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The future of farming and agricultural practices in Western Italian Alps

Master's thesis in Industrial Ecology

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SUMMARY

Mountain areas are recognized to be environments rich in resources and providing uncountable ecosystem services; however, they also host fragile territories and ecosystems that are based on delicate equilibria. Aosta Valley is an excellent example of an Alpine area where the local population lives in close relationship with its territory, as mountains are part of the identity and culture of these communities, as well as their traditional activities related to agriculture.

In this context, climate change is expected to affect not only Aosta Valley's landscape and climate, but also its economic and social structure, by reason of the intimate relationships existing between environment, economy and society. Moreover, modifications introduced by human activities risk to worsen or accelerate the environmental degradation and the draining of natural resources, like urbanization and the development of tourism sector.

In this sense, action is necessary to mitigate climate change and even more, at a local level, to adapt to its inevitable consequences. Initiatives and policies from a European to a local level can help steer the economy towards a more sustainable pattern.

An extensive literature review and three interviews were carried out for modeling the climatic and socio-economic systems. Ongoing and planned initiatives were categorized by their main objective and then examined for how they can affect the described systems.

The analysis shows that the traditional agricultural practices and their high-quality products have a key role in preserving the environment and enhancing the regional cultural heritage; the tourism sector can help in this sense and contribute to the development of Aosta Valley's economy only if it is diffused on the entire regional territory and respectful of the environment.

Initiatives can be taken at a local, regional or national level, and they can tackle different challenges: the availability of resources like water and fertile land, with construction of water storage reservoirs, the conservation and upgrading of the rural context or the introduction of grazing plans for the Alpine pastures; the conservation of the environment and landscape, with the introduction of protected areas or the adoption of innovative farm management systems; the valorization of the cultural heritage with the definition of quality schemes for the traditional products.

Keywords: farming, climate change, adaptation strategies, environmental protection, economic development

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PART I: METHODOLOGY AND STUDY REGION

1 INTRODUCTION

1.1 MOUNTAIN REGIONS AND CLIMATE CHANGE

The issue of mountain regions governance has been recognized to be of importance in the global agenda of sustainable development, from a local to a national and international level. In fact, not only the mountain ecosystems are essential for providing up to 80% of the world's freshwater: they also host 50% of the globally recognized biodiversity hotspots, and they offer uncountable environmental services, from fodder production to soil erosion control, from provision of food and wood to aesthetic value. These areas are also rich in diverse human cultural heritages, due to the complex conformation of the territory that often implies inaccessibility and isolation, as well as the need to learn how to survive in an environment that requires a great adaptability to extreme conditions (United Nations, 2012; Balsiger and Debarbieux, 2015; Lavorel *et al.*, 2019).

In the past decades, and even more today, these regions are displaying an accentuated vulnerability to the impacts of climate change and land degradation compared to other realities. This is a consequence to the fact that rises in temperatures within the Alpine regions have been two to three times more accentuated than the global trends: the presence of highly specialized species to harsh climates, along with the fragility of the territory due to the diffuse hydrogeological risk, raise concerns for the survival of Alpine ecosystems and the land they live on.

This evidence makes it crucial to design a strategy for a sustainable transition, in order to promote adaptation to the future climatic conditions, in which water scarcity and food insecurity are foreseen to be amongst the most urgent challenges (United Nations, 2012; Balsiger and Debarbieux, 2015; Brunner and Grêt-Regamey, 2016).

Several studies agree that this should be done adopting a holistic approach, integrating in the analysis both environmental variables and the socio-economical structure. In fact, a new plan for sustainable land use and water resources management cannot prescind form a thorough investigation of synergies and trade-offs between the multiple factors that play a role in the regulation of the mountain environment (Briner *et al.*, 2013; Briner, Elkin and Huber, 2013; Brönnimann *et al.*, 2014).

This research focuses on Aosta Valley, an Alpine region in the North-West of Italy, by reason of the strict dependence of the local communities on a natural resource economy, which could be threatened by climatic changes in the coming decades. Moreover, these communities' relationship with the mountains is a fundamental part of their identity, and the traditional agricultural practices are part of a precious cultural heritage that is worth preserving.

Therefore, the following questions will be addressed for the development of this research project:

- What are the foreseen scenarios of climatic conditions and the consequent environmental responses in Aosta Valley for the coming 30 years?
- How is climate change expected to affect the socioeconomic system of the region, with particular reference to the agricultural sector and in relation with tourism?
- Which strategies are the most advisable for the adaptation of agro-pastoral practices to said new conditions and how can they be promoted by local, national, or international administrations?

1.2 PROJECT OUTLINE

This work is carried out in two major phases, which reflect the structure of the present report: the first part consists in description of the methodology adopted for this project and the characterization of the study region and the legal framework, while the second one reports the subsequent analysis of the system and future climatic and socio-economic scenarios, as well as the assessment of several interventions aimed at making the agricultural sector of Aosta Valley sustainable in the long term.

The steps of this work correspond to the following chapters:

- Chapter 2: description of the adopted methodology and the limitations of the study.
- Chapter 3: general description of the study region, in terms of climatic and territorial conditions, administration, economy and peculiarities of the agricultural sector.
- Chapter 4: description of the existing legal framework at an international, national and local level.
- Chapter 5: summary and main take-aways of the interviews carried out with different regional actors.
- Chapter 6: assessment of the effects of climate change on the regional environment and description of the foreseen scenarios for 2050; identification of the cause-effect relations that exist between environment and agricultural production, and analysis of the effects of climatic alterations to the system.
- Chapter 7: description of the ongoing and planned projects, classified by aim of intervention: improvement of water or fertile land availability, improvement of biodiversity and ecosystem services, valorization of the cultural heritage.
- Chapter 8: analysis and comparison of the alternative strategies for the future, along with the review of the competence on their implementation and their feasibility and compatibility.
- Chapter 9: conclusion and final considerations.

2 METHOD

In this chapter, the methodology used in attempt to answer the research questions is described.

2.1 DATA GATHERING AND LITERATURE REVIEW

The first part of the project, concerning the description of the territory, climate, and socio-economic features of the Aosta Valley region, was carried out by performing a literature review and data collection about the state and trends of environmental conditions, economic activities as well as social structure. The major sources in this sense were:

- Web of Science – database for citation data
- ARPA Valle d'Aosta – Regional Agency for Environmental Protection (www.arpa.vda.it)
- ISTAT – National Institute of Statistics
- Regione Autonoma Valle d'Aosta – official administrative region (www.regione.vda.it)
- Other local agencies' documents – GAL, CREA, Espace Mont-Blanc, …

2.2 LEGAL AND ADMINISTRATIVE ANALYSIS

A legal research was made necessary for a dual purpose: firstly, to frame this study's content within its legal context, thus extending the knowledge of aspects of law and the operation of the legal system that are of interest this report's objectives; secondly, to have an overview of social, political, and economic implications of current and proposed legislation.

The first method uses is the so-called "black-letter" research, which aims to « *systematize, rectify and clarify the law on any particular topic by a distinctive mode of analysis of authoritative texts that consist of primary and secondary sources*[*] » (McConville and Chui, 2017).

The second method is the international and comparative legal research, which crosses traditional categories of law, in our case combining domestic law with European and international regulations. This facilitates the understanding of the international law and legal system and its impacts on the formulation of public policy at a national and local level, in an era of global interdependence.

A legal research was carried out to that end at several scales:

- Transnational and international: an analysis of the EU regulations in the areas of sustainable development and agriculture was carried out, together with the review of the objectives of the entire Alpine area united within the Alpine Convention;

[*] Primary sources are legislative and case law; they come from official bodies.
Secondary sources explain, interpret and analyze the law; they include legal dictionaries, legal encyclopedias, legal periodicals, law reviews, annotations, and treatises (Tufts University, 2021).

- National: the legal framework safeguarding the national landscape was examined, as well as the national Recovery and Resilience plan, with particular reference to the development of agriculture and the agenda for the adaptation to climate change;
- Local: within the regional directives, the Landscape Territorial Plan was reviewed, along with the regional strategies for the development of agriculture within the Rural Development Program for Aosta Valley.

2.3 INTERVIEWS

During the early stage of the project, three interviews were carried out with people working in different sectors and with different roles: research and administration, at a planning and management level as well as in close proximity with the local population. The involvement of different categories of respondents was meant to obtain relevant and up-to-date information, as well as give reliability and significance to the whole project work. Moreover, a direct contact with people was necessary to clarify their fears and hopes for the future, and their consequent needs and expectations.

For reasons of distance, leaving aside the context of global pandemic, it was not possible to meet in person; two interviews were carried out via video call (via Google Meet and Skype), and one telephonically. The average duration of the calls was about an hour and a half.

The methodology that was chosen for the involvement of the participants is the semi-structured interview. It stands at the middle of the interview methods range, which goes from structured to unstructured, with decreasing levels of flexibility. In fact, the first is based on a questionnaire to be asked in a certain way and order, as the interviewer is expected to not introduce any bias into the research and data, while the latter is based on the interaction between the interviewer and the interviewee. The semi-structured interview methodology maintains a guiding structure, in the form of an interview guide. It consists in a questionnaire with a list of questions concerning the topics the researcher wants to cover, thus requiring a previous knowledge of the research topic area. However, this alternative is characterized by a higher level of flexibility compared to a structured interview: the sequence and formulation of questions is not definite, and the interviewer has possibility to improvise follow-up questions and pursue a line of discussion that could open up during the dialogue. The interview guide is therefore developed for providing a guidance on what to talk about, but it is not meant to be followed strictly.

