial aid linked to pasture. Indeed, producers have the possibility of using the principle of "portability" of the aid and therefore they can declare a crop in pastoral areas, which allows them to increase the aid given that pastoral areas are generally large.

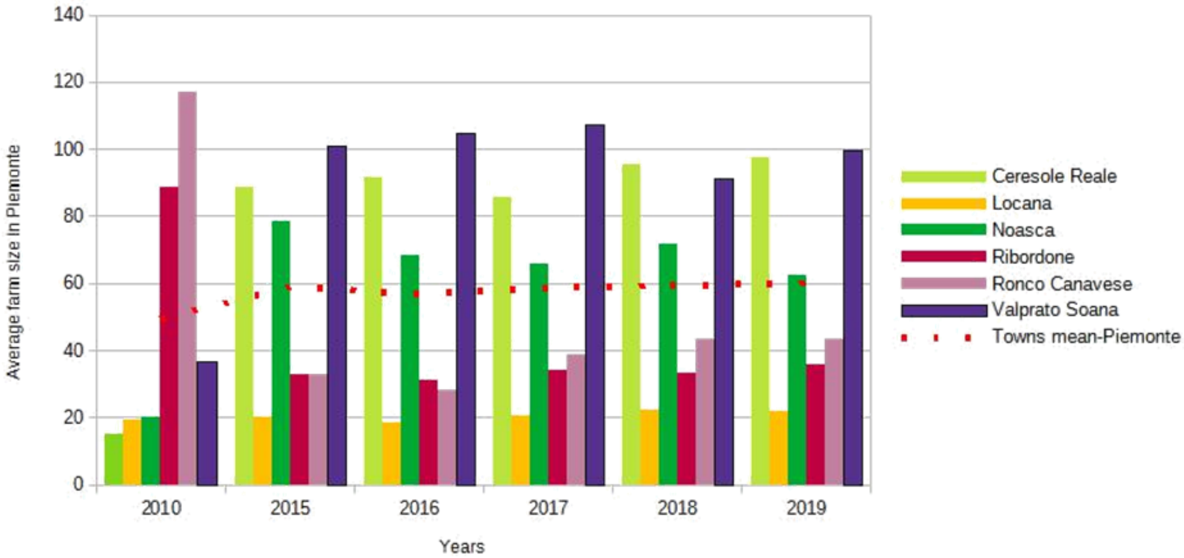


Fig. 6: Evolution of the average size of farms for Piedmont.

For the park as a whole, the average size of the farms has varied over the years but if we look at the general trend, the average size increased between 2010 (713,9 UAA/farm) and 2019 (910.5 UAA/farm).

For breeding activities, in Aosta Valley an average of 31.2% of farms have cattle, with a minimum of 17.7% and a maximum of 80% for municipalities (Fig. 7). There is also 9.6% of farms owning pastures.

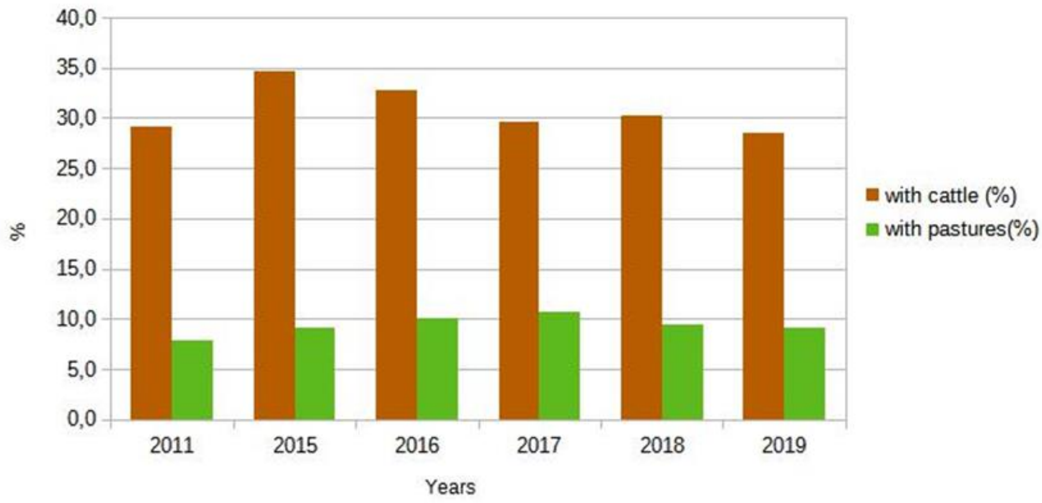


Fig. 7: Evolution of the average share of holdings with cattle breeding and the share of holdings with pasture for the municipalities of Aosta Valley.

In Piedmont, cattle are raised a little less than in Aosta Valley and the mean of farms with cattle is 22,7%, a minimum of 0% and a maximum of 42.6% (Fig. 8).

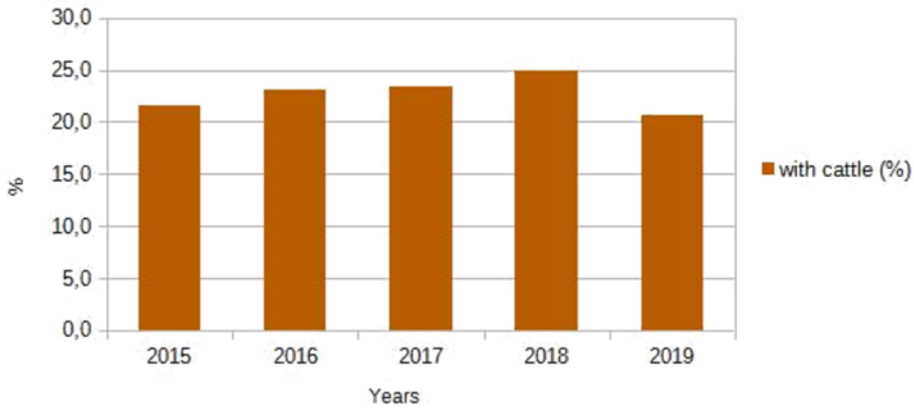


Fig. 8: Evolution of the average share of holdings with cattle breeding and the share of holdings with pasture for the municipalities of Piedmont.

For the park, breeding activity is generally constant over the years. Not all farms are involved in dairy farming and those that are have quite varied herd sizes.

The number of heads of cattle per farm is higher in Piedmont than in Aosta Valley. Finally, we note a slight decrease in this average in Piedmont between 2015 and 2018. For Aosta Valley, this mean is constant (Fig. 9).

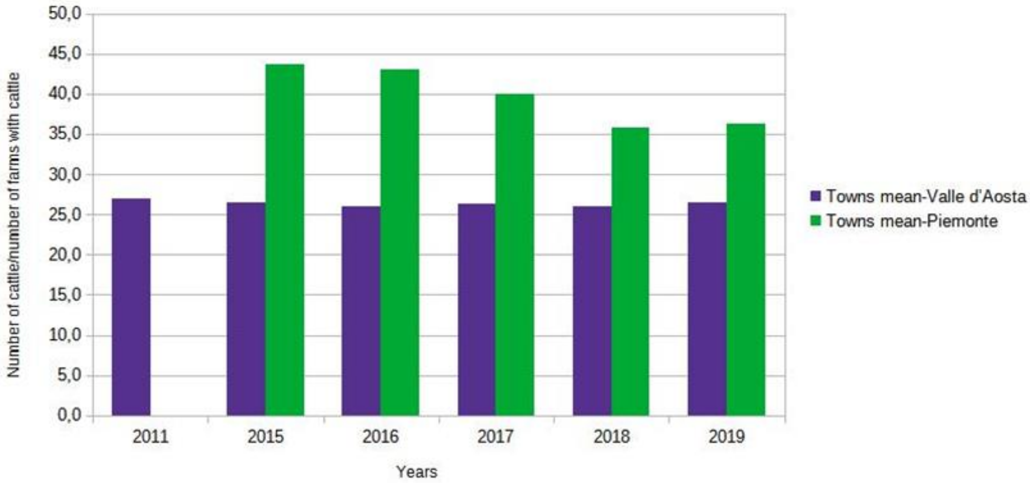


Fig. 9: Evolution of the average number of cattle per farm for the municipalities of Aosta Valley and Piedmont.

For the park, the number of cattle per farm decreased significantly between 2015 (450.9 heads) and 2019 (425.9 heads). Regarding population dynamics, in Aosta Valley, the number of cattle has slightly decreased since 2010/2015. The number of sheep is variable: it increased between 2011 and 2017, and then decreased. The number of goats is constant (Fig. 10).

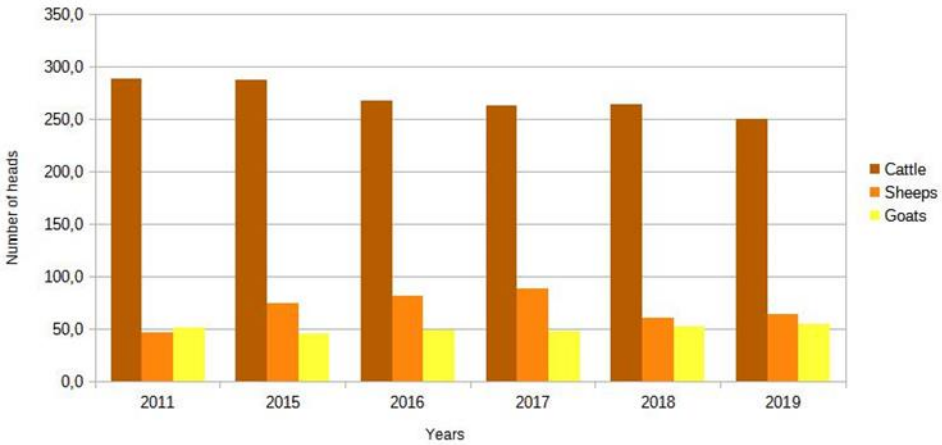


Fig. 13: Evolution of the average number of heads of cattle, sheep and goats for the municipalities of Aosta Valley.

In Piedmont, the number of cattle also decreased, but between 2017 and 2019. Since 2011, the number of sheep and cattle has decreased. The total number of goats has remained constant over the years, but there has been a decrease in 2019 (Fig. 14).

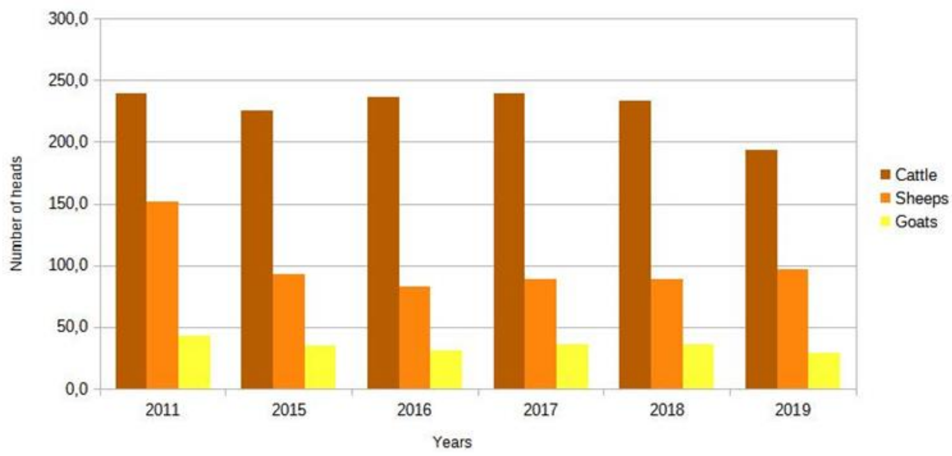


Fig.14: Evolution of the average number of heads of cattle, sheep and goats for the municipalities of Piedmont.

To summarise the current trends in PNGP, we can report that:

- The percentage of farms with cattle breeding is higher in Aosta Valley, with also a higher average number of heads per municipality;

- The average number of head per holding is higher in Piedmont. This can be explained by the fact that there are fewer farms, but those that exist have more cattle than in Aosta Valley;

- Regarding population dynamics, we can say that in Aosta Valley the number of cattle has decreased slightly since 2010/2015. It also decreased in Piedmont between 2017 and 2019;

- For each region, the share of cattle compared to other animals has decreased significantly in recent years. It is therefore possible that a change in mountain pasture practices will occur over the years.