The importance of this method is ultimately to allow the interviewee to express their own perspective using words and mental structures they feel comfortable with (Bryman and Bell, 2011; Edwards and Holland, 2013; Kallio *et al.*, 2016).

Amongst the parties that have been contacted, three agencies have agreed to participate to this project, namely:

- ARPA Aosta Valley – Regional Agency for Environmental Protection

- Management Authority for the Agricultural and Natural Resources Council of Aosta Valley
- Bureau of land improvements – agricultural department

The overall structure of the interview and interview guide that has been prepared for each interviewee can be found in Appendix A. The material obtained has been used throughout the report, while a summary of the dialogues and related specific insights are reported in Chapter 5.

2.4 DEFINITION OF CLIMATIC AND SOCIO-ECONOMIC MODELS

Two models of the system in focus are presented, providing a synthetic but realistic overview of the problem and the underlying cause-effect relationships that determine its functioning. The first model comprises only how climate change impacts the physical environment, starting from the major climatic alterations regarding temperature and precipitation patterns, to get to understand their effects on ecological and environmental factors, namely: water availability, biodiversity and ecosystem services, and fertile land availability. The second model describes the cause-effect relationships between environment and human economic activities, with a special focus on the interactions between agricultural and tourism sectors.

The second model has been developed as a causal loop diagram, which serves the purpose of making a qualitative analysis of a complex system. The elements of the system are graphically connected using arrows that link the cause to the effect variables. A positive sign "+" indicates a parallel behavior of the variables, meaning that an increase in the cause generates an increase in the effect, while the negative sign "-" is put where there is an inverse linkage between the variables: the effect decreases for an increase in the cause variable. A reinforcing loop is created when the effect of a variation propagates through a cycle and reinforces the initial input; it is identified by a closing loop within the diagram, where all the arrows show the "+" (or "-") sign. A balancing loop is a cycle in which the same propagation happens, but it returns to the initial variable with an opposite deviation; in the diagram, arrows with both "+" and "-" signs are present in the loop (Inam *et al.*, 2015; Riva *et al.*, 2018).

2.5 CLASSIFICATION AND COMPARISON OF INTERVENTIONS

To allow evaluation and comparison, interventions were classified following several criteria. The first distinction was made based on the aim of the actions, in this case improving water availability, conserving biodiversity and ecosystem services, increasing fertile land availability and valorizing the cultural heritage of the region. A further classification was performed according to the decision maker responsible for the decision. In the context of this report, the decision makers were identified as the national and regional administrations, regional entities, farmers and private citizens.

Other classification criteria distinguish between structural and non-structural actions, which imply or not the physical modification of the system, such as the building of a civil engineering work or an infrastructure network.

Lastly, another distinction regards planning interventions, which are decided once and for all, and management ones, that are decided upon frequently and periodically. An example of the first is the location of a dam, while the decision over the type of crops and the cultivation zones can be a management one (Soncini-Sessa, Weber and Castelletti, 2007).

Some final remarks concern the evaluation of practical and economic feasibility of each intervention and their compatibility with one another. The role and implication of each actor's actions is pointed out as well.

2.6 LIMITATIONS

For reasons of coherence and clarity, the level of detail of the present report attempts to balance the need for a deep understanding of the described phenomena and the one to follow along the train of thought without losing sight of the ultimate meaning of this work.

With the same idea it was decided to adjust the comprehensiveness of the content to the aspects that resulted more relevant for answering the research questions. More specifically, the present study analyzes the agricultural sector and its expected responses to climate change, with a particular focus on the interaction with the touristic sector for the definition of the possible adaptation plans.

Further research could explore the possible symbiosis of Alpine farming with the renewable energy sector facing the challenges of climate change. In fact, green power production is a particularly developed field in Aosta Valley, producing over 80% of its energy with renewable sources, namely: hydropower, biomass, biogas, and solar.

Lastly, the analysis was carried out without considering the impacts of the current crisis related to the Covid-19 global pandemic, as it was assumed that within the timeframe selected its effects would be negligible compared to slower phenomena like climate change and socio-economic transformations that have long-term consequences. Also, food commodities are essential goods and suffered less from the global crisis, although mention was made of the economic instruments put in place by the EU and the national government for responding to it. Future analyses could integrate the socio-economic changes induced by the spread of the virus with the findings of this work.

3 STUDY REGION: AOSTA VALLEY

3.1 GENERAL DESCRIPTION

Aosta valley is a concentrate of nature and beauty, where the thousands shades of green of the forests and alpine pastures contrast with the white of the perennial glaciers and the grey of the rocky cliffs. But its landscape is far from being the only feature that makes this region unique.

First of all, it is the smallest region in Italy, and the least densely populated. It extends over 80 km in the east-west direction, and 40 km north south. Its territory is entirely located in the Alpine region, with an average altitude over 2,100 m a.s.l., and hosts the highest peaks in Europe: the Mont Blanc (4,810 m a.s.l.), Monte Rosa (4,634 m a.s.l.), Matterhorn (4,478 m a.s.l.) and Gran Paradiso (4,061 m s.l.m.) are only a few of the over 20 peaks that surpass the altitude of 4,000 m a.s.l (Regione Autonoma Valle d'Aosta, 2006; ISTAT; IMONT, 2007; naturaosta.it, 2015).

The region borders to the North with Switzerland and to the West with France, while to the East and South it is bordered by the Italian region Piedmont (Figure 1).

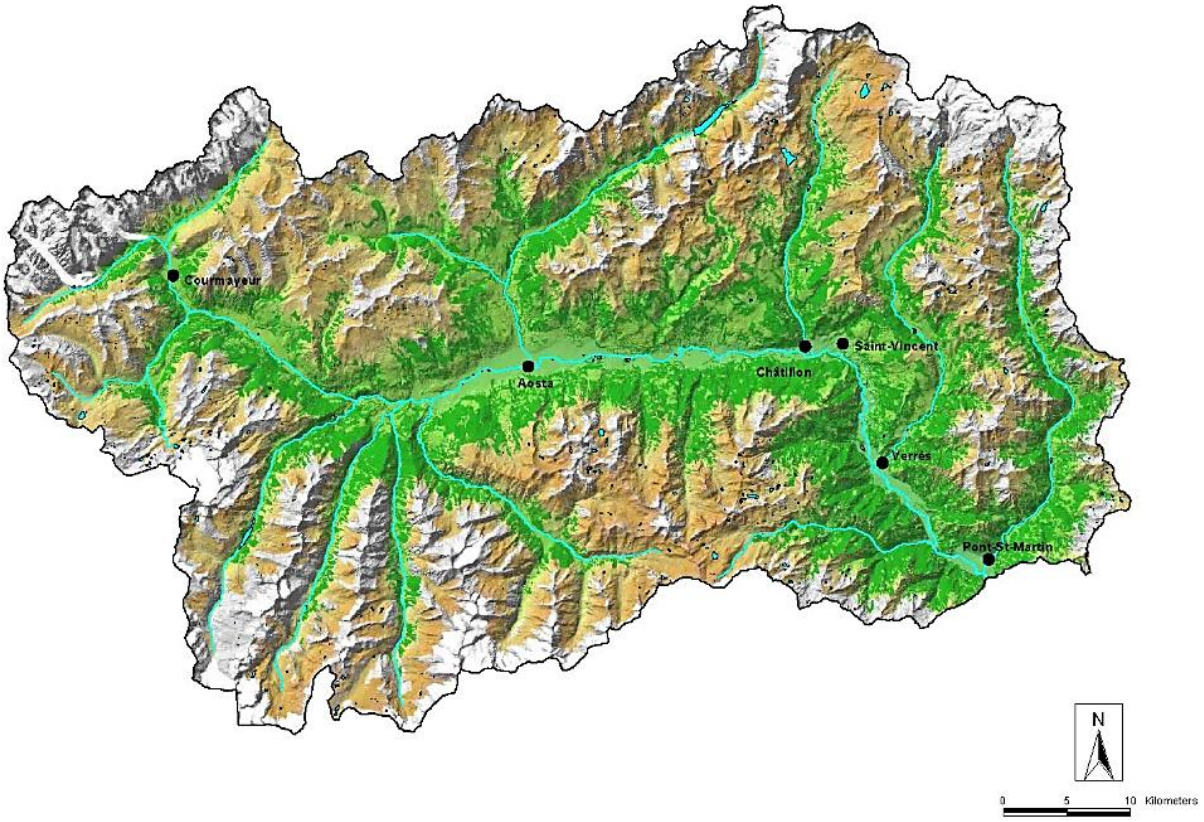

Figure 1 – Aosta Valley (Regione Autonoma Valle d'Aosta, 2006)

The orography of this mountainous region is characterized by steep slopes, oriented in different directions thus affecting the daily and seasonal insolation, with few flat areas. That, combined with the harsh climatic conditions and the relatively scarce annual precipitations, makes agricultural land

limited to 18% of the territory, while the rest of the region is occupied by mountains and glaciers, or covered by forests (EAFRD, 2020).

The river Dora Baltea, a tributary of the Po, flows in the central deep valley and marks the border between the *adret* and the *envers*, respectively the south and north facing mountain slopes, characterized by different microclimatic conditions. The *adret*, the word for "direct" in the local dialect *patois*, is the left bank* of the river and the most exposed to the sun; it generally hosts the grasslands and pastures, while the *envers* (meaning "reverse") is more in the shade and mostly covered with forests.