The age structure is reported below, but it is important to note that these data are for the general population and not just for the agricultural population. These results were also discussed with local stakeholders in order to compare the total population with the agricultural population (without quantified data, see also action A.6). The results can be very variable because for some municipalities the number of inhabitants is very low and therefore the variations are large (Fig. 15 and Fig. 16). We can see that in some municipalities , the share of over-65s is large compared to the national level (around 22% for Italy between 2015 and 2019). For Aosta Valley, between 2015 and 2019, the share of 15-64 year olds increased to the detriment of the ‘65 and +’ category. In Piedmont, the variations are lighter and more homogeneous between the three categories, but the mean of the 65 and +’ category is higher than in Aosta Valley. The towns with the highest over 65 population in 2019 are Valprato Soana (35.79%), Noasca (42.73%), Ronco Canavese (41.75%) and Ribordone (53.06%) where the over 65 population rate is higher than the "active population" aged 15 to 64 years.

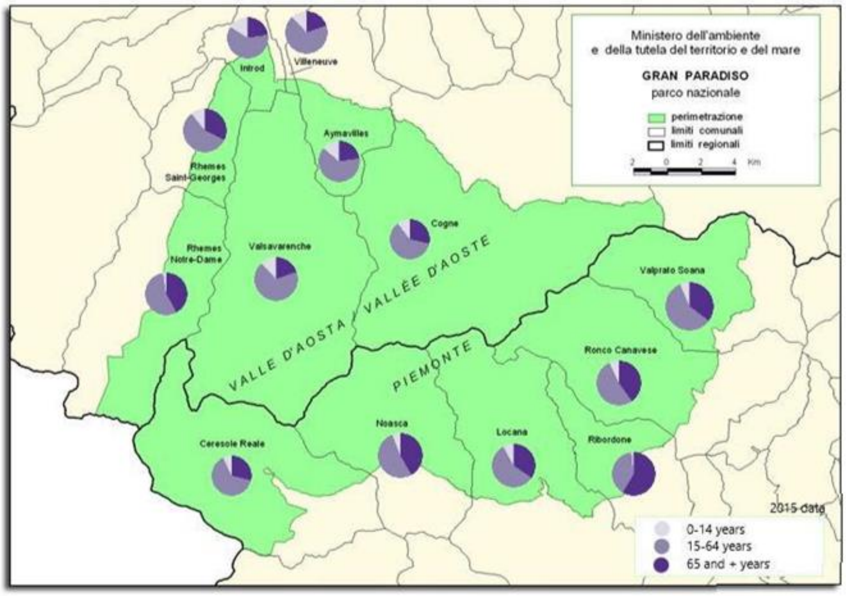


Fig. 15: Distribution of the population in age groups for all the municipalities of Aosta Valley and Piedmont in 2015.

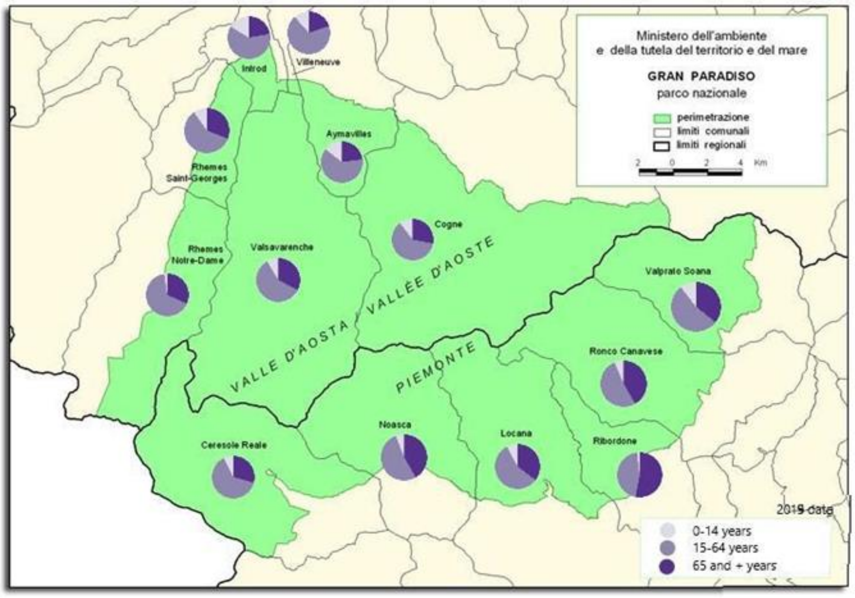


Fig. 16: Distribution of the population in age groups for all the municipalities of Aosta Valley and Piedmont in 2019.

In Fig. 17, all towns report a high rate of over 65s compared to the overall mean for Italy with the exception of Aymavilles, Introd and Villeneuve. For the park, the general trend that is outlined is an aging of the population, but as previously stated, the figures can easily vary given that some municipalities are particularly small (as per inhabitant number).

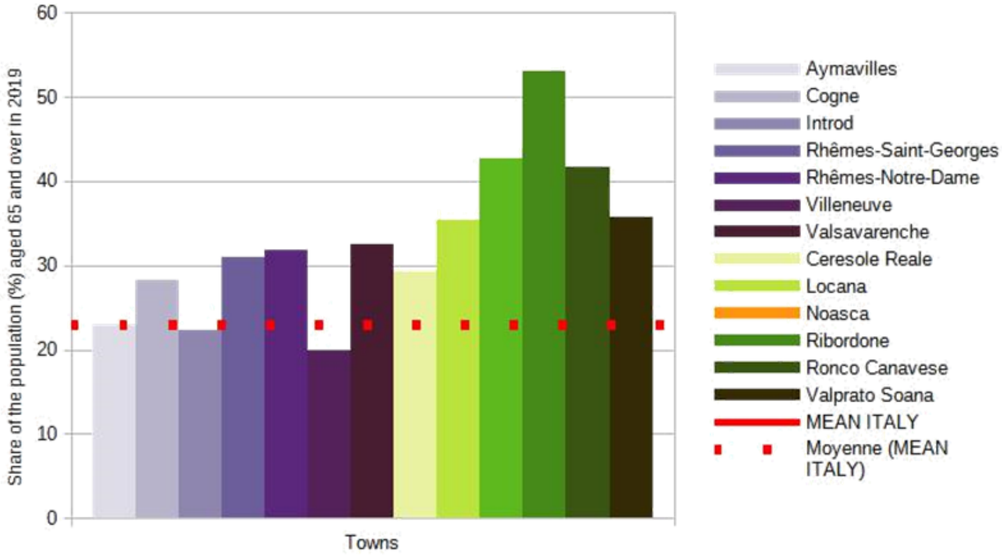


Fig. 17: Share of population (%) aged 65 and over in 2019 for the municipalities studied.

Below are the distilled results of the action C.6 survey of farmers to outline demographics with a focus on the agricultural sector (Fig. 18 and Fig. 19).

In addition to the previous information, according to local stakeholders in Aosta Valley (source: IAR), there has not been a drastic change in the average age of farmers in recent years. It can therefore be assumed that the figures presented in Fig. 18 and Fig. 19 represent the distribution of farmers by age group in recent years. However, it should be kept in mind that these results are based on a sample of PNGP farmers (livestock farmers grazing in the PNGP area) and not on the total population of Aosta Valley. For both regions (Aosta Valley and Piedmont), there is a majority of male farmers at the head of farms (Fig. 18). In Aosta Valley, farmers are generally younger (under 50) than in Piedmont: the share of farmers under 50 is around 58% for Aosta Valley and 50% for Piedmont (Fig. 19). Moreover, for the share over 50 years old, there are more farmers aged 70 in Piedmont than in Aosta Valley.

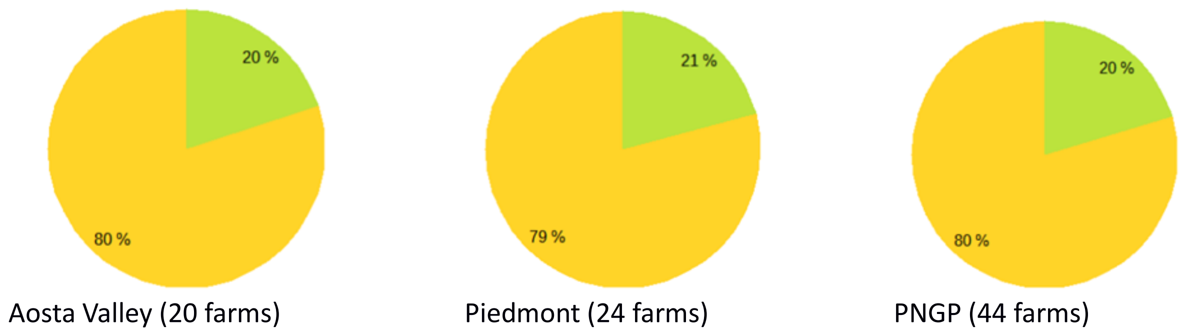
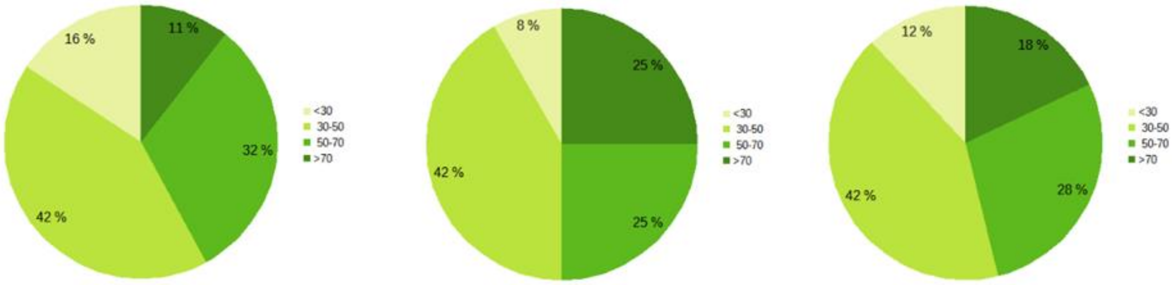


Fig. 18: Division of surveyed farmers by sex in 2020 (yellow: men; green: women).



Aosta Valley (20 farms) Piedmont (24 farms) PNGP (44 farms)

Fig. 19: Division of surveyed farmers by age group in 2020.

4.2 Land-use mapping: Recent trends on grasslands

Concerning the changes in land-use assessed with the aid of the NDVI index (Figs. 20 to 23), we can notice that Villeneuve and Cogne are the two municipalities with the highest percentage of non-grassy areas in 2015 and 2018 (more than 80% of the total area classified as non-grassy). The municipality with the highest rate of grassland loss is Valprato Soana with a loss of 11.4% on the total municipal area. The municipality with the highest rate of grassland gain is, on the other hand, Valsavarenche with a gain of 25.8% on the total municipal area.

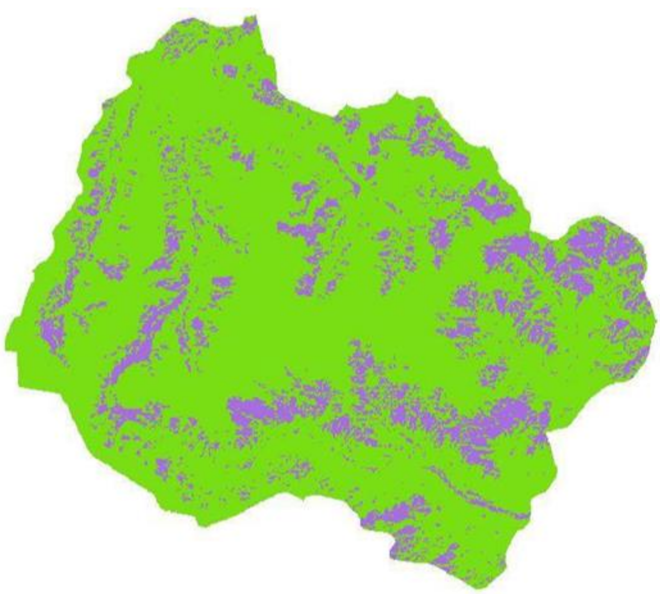


Fig. 20: PNGP map showing the distribution of grasslands in 2015 (purple: grasslands; green: no grasslands).