The region hosts Mont Avic Natural Park and Gran Paradiso National Park, which is the first national park in Italy, alongside with 10 natural reserves and 4 botanical gardens. They were created for protecting this region's biodiversity: the 62 habitats that have been counted, of which 8 of priority interest, testify to the richness in biodiversity of the region, not to mention the remarkable abundance of mid and large size mammals like marmots, chamois, ibex (GAL Valle d'Aosta, 2020; Osservatorio della Biodiversità - VdA, 2020).

Aosta, the regional capital and the only urban area in the region, is situated in the central river valley, where 76% of the population and 71% of the enterprises are concentrated. However, urban centers are scattered throughout the regional territory, with over 1200 historical settlements. Aosta Valley accounts for 2% of the national resident population, and regional residents are slowly dwindling due to a negative population growth rate and negative net migration. This contributes to the abandonment of the marginalized valleys and villages, where some pastures are experiencing recolonization by shrubs and forests (GAL Valle d'Aosta, 2020).

3.2 ADMINISTRATION

Due to the conformation of the territory and the settlement distribution within Aosta Valley, the administration of the region involves players on multiple levels, from the regional to the local scale: regional administration, Unités des Communes valdôtaines, municipalities.

- **Region.** Aosta Valley is a region with its own special status: Italian Constitutional Charter in Article 116 grants it specific forms of autonomy regarding administrative and legislative matters, by reason of its geography and history. The most eloquent form of autonomy is displayed in the bilingualism of the region, where francophone culture is considered equal to Italian and is legally safeguarded. Other special laws pertain the assets of the state, like forests and caves, which are transferred to the region; moreover, public waters have been given in free concession to the Aosta Valley administration for 99 years, from 7th September 1945, with the possibility of renewal. For this reason, waters for public use or irrigation are not subject to tax (Consiglio Regionale della Valle d'Aosta, 2018; Camera dei Deputati, 2021).

* Left bank: defined from the perspective of an observer looking downstream.

- **Unités des Communes valdôtaines.** Set aside the only relatively big urban settlement and regional capital Aosta, the region is divided into 8 sub-regional administrative areas, called *Unités des Communes valdôtaines*, or Unions or the communes of the Aosta Valley (Figure 2). The main function of these agencies is to coordinate the activities of the municipalities, as well as to represent the interests of their territories towards the region (ISTAT; IMONT, 2007; Unité des Communes valdôtaines Évançon, 2015).
- **Municipalities.** The lowest level of the local authorities are the communes, which are meant to administrate the interests of the local community. Aosta Valley counts 74 municipalities, each of them having a mayor and an administrative council. The most populated one is Aosta, which is the only urban area in the region, while 60% of the rest of the others count less than 1,000 inhabitants (ISTAT; IMONT, 2007; GAL Valle d'Aosta, 2020). These are classified into two categories:
  - ⇒ Marginal Rural Areas – 36 municpialities that, for their geographical location, have more commercial and/or touristic characteristics.
  - ⇒ Particularly Marginal Rural Areas – 37 municipalities in middle and high mountains, which are excluded from the main touristic areas and have strong rural features.

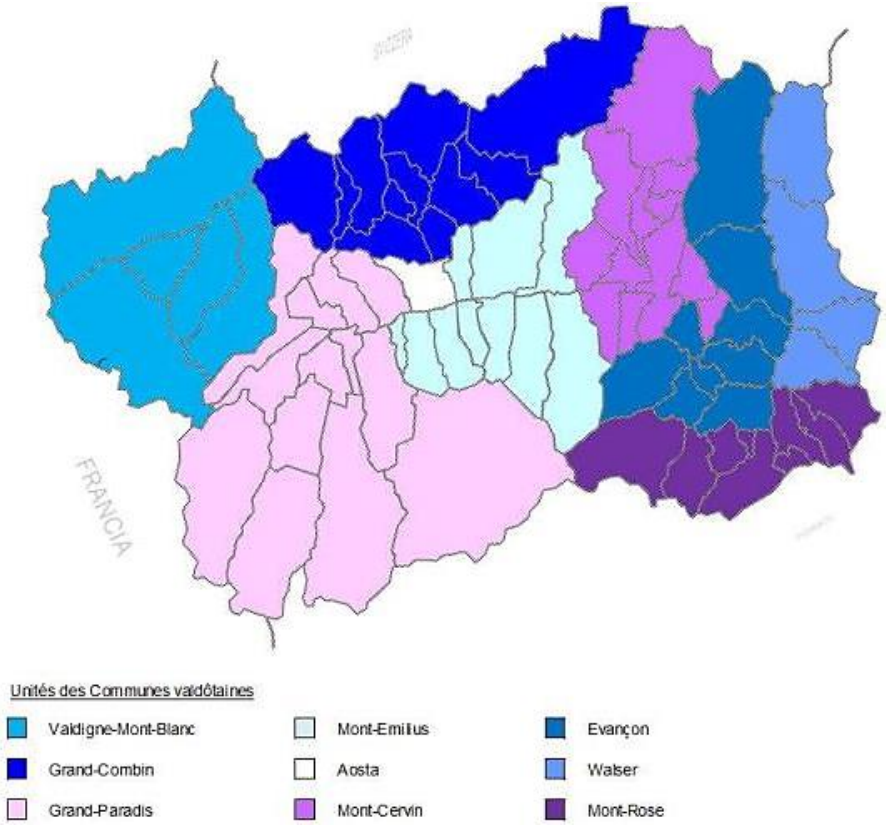

Figure 2 – Subdivision of Valle d'Aosta in communes and unites des communes (Regione Autonoma Valle d'Aosta, no date)

3.3 TERRITORY AND CLIMATE

The mountainous nature of Aosta Valley and its complex morphology determine the variety of climates and landscapes that characterize the region. A great amount of land surfaces is located at very high altitudes: around 80% of the territory is over 1,500 m a.s.l. This results in almost 40% of the regional land surface is occupied by mountain peaks and glaciers, and another 51% covered by pastures and forests, leaving a mere 9% to human settlements (Regione Autonoma Valle d'Aosta, 2006).

3.3.1 Hydrology

The tectonic uplift during the Alpine orogeny formed the high peaks and shaped the deep central valley which crosses the region east-west, where the river Dora Baltea flows. The latter is a tributary of the Po, the longest river in Italy. Side valleys generally have a north-south orientation and were eroded by the tributaries of Dora Baltea and secondary water streams or shaped by glaciers during ice ages.

High-elevation mountain catchments play an important role in mountain hydrology: they recharge both underground and spring waters, with inputs coming from snowmelt in late spring to summer and from rainfall during autumn and early winter. The presence of glaciers at high altitudes greatly determines the typical annual river regime, with minimum discharge during winter season and peaks during the summer ablation of the ice deposits (de Jong, 2015; Cremonese *et al.*, 2019).

The region also counts 707 lakes, natural and artificial, the latter being water storage basins. Where possible, the outflow is regulated in order to meet the needs of several downstream users: local population with domestic and industrial use, agriculture, hydropower production, and downstream ecosystems. The aggregate capacity of the major artificial reservoirs barely exceeds 200 Mm^3.

The quality of surface water bodies is generally good or very good, with a minimal percentage of waters classified in poor state in the most anthropized areas (Figure 3).

Underground water manifests itself mainly in the form of water springs. The presence of springs is widespread throughout the territory, with an overall number of over 5,000 spill points. Their waters are used for multiple purposes, from irrigation to human drinking, from industrial to firefighting (Regione Autonoma Valle d'Aosta, 2006; ARPA, 2016).

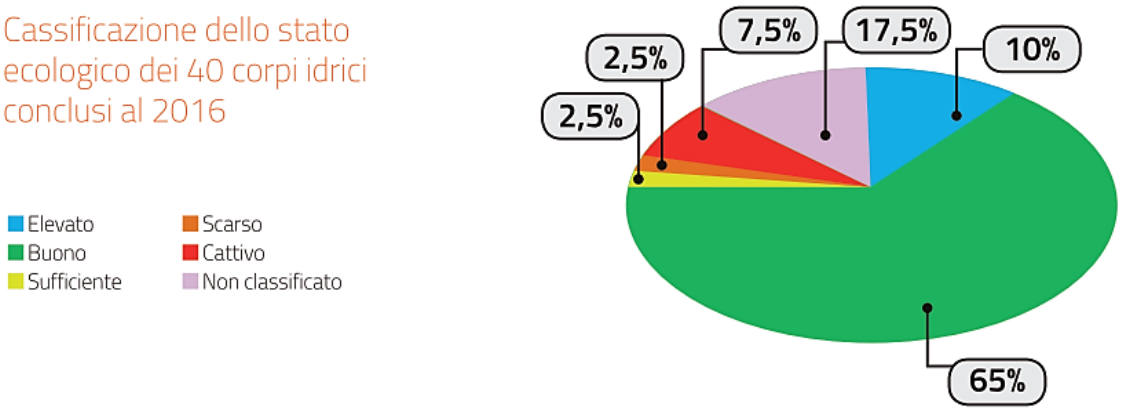

Figure 3 – Classification of environmental state of superficial water bodies in Aosta Valley, ranked as high, good, sufficient, poor and bad (blue to red). The last category is non-classified (ARPA, 2016)

3.3.2 Insolation and climate

The river Dora Baltea marks the border between the *adret* and the *envers*, characterized by different microclimatic conditions and consequently different predominant vegetation. The *adret*, the word for "direct" in the local dialect *patois*, is the south-facing slope identified with the left bank of the river, and the most exposed to the sun: it generally hosts the grasslands and pastures, as it is hit with the sun's rays with inclinations close to 90° and high calorific power. On the contrary, the *envers*, meaning "reverse" in *patois*, is more in the shade and mostly covered with forests (Figure 26, Appendix B). In fact, this mountainside is characterized by little inclinations of sun rays and no direct sun for several months a year, resulting in being covered with snow for longer periods and being less suitable for agriculture.

Strong temperature differences are registered between winter and summer seasons and at different elevations, with typically continental climate in the valleys and alpine climate above 2,400 m a.s.l., where the precipitation is often converted in snow. Annual precipitations are generally scarce, winter temperatures are often below 0°C while summers are sultry and not particularly windy (Regione Autonoma Valle d'Aosta, 2006; GAL Valle d'Aosta, 2020).

3.4 ECONOMY: THE IMPORTANCE OF AGRICULTURE

Aosta Valley is amongst the regions in Italy with the highest level of individual wealth, with a GDP per capita that is 26% higher than the national average, amounting to € 34,949 in 2016. Also, the percentage of families below relative poverty threshold* are far less than the Italian average: 4.4% of the total, compared to the 12.3% in the country. Primary sector (agriculture, forestry and raw material extraction) contributes to the region's added value for only 1%, while employing the 3.8% of the working population; another 25,6% work in the secondary sector (manufacturing) and 70,6% in

* Poverty line: *"An income level that is considered minimally sufficient to sustain a family in terms of food, housing, clothing, medical needs, and so on"*. (Shim and Siegel, 1995)

the tertiary (services), especially in activities related to tourist accommodation and recreational services (ISTAT; IMONT, 2007; CREA, 2019b).

Despite the limited revenue and employment rate in agriculture in the region, traditional practices like seasonal Alpine grazing and the small-scale farming practices are fundamental for maintaining the typical character of the landscape and the provision of essential ecosystem services. Moreover, the local cultural identity is deeply rooted in the agricultural traditions and products, which are considered to be among the most important features determining the future development of the Alpine regions (Brunner and Grêt-Regamey, 2016).

3.4.1 Agricultural enterprises

The rural communities in Aosta Valley rely on the traditional farming practices for sustaining their livelihoods. In the region's agricultural sector, the entrepreneurial fabric consists of small or very small family farms, where only 8% of the businesses employs workforce outside the family. However, the sector is experiencing a process of reduction in the number of farms and concentration of pasture surfaces and heads of cattle, leading to the creation of agricultural enterprises that are more relevant in terms of both physical and economical dimensions. Looking at statistics, the number of farms present in Aosta Valley has shrunk by over 45% between 2010 and 2016, while in the same period the utilized agricultural land has decreased only by 4.9%. (CREA, 2019b; EAFRD, 2020; GAL Valle d'Aosta, 2020).

It is interesting to highlight that, unlike what happens in most Italian regions, the predominant mode of acquiring a land surface for agricultural purposes is rent rather than ownership: 89% of the utilized agricultural land is either rented or given free of charge.

Caratteristiche strutturali dell'agricoltura valdostana e italiana

	Valle d'Aosta	Variaz. % 2013-2016
Aziende agricole (n.)	2.320	-17,2
Superficie agricola e Forestale - SAT (ha)	108.687	3,6
Superficie agricola utilizzata - SAU (ha)	52.856	0,0
Lavoratori nelle aziende agricole (n.)	5.490	-5,2
- di cui familiari (n.)	4.643	-12,5
Giornate di lavoro totali (000)	822	5,0
- di cui familiari (000)	741	2,8
SAT media per azienda (ha)	46,85	25,2
SAU media per azienda (ha)	22,78	20,8
Lavoratori per azienda (n.)	2,37	14,5
Giornate di lavoro per azienda (n.)	354	26,8
Giornate di lavoro /SAU (n.)	16	5,0
Giornate lavorative familiari (%)	90,2	-2,1

Fonte: ISTAT, SPA 2016

Figure 4 – General data about agricultural sector in Aosta Valley (CREA, 2019b)

Looking at economic data, in 2019 the value of agro-pastoral production within the region was 98.5 M €. However, there is a problem of poor remuneration of farm activities, combined with the high

investments that are necessary in this type of terrains due to the altitude and the difficult topography. In fact, high production costs are linked to problems that are characteristic of mountain landscapes, like poor accessibility for machinery, lower productivity due to steep slopes, higher edification costs. Figure 5 gives an idea of the comparison between the cost of fixed investments in Aosta Valley and the national average. Moreover, the small scale of family farms precludes them from benefitting of the savings offered by an economy of scale. The cost of milk is an eloquent example of how disproportionate revenues are if compared to costs: the price of 100 kg of milk at the farm is 50 €; the production cost of the same quantity of milk ranges between 60 and 85 €, depending on the farm typology (CREA, 2019b; EAFRD, 2020).

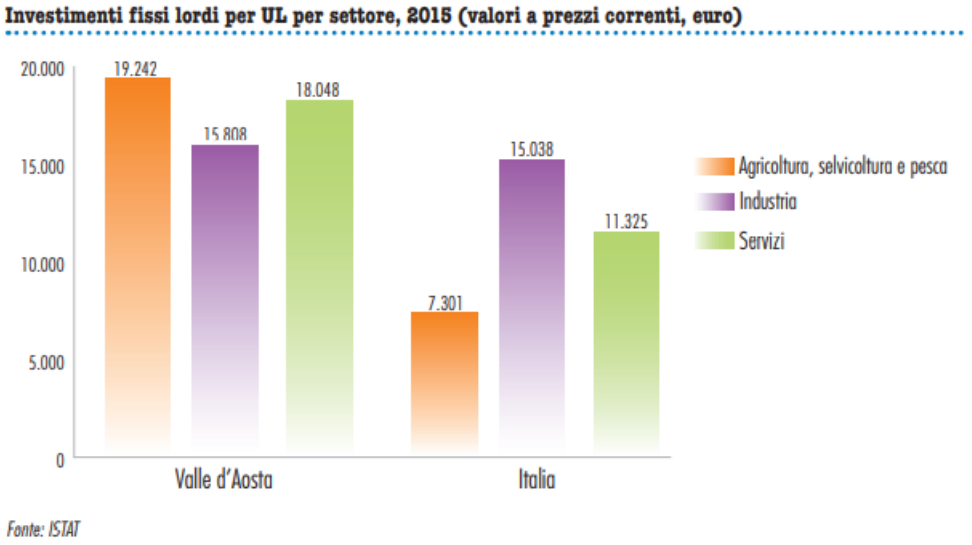

Figure 5 – Comparison of fixed investment costs between Aosta Valley and Italy, divided by economic sector (CREA, 2019b)

However, the family agricultural work is often carried out alongside other activities (53% of the workers in the sector), while over 10% of the farms also operates in other sectors, mostly in the animal products processing industry or agro-tourism. Tourism can truly represent an excellent opportunity for business diversification and a means to sustain livelihoods in rural mountain areas. In fact, agritourism activities are still relatively poorly developed in Aosta Valley if compared to other regions with similar potential: only 15% of farms also has extra-agricultural activities, a small number in relation to the province of Bolzano, in Alto Adige, where the percentage reaches the 56%. It is also interesting to notice that 96% of beds in tourist infrastructure is located in rural areas, where nowadays agriculture often represents the only employment opportunity (CREA, 2019a; EAFRD, 2020).

3.4.2 Typical crops and agri-food products

Agricultural development is highly reliant on, and limited by, the complex orography of the region; as a consequence, cultivations are little diversified and almost exclusively present in the form of permanent pastures. In fact, forage production represents 97.7% of the regional agricultural land and is distinguished between 84% of mountain pastures at medium-high altitudes (1,800 to 2,600 m

a.s.l.) and 16% of haymaking lands on the valley floor. The agricultural land that is not devoted to grazing or haymaking is used for horticulture and viticulture, which produces red and white wines with PDO status (CREA, 2019b; EAFRD, 2020; GAL Valle d'Aosta, 2020).

As it was described, the regional agriculture is deeply connected with farming activities, which are unique in three ways: the management system of the permanent grasslands for pasture, the cattle breed *Valdostana,* and the traditional agri-food products.

The *Valdostana* breed of cattle (in its varieties Pezzata Rossa, Pezzata Nera, Castana) is autochthonous and well adapted to the alpine environment; however, it is characterized by low milk productivity, averaging a yearly production of 3,750 liters of milk per cow, which is less than half of what a *Frisona* breed produces. In recent years, the breeding of other animals like sheep, buffalos and especially goats is expanding, although volumes of milk from the latter productions are still limited (Figure 6).

Seasonal transhumance is the traditional practice of migrating the bovines to summer pastures from June to September/October, and it is still in use for around 80% of the heads of cattle, although this number is shrinking in recent years. Around 300 mountain pastures can be counted throughout the region, located at altitudes of 1,400 to 2,800 m a.s.l. and destined for summer grazing of dairy cows for a period of 100-120 days. This allows to replenish stocks of fodder in the valleys, for feeding the cattle during winter. This is necessary for granting the PDO status to the Fontina cheese that is produced (CREA, 2019b; EAFRD, 2020; GAL Valle d'Aosta, 2020).