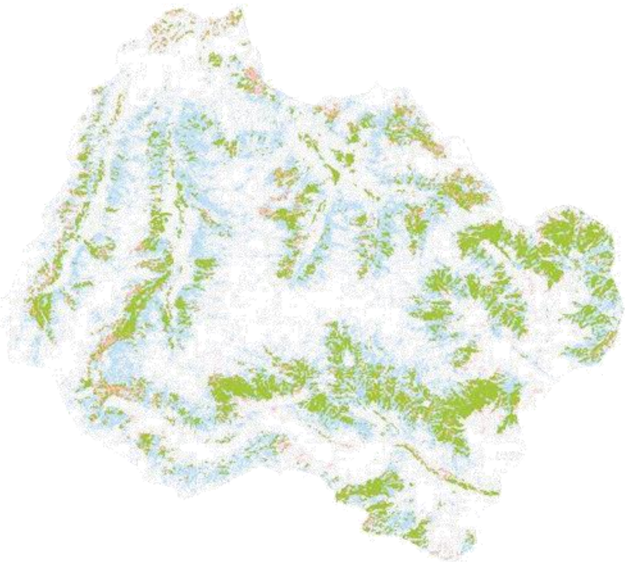


Fig. 21: PNGP map showing the distribution of the grassland difference between 2015 and 2018 (green: grassland unchanged in both years; blue: grassland gain not verified; red: grassland loss not verified; grey: no grassland).

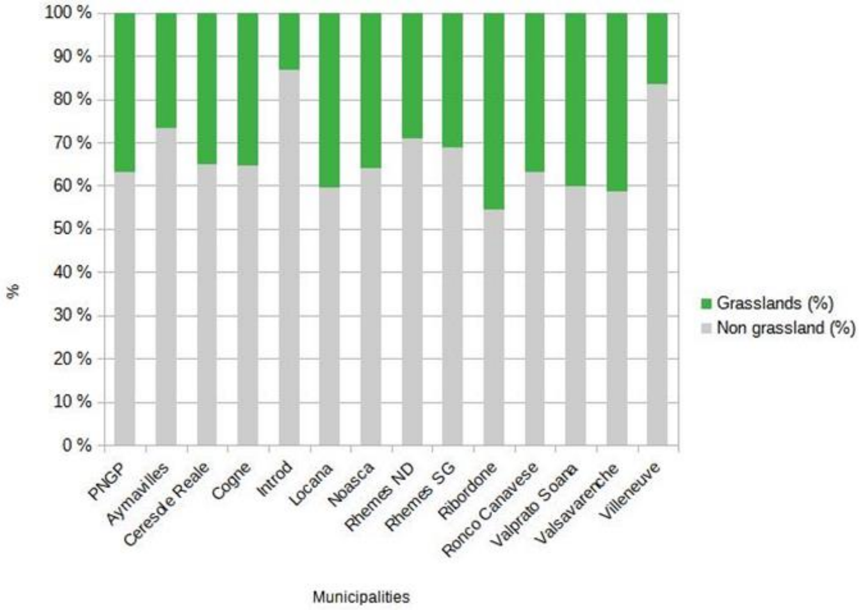


Fig. 22: Percentages of grassland and non-grassland areas for the municipalities between 2015 and 2018.

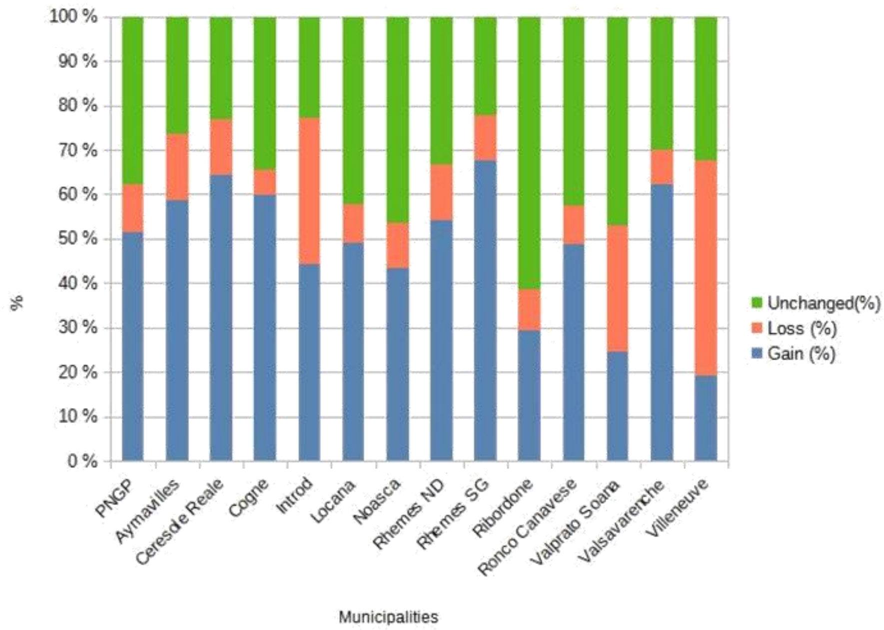


Fig. 23: Percentages of change in NDVI in grasslands and non-grasslands areas for each municipality between 2015 and 2018.

In Figs. 24 to 27, it is showed that all municipalities have experienced an increase in NDVI on their territory. Aymavilles, Introd, Locana, Rhêmes-Saint-Georges, Ribordone, Ronco Canavese, Valprato Soana and Villeneuve have experienced an increase in NDVI over more than 50% of their total municipal area. Cogne, Rhêmes-Notre-Dame and Valsavarenche show a more limited impact of the NDVI increase. For the park, 42.15% of the total area experienced an increase in NDVI between 2006 and 2013. An increase in NDVI can be a marker of abandonment or reduction of pastoral activity in these areas of the park as it is linked with a more dense vegetation (Meneses-Tovar, 2011). The hypothesis was confirmed by the IAR team for Aosta Valley municipalities and by the PNGP staff for Piedmont side.