Fontina DOP is the most well-known agri-food product typical of Aosta Valley; it is a semi-cooked fat cheese made from whole cow's milk, produced in over 350,000 9-kg cheese wheels every year (Figure 7). Other products with a designation origin are Formadzo, Lard d'Arnad, and Jambon de Bosses, respectively a cheese and two typologies of processed meat.

	Latte raccolto (q)	Variaz. % 2017-2016
Latte di vacca	234.334	-0,2
Latte di pecora	-	-
Latte di capra	846	57,8
Latte di bufala	-	-
Totale	**235.180**	**0,0**

Fonte: ISTAT

Figure 6 – Milk production in Aosta Valley per typology of livestock (cattle, sheep, goats, buffalo) and relative variation between the years 2016-17 (CREA, 2019b)

Anni	Numero di forme presentate al Consorzio per la marchiatura	di cui:		
		Fontina	Formaggio Valdostano	Scarto
2011	428.326	389.984	35.980	2.362
2012	426.159	382.406	40.948	2.805
2013	429.932	388.235	39.987	1.710
2014	441.310	393.776	46.122	1.412
2015	406.038	363.544	41.308	1.186
2016	406.820	371.768	34.837	215
2017	424.858	329.937	31.440	481

(*) relativamente al peso si stimano circa 9 kg per forma

Fonte: Consorzio Produzione e Tutela della DOP Fontina

Figure 7 – Number of farms for typical regional agri-food products: Fontina and Formaggio Valdostano, and the number of cheese wheels that did not receive the DOP certification (CREA, 2019b)

4 DESCRIPTION OF LEGAL AND ADMINISTRATIVE CONTEXT

The document *The Future We Want*, which was the outcome of the 2012 Rio+ Conference, encourages coordinated regional actions for promoting sustainable development, as it recognized the importance of the regional frameworks in complementing action at a national level. National policies, in turn, follow international directives, especially in the context of the European Union. As for mountain regions, policy systems regulating land use and the provision of ecosystem services are necessarily multi-sectorial and multi-level, as the territories and the people who live in them are inextricably linked in a complex network of interactions, benefits and services (United Nations, 2012; Balsiger and Debarbieux, 2015; Brunner and Grêt-Regamey, 2016).

With this in mind, it is crucial to have a clear idea of the existing policies and directives regarding the management of agriculture and development of mountain areas. A general description of the legal and administrative framework was carried out at several levels: international, national, and local.

4.1 TRANSNATIONAL AND INTERNATIONAL LEVEL

The transnational level refers to the EU objectives and regulations, while international initiatives are the ones undertaken with the cooperation of more than one national country.

4.1.1 European Green Deal and the new CAP

In 2019, the newly elected European Commission under Von der Leyen presidency presented the European Green Deal for the EU, a set of policy proposals which outline the new strategy for relaunching economic growth and competitiveness for the coming decades. It also demonstrates the Commission's commitment to tackling environmental challenges and the willingness to build a more prosperous and fairer society. The plan includes concrete actions to reach climate neutrality by 2050, decoupling of growth from resource use by moving to a circular economy model, and restore biodiversity and cut pollution (European Commission, 2019).

With regards to the EU's food system, the main goals are to reduce the environmental and climate footprint, leading a global transition towards sustainable food chains by creating new business opportunities while ensuring food security and building system's resilience (Figure 8).

Figure 8 – EU's goals regarding the future of European food systems

The Green Deal covers all sectors, amongst which farming and agri-food have a crucial role in several key policy areas:

- Farm to Fork: a strategy for building a sustainable food system, both by building a food supply chain that is sustainable throughout all its phases, production, processing and distribution, and by providing advisory services, data and knowledge-sharing for fostering research and innovation and enabling the transition (Figure 9).
- Biodiversity: protecting and enhancing the variety of plants and animals in the rural ecosystem.
- Climate action: contributing to achieve the goal of net-zero emissions in the EU by 2050.
- Zero pollution action plan: safeguarding natural resources like water, air, and soil.

Figure 9 – Illustration of the action plan of the Farm to Fork strategy. Source: European Commission

All these policies are specifically addressed by the Common Agricultural Policy (CAP), which promotes and coordinates the development of the agricultural sector within the EU. The objectives of said regulations are to stimulate the transition towards a more modern, efficient, and sustainable food production system. The CAP is structured in two funds, or *pillars*: the European agricultural guarantee fund (EAGF) and the European agricultural fund for rural development (EAFRD).

The set of policies is revised and updated every seven years in order to adapt to the changing economic and geopolitical context in which it applies. The new CAP will be implemented from 1 January 2023 and shall remain in force until 2027; the years 2021-22 serve as a transitional period from the 2014-2020 legislation to the new, and the existing CAP continues to apply. The budget allocated for the CAP is 378.5 billion euros, corresponding to the 30.9% of the total EU's long-term budget for 2021-2027. Such expenditure testifies that agriculture is a priority within the European development strategy despite the advent of new priorities for the EU in the past decades (Figure 10). The EAGF is allocated 291.1 billion euros; the remaining 87.4 finance the EAFRD. Another 8.1

billion euros will be added to the latter, coming from the Next Generation EU recovery fund (Assessorato Agricoltura e Risorse naturali, 2017; European Union, 2021).

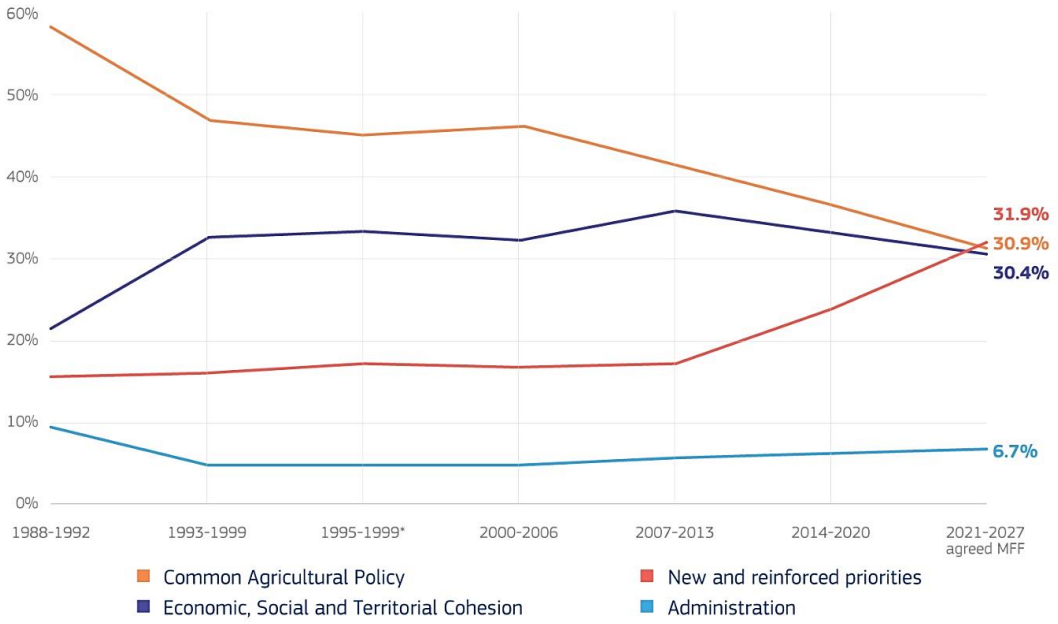

Figure 10 – Share of the main policy areas in the multiannual financial frameworks (European Union, 2021)

4.1.2 Alpine Convention

The Alpine convention is an international treaty that was created for the protection and the sustainable development of the Alps. It was signed by the eight Alpine countries, Austria, France, Germany, Italy, Switzerland, Liechtenstein, Slovenia and Monaco, and the European Union.

It is a legally binding sustainability instrument that has the aim of safeguarding the Alpine ecosystems and the regional cultural identities and traditions. It is the first example of a transnational treaty of this kind, and came into force in 1995 (Alpine Convention, 1999).

Challenges related to climate change are being tackled through action on mitigation and adaptation, focusing on multiple policy sectors, such as economic development, spatial planning, transport and agriculture. The regional cultural identities, heritage and traditions are appreciated and will be maintained, as they are said to be recognized as an asset that can be used for reaching development goals (Permanent Secretariat of the Alpine Convention, 2017).

About sustainable land use and farming, the Alpine convention includes the followings in its list of objectives (Alpine Convention, 1999):

b. Spatial planning: to ensure the harmonious development of the whole region and the rational use of land.
d. Soil conservation: reduction of qualitative and quantitative soil damage by applying proper agricultural and forestry methods.
f. Conservation of nature and the countryside.

g. Mountain farming: maintain the management of land traditionally cultivated with a system that suits local conditions.
h. Mountain forests: preserve, reinforce and restore the protective role of forests.

4.2 NATIONAL LEVEL

At the national level, the priorities are protecting the territory and at the same time encouraging innovation and competitivity in strategic sectors, by fostering an ecological transition of the current economic paradigm towards a more sustainable model, including in agriculture.

4.2.1 Landscape protection

The concept of landscape has evolved throughout history. The European Landscape Convention in 2000 defined landscape as « *an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors* » (Council of Europe, 2000).

The Italian Constitution in Article 9 asserts the duty of the Republic to protect the national landscape (Senato della Repubblica, 1947). Two laws in particular regulate the protection of the landscape, and they are outlined below.