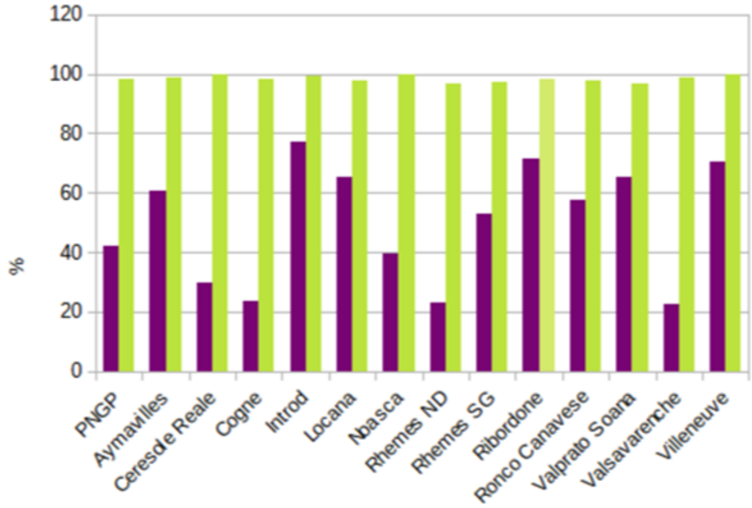


Fig. 24: Percentages of areas with NDVI increased by municipality and for the variations in total NDVI of PNGP municipalities between 2006 and 2013 (purple: % of area with NDVI increased by municipality and for their total area; green: % of area with NDVI increased for the total area with variations of NDVI).

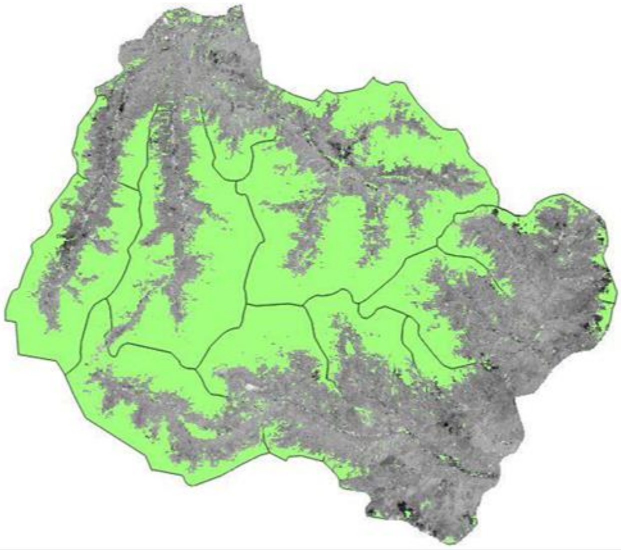


Fig. 25: PNGP map showing variations in NDVI between 2006 and 2013 and the administrative boundaries of municipalities.

It can be seen from Fig. 26 and with the values in Table 4 that 87.15% of the NDVI increase is concentrated in non-grassland areas, whereas 12.88% is reported in grassland areas. For negative variations in NDVI, 26.59% are localised on grassland areas and 73.41% on non-grassland areas. We can therefore hypothesise that the increase in the vegetation rate (increase in NDVI) is favoured in non-grassland areas and that in general grazing makes it possible to limit this plant growth. We can imagine that the grassland areas where there was an increase in NDVI between 2006 and 2013 were partly abandoned by pastoral activities. On the other hand, grassland areas where there is a decrease in NDVI could be explained by potential overgrazing dynamics.

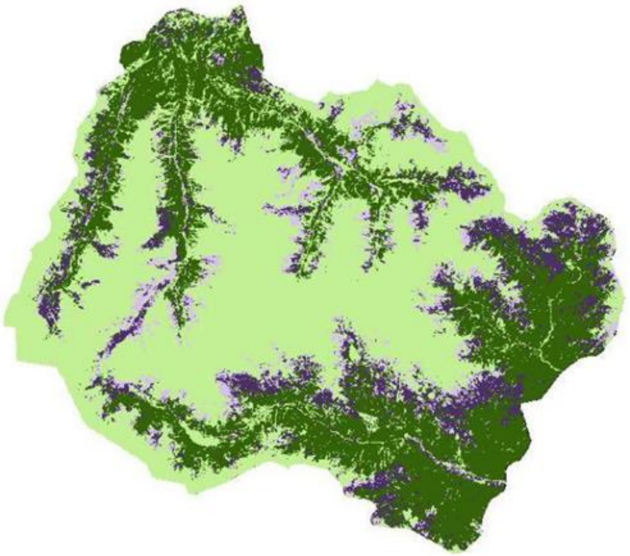


Fig. 26: PNGP map showing the positive variations in NDVI between 2006 and 2013 and the distribution of grasslands (purple: grasslands; green: no grasslands; dark colors: change of positive NDVI).

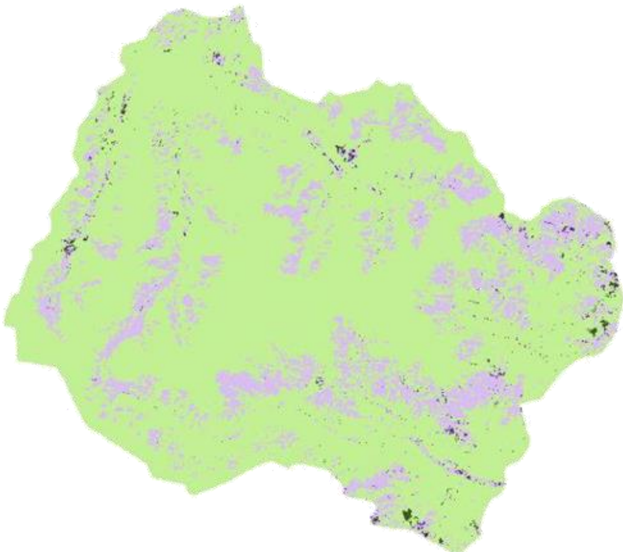


Fig. 27: PNGP map showing the negative variations of NDVI between 2006 and 2013 and the distribution of grasslands (purple: grasslands; green: no grasslands; dark colours: change of negative NDVI).