- Legally protected areas (*"aree tutelate per legge"* – art. 142 D.lgs 42/2004)

The cited law introduces restrictions over land use, declaring as protected specific features of the landscape, including:

- *Mountains for the part exceeding 1.600 m a.s.l. for the Alpine range […];*
- *Glaciers and glacial cirques;*
- *Parks and national and regional reserves, as well as external territories for park protection;*
- *Territories covered by forests and woods, albeit hit or damaged by fire […].*

- Immovables and areas of major public interest (*"immobili e aree di notevole interesse pubblico"* – art. 136 D.lgs 42/2004)

This article defines the assets of historical, cultural and natural interest:

- *Immovables with substantial character of beauty or geological uniqueness;*
- *Villas, parks and gardens […] that stand out for their beauty;*
- *Complexes of buildings that compose a characteristic aspect having aesthetic or traditional value;*
- *Beautiful sceneries considered like paintings and also viewpoints and belvedere, accessible to the public, from which it is possible to enjoy the spectacle of those beauties.*

All the mentioned area are protected in order to guarantee their conservation in the interests of public use.

4.2.2 National Recovery and Resilience Plan

In line with the Green New Deal, Italy shares the European effort towards the decarbonization of the economy and the recognition of the environment as the driving force of the economy (Ministero dello Sviluppo Economico, 2019). However, the country is experiencing a slow growth in comparison to e.g. France, Germany and Spain. Moreover, Italy suffered the consequences of the Covid-19 pandemic more than other European countries: it was hit earlier and harder by the health crisis, and by economic turndown – in 2020, the GDP shrank by 8.9 %, while the average in the EU was 6.2.

The EU responded to the crisis dictated by the pandemic with the Next Generation EU (NGEU) program, which comprises two main instruments: Recovery and Resilience Facility (RRF), and ReactEU. The funds borrowed may be used for loans up to an amount of EUR 360 billion in 2018 prices and for expenditure (grants) up to an amount of EUR 390 billion – Italy is the main beneficiary of RRF funds, 122.6 billion to be spent in the 2021-2026 period, which the country plans to make full use of (European Council, 2020; Consiglio dei Ministri, 2021).

The RRF instrument requires the member states to present a reform and investment package: the National Recovery and Resilience Plan. For Italy, it articulates in six *Missions*, coherent with the six pillars of the NGEU: digitalization, innovation, competitivity, culture and tourism; green revolution and ecological transition; infrastructure for sustainable mobility; education and research; inclusion and cohesion; health.

Within *Mission 2*, titled Green revolution and ecological transition, among others are specified the objectives of circular economy and sustainable agriculture, as well as preservation of the territory and water resources. As for the first, the aim is to develop smart and sustainable food supply lines. The "from producer to consumer" strategy states that farmers must transform more rapidly their production means, utilizing new technologies and digitalization to attain better environmental performances and increase climatic resilience, and funds will be used for the upgrade of machinery and the introduction of precision agriculture techniques. Regarding the preservation of the land, it is intended as hydrogeological risk mitigation, safeguard of green areas and biodiversity, removal of contaminants in waters and soils, and availability of water resources. The intervention in this sense will be measures of prevention and restoration of land stability, urban reforestation and digitalization of parks, and the renovation, upgrading and completion of infrastructure for diversion, storage, and supply of waters throughout the national territory.

4.3 LOCAL LEVEL

The strategies at the regional scale reflect the national objectives with reference to landscape preservation and economic development, with more specific and detailed directives and action plans.

4.3.1 Local agencies

For understanding the means of action at the local level, it is important to have an overview of the public and private agencies that assist the regional and municipal administrations in the effort of

designing a coherent development strategy for the territory of Aosta Valley. Among the agencies are included:

- **CELVA.** The activities of the local agencies within Aosta Valley are supported by CELVA, or Consortium of Local Agencies of Aosta Valley, which comprises of 72 communes (all the regional municipalities except Aosta and Courmayeur) and 8 trade associations (ADAVA, Coldiretti, AREV, VIVAL, Fédération des Coopératives valdôtaines, CNA, Confcommercio e Confindustria). The consortium offers services linked to formation, consulting, technical and legal assistance for the implementation of local territorial governance (CELVA, 2017, 2018).
- **GAL.** The Group of Local Action (GAL – *Gruppo di Azione Locale*) is an organization with the primary goal of coordinating and implementing project for the valorization of the territory, focused on sustainable tourism. The projects are funded by the EU, within the Rural Development Programme (see chapter 4.3.2).
- **Land improvement consortia.** In Aosta Valley there are 176 consortia for land improvement, established by royal decree in 1933 and active on a local context, which are responsible for the realization and maintenance of land improvement works. This translates in the construction of irrigation systems and maintenance of the existing infrastructure (the historical "*rus*" network), research and utilization of waters for irrigation, improvement in quality of terrains and pastures, building and renovation of country roads and farm buildings (Consiglio Regionale della Valle d'Aosta, 2001).

4.3.2 Landscape Territorial Plan

A landscape plan performs a guideline and coordination function with respect to the planning of the municipal territories and of the sectors of regional competence, such as agriculture and forests, transport, infrastructure, urban planning.

In Aosta Valley, the development will be based on the conservation and valorization of the natural and cultural heritage. In fact, the mountainous nature of the territory inevitably links the landscape and environmental conservation with economic and social development, by reason of the exceptional importance that the sectors of tourism and environmental resources have for the region (Regione Autonoma Valle d'Aosta, 1998).

The objectives stated in the Landscape Territorial Plan are: improvement of the efficiency of the territory, in terms of infrastructure network, for a better interregional and international connection; increase in equity of the land use, with regard to better and more equal living conditions and opportunities for all local communities; preservation and enhancement of the quality of the territory, for the valorization of the image and culture of the region.

For attaining said objectives, policies based on the passive conservation appear inadequate; the Plan offers a guideline in this sense, providing directives in the forms of *modes of action*:

- Conservation: of natural resources and processes, of landscapes, of cultural heritage;

- Maintenance: of the assets listed above, also through restoration and also minor physical modifications;
- Restoration: of environmental conditions of degraded sites, of monuments and historical sites that have been abandoned or misused;
- Requalification: for the valorization of the existing resources and heritage, also through significant construction and urban renovations which do not overload the urban and environmental setting;
- Transformation: introducing major modifications of the existing resources and heritage, also with substantial construction and urban renovations.

4.3.3 Rural Development Program for Aosta Valley

The Rural Development Plan (RDP), which represents the second pillar of the CAP, is specified at a local level for meeting the particular needs of each area. In the past years, local objectives were set at a regional level, while the current idea for the 2023-27 period is to set a general strategy between the EU and the national governments, which are then responsible for the dialogue with the single regions. From the moment that the current system allows for the identification of objectives that are specific for every region in the direct dialogue with the EU, Aosta Valley will try to oppose this resolution, in the hope of making its territory's voice heard better and have a greater force.

As the objectives for the new RDP are still being discussed, the ones set for the current period are still valid, and concern environmental protection and economic development.

- Environmental protection:
  - Maintenance of farms on the territory
  - Valorization of traditional extensive agricultural practices
  - Safeguard of ecosystems linked to agriculture
  - Prevention of soil erosion
- Economic development:
  - Modernization of farms for increasing competitivity
  - Diversification of activities, in particular towards agritourism
  - Support for young people entering farming

Three typologies of interventions are planned: measures that require an investment, such as the support for the participation to quality schemes (see chapter 7.4.1) and for the environmental and landscape restoration; area or animal based measures, which are funds for farmers in mountain areas, for organic farming and for compensating Natura 2000 surfaces. These top-down measures will be complemented by grassroot initiatives by the citizens: a minimum of 5% of the resources coming from the EU will be dedicated to the so-called Leader approach.

The Leader strategy is a participatory one, where the GAL, through the dialogue with CELVA, develops strategies based on the regional objectives and the specific needs that emerge locally. It then develops invitations to tender for the financing of said projects, that generally involve the touristic sector, as sustainable tourism is recognized as strictly connected with the development of

the agricultural contexts. Private parties of microenterprises that win the invitations to tender are the recipients of the funds, and their investments contribute to the revival of the region (GAL Valle d'Aosta, 2020).

PART II: PRACTICE

5 EMPIRICAL FINDINGS

The outcome from the interviews was valuable in two ways:

- Important data and documentation were provided by the agencies that accepted the collaboration;
- General information was shared, together with more personal insights and viewpoints.

While the documents have been used as literature sources throughout the report, here are condensed the main takeaways from the dialogues with ARPA, the management authority for the agricultural and natural resources council of Aosta Valley, and the spokesperson for the bureau of land improvements.

5.1 INTERVIEW WITH ARPA – AOSTA VALLEY

The interview was carried out with a researcher working in the *Physical Agents* sector of Aosta Valley's environmental protection agency. His field of studies is the effects of climate change on the territory; he works with the monitoring and analysis of plant phenology and CO_2 fluxes in pasture and forest systems, snow hydrology and of permafrost monitoring.

He described the agricultural sector in Aosta Valley, and how different approaches are necessary when analyzing different crops: viticulture has a lot to do with innovation and technology, it is economically profitable and is likely to be heavily affected by climate change with extreme events, the increased pest growth and so on. However, a small circle of farmers works in this field, as the great majority of people employed in the primary sector are engaged in alpine agriculture and pastoralism. The latter has a greater impact on the territory, in terms of extension as well as positive externalities for mountain areas, and it is deeply connected with the social and cultural life of the region; however, it makes up only around 2% of the region's GDP.

The researcher argued that this ambivalence of pastoralism, which is important for the landscape and culture but not as central economically, paves the way to several questions, like: would it be desirable to let people abandon the cultivated pastures and dedicate themselves to other activities? On one hand, woods would be able to recolonize the areas, also contributing to uptake CO_2 from the atmosphere and mitigate the effects of climate change; on the other hand, the cultural heritage would be lost. Therefore, an economic analysis is not sufficient: an understanding of the sociological aspects and the ecosystem services provided by agriculture is necessary.

The numerical modeling approaches that have been developed in the recent years take into account the physics of the environment and climate change, but they lack an agronomist approach: they give no information on shifts in water distribution, dates for moving the herds, the paths to follow and so on.

During the interview, EU regulations and initiatives were touched upon, which have been described in chapter 4.1. For example, the need for more operational guidelines for farmers for accessing the funding, in order to avoid the risk to promote only cosmetic changes and not a real commitment of the sector to the EU directives.

Also, ongoing and planned initiatives were outlined, for example the Pastoralp project, reported in chapter 7.3.3.

5.2 Interview with the Management Authority for the Agricultural and Natural Resources Council of Aosta Valley

A description of alpine farming was provided by the representatives of the Agricultural and natural resources council of the region, but in different terms compared to the previous one. They focused on the quantitative data, offering an overview of the amount of agricultural land that is utilized, the main crops and cattle breeds, the number and dimension of the farms and the recent trends in this sense; all information has been already presented in chapter 3.4. They emphasized the fact that the traditional Aosta Valley's agricultural system is extensive rather that intensive: indeed, excluding local exceptions, the pressure on the environment is not heavy. For example, contamination of waters from nitrates is negligible, both for surface and underground waters, while this problem is relevant in all other regions of northern Italy where farming is more intensive.

According to them, given the overall good health of the alpine environment, the sustainable development strategy for the region should be to maintain the status quo, by preserving the pasture system and conserving the biodiversity heritage, both in agricultural and natural ecosystems. Human presence on the territory has a function of monitoring and defense of these fragile areas. The valorization of the high quality of the agricultural products would help this activity; this is why it is fundamental that the EU considers the uniqueness of this reality when deliberating on new regulations and directives concerning the agricultural sector.

Once again, the interview gave ample room to discussions about the new CAP that is being discussed in the EU council (see chapter 4.1), and the existing projects: from the EU strategies to the local grazing plans, described in chapter 7.

5.3 Interview with the Bureau of land improvements – agricultural department

A spokesperson for the bureau of land improvements was interviewed to talk about the role of the land improvement consortia in the monitoring and maintenance of the regional territory and infrastructure (see chapter 3.3), and also about the general state of the economy and agriculture in Aosta Valley.

He explained how the consortia come around only when there is a need for their intervention: if there is an obstruction on a marginal road, or there is a need for maintenance or construction of an irrigation system or another installation, they intervene by applying for a contribution. However,

large projects and major interventions, which could be the construction of a new canal or a storage reservoir, are extremely difficult to carry out. In fact, the funding provided to the consortia is limited, and the region cannot afford large investments.

It was explained that, without the region's interventions, many of the historical canals would have already been abandoned. This situation rises from the fact that, as mentioned in chapter 3.4.2, the land farmers work is rarely their own: on average, 89% of the agricultural land is either rented or given free of charge. Consequently, farmers are discouraged from making important investments on a land that they do not own, and the owners are reluctant to spend money for something they earn nothing for.

A large portion of the interview was dedicated to telling a brief story of the region, from the point of view of landscape and agriculture. In the Middle Ages, the sight would have been of a wild scenery, where mostly goats and sheep were farmed, as they do not require specific pasture maintenance. It was in those times that the irrigation network started to be built in order to bring water to the marginal fields. The main crop has been rye for several centuries, as it is not highly hydro-demanding and can grow on marginal terrains. During the industrial era, the landscape would have mostly appeared yellow and green: large parts of the woods were cut down to give space to the fields, also with consequences linked to slope instability and avalanches. Today, rye production has almost completely been replaced by grazing pastures, and cattle has slowly taken over goat and sheep farming. Woods are back in the scenery, which has become greener. Pastures make up the 98% of the agricultural land, thanks to the presence of the dense network of canals that are essential for their irrigation.

Some remarks were made about the economic situation: if in the '60s a farm owning 2 or 3 cows could be profitable, today that is impossible: every year the number of farms decreases while the existing ones become bigger. Still, the price of the milk often does not ever repay the cost of the high-quality feed that is necessary for the PDO brand. The "direct payments" provided to farmers by the EU as income support often make a real difference for the profitability of their work. Others choose to diversify their activities: some produce their own dairy products and have a side activity of retail, while others engage in agritourism. However, this is only possible if within the farm – therefore usually within the family – there is someone taking care of these activities, as the cattle farmers have very little time to dedicate to side activities.

6 CLIMATE CHANGE AND IMPACTS ON HUMAN ACTIVITIES

6.1 FUTURE SCENARIOS

The effects of climate change in mountain regions are already observable worldwide, and Aosta Valley is no exception. The current trend is a rise in temperatures in all seasons, and a change in the precipitation patterns; future scenarios foresee an intensification of said phenomena, and the consequent responses on the environment and the socio-economic network that will be further described in chapter 4.2 and 4.3. In the present chapter, the expected temperature and precipitation scenarios will be described using data from the studies that have been conducted for the *Espace Mont Blanc* initiative. Therefore, data relative to the Mont-Blanc massif will be used as indicators of the change in climatic conditions that interests the whole region.

For the *Climate Repot* drawn up for the project AdaPT Mont-Blanc, three different pathways for anthropogenic greenhouse gas emissions have been considered: a stringent mitigation scenario (RCP2.6), an intermediate scenario (RCP4.5) and a high emission scenario (RCP8.5) (IPCC, 2014; Cremonese *et al.*, 2019). A more detailed description of RPCs is provided in Appendix C.

6.1.1 Temperature

The rise in average temperatures that has been observed since the end of the 1980s is between 0.2 and 0.5°C per decade in the Mont Blanc area, with a registered value of 0.58°C every 10 years for Aosta Valley. In the coming decades, average temperatures are expected to rise differently for different elevation ranges: valley floor, mid mountain, and high mountain. As shown in figure 11, the warming is likely to be more pronounced at high altitudes, with seasonal peaks during spring and summer. In 2050, the summer 0° isotherm is expected to rise 300 m in elevation, reaching 4,100 m of altitude.

Climate change also entails an increase in extreme weather events, which is to say, larger deviations from the meteorological average. For instance, studies show that the length of heatwaves has already doubled in Western Europe in little more than a century, and the frequency of hot days has tripled (Brönnimann *et al.*, 2014). In the Mont Blanc area, the number of summer days per year is being monitored, which is an indicator that keeps count of the days when maximum temperatures registered are above 25°C. As displayed in figure 12, for scenario RCP4.5 this parameter is expected to increase to about three months in the valley floors by 2050, and to a full month in mid mountain elevations.

The number of ice days is another important parameter that counts the days when the maximum temperature does not exceed 0°C; it is used for monitoring the conservation of permafrost, glaciers, and snow cover layer. The RCP8.5 scenario in the figure 13 shows that, if no action is taken to reduce the GHG emissions globally, the number of ice days in high mountain elevations may decrease by over a month by 2050, compared to the average of 137 days registered in the period 1980-2010.

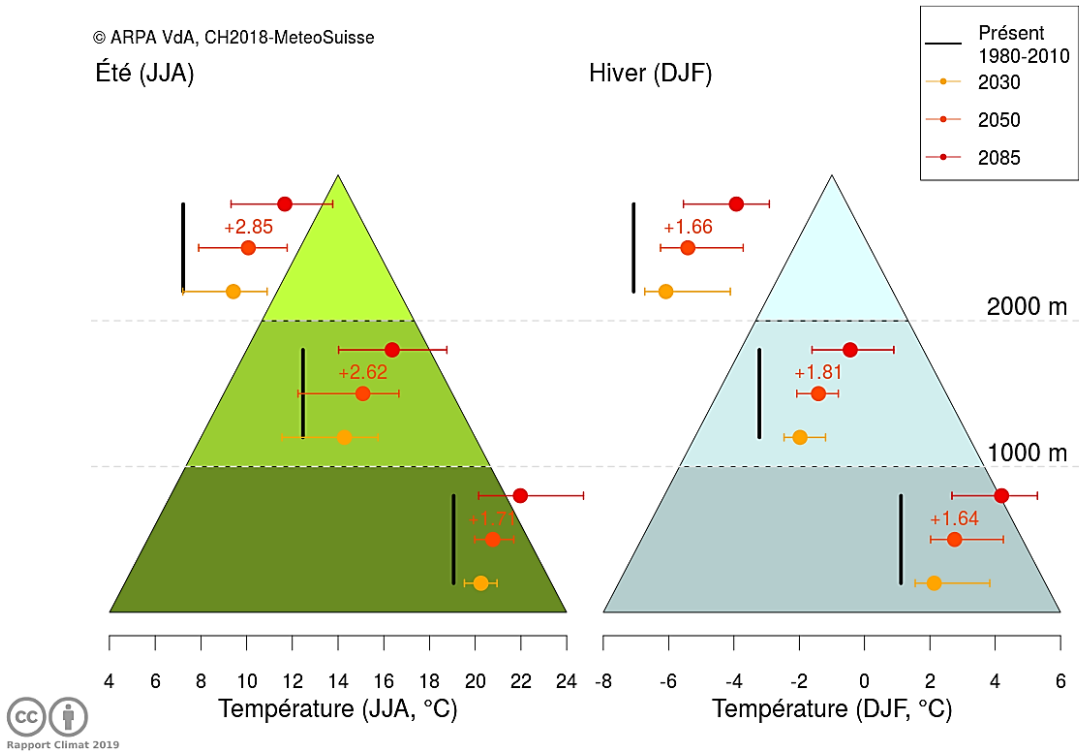

Figure 11 – Expected changes in summer (on the left) and winter (on the right) average temperatures at different altitudes, for different time horizons: 2030, 2050, 2085 (respectively: in yellow, orange, and red). The black lines represent the present average temperatures (measured in the period 1980-2010); the points represent the predicted average values, with the bars corresponding to the margins of uncertainty (Cremonese *et al.*, 2019)