Table 4: Data on NDVI distributions on grassland and non-grassland areas.

NDVI >0 in grasslands	12.88 %
NDVI >0 in non-grasslands	87.15 %
NDVI< 0 in grasslands	26.59 %
NDVI< 0 in non-grasslands	73.41 %

Table 5 reports the factors included in the FCM for PNE and PNGP. Agricultural policy subsidies, wolf predation, hiring of expert shepherds and grass quality reduction were characterised by a considerably higher cumulative relevance in the PNE network (i.e. centrality index). In the PNGP, 'Upland grasslands', 'Relevance of farm productivity', 'Revenue' and 'Bottom valley meadows' were considered more relevant. Although different, the factors have outlined some similarities (reported in red in Table 5). In particular, predation, abandonment and revenues/subsidies are important factors in both case study areas.

Table 5: Data on NDVI distributions on grasslands and non-grass areas.

PNGP		**PNE**	
Factors	**Centrality score**	**Factors**	**Centrality score**
Upland grasslands	14.47	CAP subsidies	8.88
Relevance of farm productivity	12.01	Predation	8.73
Revenue	11.15	Experienced shepherd hiring	8.30
Bottom valley meadows	10.00	Upland grassland quality reduction	8.20
Tourism	8.00	Search for alternative forage resources	6.17
Farm organization and life quality	7.96	Investments	6.15
Predation	7.87	Abandonment	5.98

4.3 Defining potential impacts of Pastoralp adaptation strategies on the local grassland systems

The qualitative assessment performed by means of the FCM allowed us to devise some potential impacts of the Pastoralp and, in particular, some of the adaptation strategies suggested by the project for the two case study areas.

Concerning the PNE, a focus on reinforcing the advisory service (CERPAM) in support of a correct utilisation of grasslands and higher budgets for shepherds' schools would be effective in reducing the impact of climate variability on abandonment without incurring an increased workload for farmers (Fig. 28). However, some trends towards intensification are still evident. These impacts are likely related to climate changes, predation and the role of CAP incentives.

	Baseline	With shepherds and CERPAM
Abandonment	↑↑	↓↓
Hay buying	↑↑↑	↔
Intensification (bergerie)	↑↑↑	↑
Work charge	↑↑	↔

Fig. 28: Expected impact of adaptation strategies focused on trained shepherds and CERPAM in the PNE.

Concerning the PNGP, the focus on training as in the PNE is suggested together with the development of infrastructure on the uplands ('*alpage'* structures, irrigation facilities) would be effective in tackling the abandonment of grasslands. However, several factors are concurring together with climate changes in the abandonment dynamic and the adaptation strategy alone is thus less effective in comparison to the PNE (Fig. 29). In particular, needs of hay result as a relevant problem for the future sustainability of the grassland system. That issue is likely related to several factors including the requirement of the Fontina cheese PDO to employ local hays.

	Baseline	With training and infrastructure
Relevance of upland pastures	⇩⇩⇩	⇩⇩
Hay buying	⇧⇧⇧	⇧⇧⇧
Intensification (bergerie)	⇧⇧	⇔
Organization and life quality	⇩⇩	⇩

Fig. 29: Expected impact of adaptation strategies focused on training and infrastructure development on the upland grasslands in the PNGP.

5. Discussion and conclusions

Measuring the extent of the social and economic impacts of a project on two regions of different countries is hugely complex. Thus, our purpose in the action D.2 was to build and highlight a methodology for assessing the socio-economic impact of the Pastoralp project on the local economy that may be used by local stakeholders.

The main issue is that the socio-economic dynamics are very different between each national area (Écrins vs. Gran Paradiso) and inside the Gran Paradiso Park, between Aosta Valley and Piedmont. This is mainly due to differences in each area's history and in the management of the agricultural territory as well as the policies put in place. For the French side, there is an on-going land competition inherent to the PAC incentive and climate change in the plains, which encourages herders to go further north, earlier and longer in the mountains. On the Italian side, in Aosta Valley there is a system of small farms with the maintenance of historical techniques and productions, while in Piedmont productivity and the search for agricultural financing are more present. In the Gran Paradiso Park area, livestock farms and the use of pastures are more widespread in Aosta Valley, while in Piedmont there is a loss of this family activity in favour of the size of farms.

Overall, the transmission of farms is, for the moment, still effective in the context of pastoralism, even if we can notice a slight decrease in pastoral activity within the PNGP and a change in its management over the years. However, climate change has therefore had an impact on pastoral activity. The adaptation of mountainous pastoral systems to climate changes requires enabling changes in practice because grass stock, water availability or grazing season length are expected to change (Mayer et al. 2022). Even though the impact of climate changes and, in particular, of climate variability is perceived by farmers, its relevance is considered less relevant than predation. That can be related to two different aspects. First, pasture-based farming is a human activity, which is used to adapt to climate conditions. Therefore, farmers perceive they have 'room for manoeuvre' and a range of different strategies at their disposal to adapt (Lamarque et al. 2014). For instance, some adaptation strategies like adjusting the grazing season to the availability of semi-natural forage resources are part of the traditional know-how of pastoral farmers (Maru et al. 2014). Second, climate changes are perceived as happening in a rather long-time frame that will need year-by-year adjustments (Asseng and Pannell 2012), whereas predation is the most unpredictable current threat causing economic damage. The consideration of climate variability as the most relevant climate-related factor confirms on the other hand that unpredictability is an important aspect with strong consequences on local farming management aspects, such as fodder quality on pastures and consequently the need of hay.

In this context, a first outcome of the Pastoralp project is to highlight an insufficient consideration of the uncertainties regarding the impact of climate changes (Komac et al. 2013, Duru et al. 2015, Girard et al. 2015). Indeed, the effects of climate changes on pastoral resources are still being debated and do not bring sufficiently robust outcome to propose technical changes for breeders (knowing that temperature is a main constraint for grass in high mountain, global warming is generating an increase in the amount of grass at higher elevations - Choler et al. 2021). However, if increasing temperatures are rather beneficial for primary productivity in high altitude systems, their effect is reversed when considering the effect of drought, which reduces forage availability in the bottom valleys. In addition, even though the quantity of grass biomass on pastures may increase, concerns regard the quality of the biomass surplus and its availability (in terms of access for the herds or in terms of phenology compatible with pastoral management). Thus, farmers have to cope with relevant uncertainties linked to expected changes of climate and an incremental change in the stock of resources *per se* is not the primary driver of choice in practices. On the contrary, the increased uncertainty about the forage resources available in the season is a huge organisation constraint for pastoral farmers that hampers management decisions such as renting pastoral areas, booking trucks for flocks' transport and so on. In this respect, climate variability and predation bring primary uncertainties to the system. Thus, an impact of the Pastoralp project is to show how to take into account such uncertainties (FCM model) in order to mitigate an expected trend of abandonment of high mountain lots and an increase of hay purchase to feed the animals.

Another outcome of the action D.2 of the Pastoralp project is to highlight the ambiguous effect of CAP subsidies on the effectiveness in preserving the utilisation of upland pastures. There is a high share of subsidies on current farm revenues, which strongly determine farming management. They are a direct and positive effect on the resilience of mountain farms. But at the same time, CAP subsidies based on flock and farmland sizes tend to favour large farms and larger flocks (Delattre et al. 2020), which potentially decreases the effectiveness of protection means. Guardian dogs are less effective with many sheep being frightened by a wolf, for instance (Rossi et al. 2012). Thus, CAP subsidies determine both farming management and the exposure of pastoral farms to the risk of predation currently affecting upland grasslands. Moreover, larger flocks need wider pastures, reduce management elasticity and increase the need for hay in unfavourable years. All these aspects concur to reducing the capacity of the pastoral system to cope with the unpredictable impacts of predation and climate variability. Hence, our results point to the need for a shift towards higher policy flexibility based on the indication of environmental outcomes to be achieved and less on prescribed practices. These considerations strongly support outcome-based agri-environmental schemes as efficient solutions for mountain grassland systems. Even though the implementation of outcome-based schemes is complicate (Bartkowski et al. 2021), there are several examples adapted to pasture-based farming (e.g. Fleury et al. 2015, Zabel 2019, Pinto-Correia et al. 2022) and their application should be encouraged. However, an issue that needs to be considered is whether the time needed to develop knowledge-based practice adaptations will fit the expected time-scale on which climate changes will affect the pastoral system.

The third outcome of the action D.2 of Pastoralp project is to propose an analytical framework that takes into account the net cumulate effects between drivers such as subsidies, predation or climate that are able to reinforce or compensate each other. For instance, the level of wildlife predation is a constraint for breeders and, at the same time, loss compensation premiums are incentive to keep flocks on upland pastures. In this framework, as already quoted by Hinojosa at al. (2016a and b), we show that there are abandonment trends linked to stress factors, but a total abandonment for mountain pastoral areas is not to be expected as long as the CAP incentives are present. Nonetheless, the combination of CAP and predation effects generates dynamics such as intensification in the case study area. This intensification trend consists in increasing herd sizes (to reduce the per head cost of hiring shepherds[1]) and keeping the traditional high mountain pastures with a progressive abandonment of marginal grazing lots (remote areas hard to defend against predation and not suitable for large flocks), and with more reliance on hay and low valley forage resources. This trend, which reproduces the "lowland" system on mountain pastures, is indirectly facilitated by CAP incentives, which aim to improve labour productivity through process intensification (e.g. increasing herd size, reduction of the capping of the size of pastures per farm).

Pastoralp's work based on a participatory-based FCM has made it possible to identify the drivers of vulnerability and adaptation strategies (namely in the Écrins pastoral system for the empirical example). Our study confirmed that wolf presence and CAP subsidies are among the main factors that drive the management of the pastoral system. On one hand, wolf predation is a clear factor inducing the abandonment of upland grasslands. On the other hand, the CAP is effective in counterbalancing this impact. In this framework, while the current level of premiums is crucial overall, an additional premium to compensate for wolf predation or climate constraints would not be effective for drastically changing practices. In particular, our model outlined that under the interaction of different stressors a limiting factor that needs to be considered is workload, a well-known driver of pastoral systems (Aubron et al. 2016). Even though revenue is surely important, the amount of work needed to earn that income is also very important for farmers (Vanclay 2004). This is particularly relevant for pastoral farmers (Hill and Bradley 2022). In this perspective, our analysis highlights that the availability of skilled shepherds and alternative forage resources resulted as the most relevant factors in a scenario where the pastoral system is affected by several stressors like predation and climate variability. The more competent the shepherds are, the less farmers' intervention is required during the season. This factor can also reduce farmers' workload. In this view, skilled shepherds can be considered a factor able to lead towards pastoral system adaptation to climate changes and able to support farming systems with a higher capacity to cope with uncertainty.

To conclude, the scenarios developed through the FCM approach show that the impacts of interactions between CAP, predation and climate uncertainty on farmers' workload is relevant. This supports the evidence reported in other research concerning the drivers of change of pastoral systems in the French Alps (e.g. Aubron et al. 2016). These aspects should be attentively considered for the future sustainability of local pastoral systems and policy design. For instance, the availability of skilled shepherds will be an effective tool to contrast the abandonment of mountain grasslands. Indeed, during the summer period, the possibility to rely on expert shepherds allow farmers to devote their time to forage crops, secondary/diversified activities, etc. On the contrary, increased problems for the management of upland grasslands (e.g. predation, grass quality) will forcefully trigger dynamics towards farming systems affected by lower unpredictability such as indoor breeding. Therefore, the resources and infrastructure needed by shepherds, as well as the training of new labour forces and shepherds in protection from wildlife predation and techniques to mitigate climate uncertainty effects could be important factors to enhance the adaptation capacity of the local pastoral system. Other alternative strategies like increasing the availability of alternative forage resources are also important, but their effectiveness resulted less relevant than the role of shepherds. This is likely linked to predation risks (for instance, more wooded areas are prone to higher predation) and to the need for a relatively high rate of working units required for the utilisation of such resources.

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[1] Also, the French pastoral law (Loi Pastorale) supports the organisation of pastoral collectives.

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