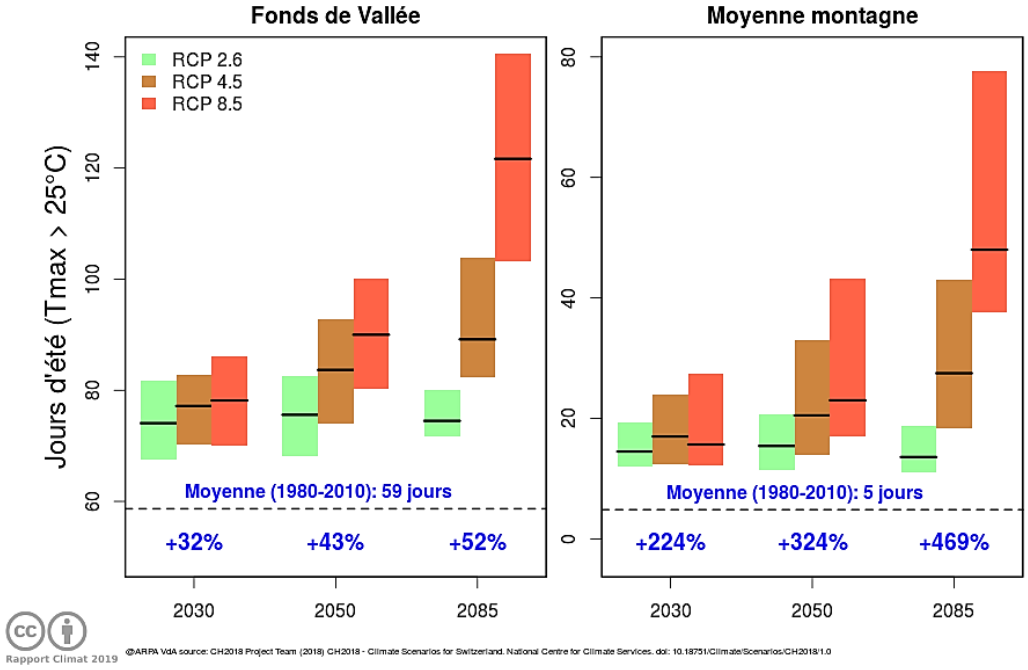

Figure 12 – Expected change in the number of summer days in the valley floors and mid mountain elevations. Different color bars correspond to different emission scenarios: green low emissions, brown intermediate, red high emissions (Cremonese *et al.*, 2019)

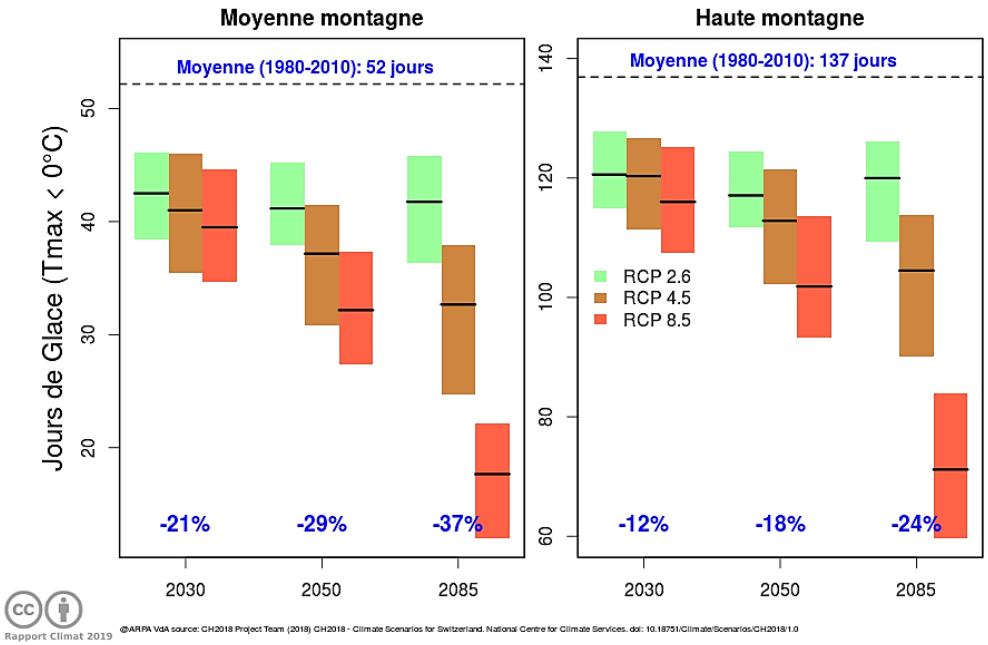

Figure 13 – Expected change in the number of ice days per year in the mid and high mountains. Different color bars correspond to different emission scenarios: green low emissions, brown intermediate, red high emissions (Cremonese *et al.*, 2019)

6.1.2 Precipitation

Annual precipitation scenarios predict no significant change in the cumulative annual volume of precipitation; however, an alteration in the seasonal distribution of rain and snowfall is likely to happen. Winter precipitation is expected to rise by 15-20%, falling more frequently as rain rather than snow even at mid and high elevations (around 2,500 m a.s.l.). Figure 14 shows a general reduction in summer rainfall at all elevations, accompanied by a significant increase in winter precipitation, especially in high mountains. A slight decline in summer precipitation, combined with the mentioned increase in temperatures, would also result in a greater risk of droughts.

Intensity of precipitation events is also expected to rise: the quantity of water that will fall during extreme events is expected to be 10 to 20% higher than the current annual average.

Moreover, snow cover is expected to keep diminishing, due to a loss in the number of snow days that can go from 10 up to 50 days, depending on the topographic context. Figure 15 displays the expected reduction in the amount of water stored as ice in the Rutor and Pré de Bar glaciers, on the Mont Blanc.

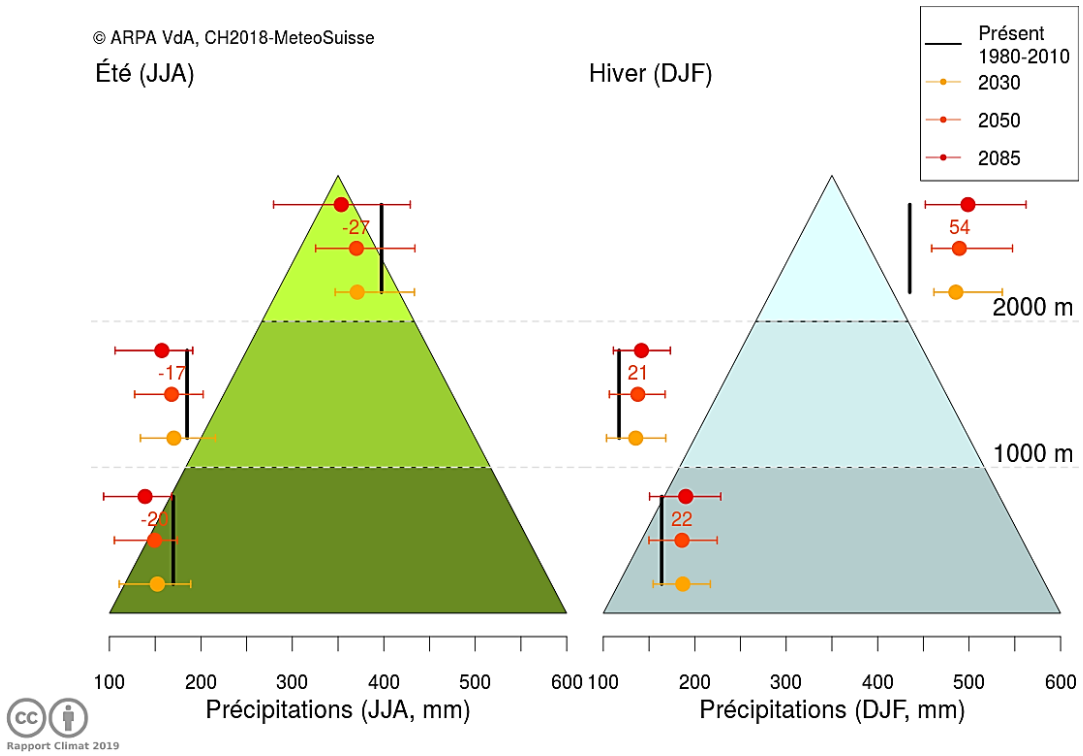

Figure 14 – Expected change in summer (on the left) and winter (on the right) average precipitation at different altitudes, for different time horizons: 2030, 2050, 2085 (respectively: in yellow, orange, and red). The black lines represent the present average precipitation levels (measured in the period 1980-2010); the points represent the predicted average values, with the bars corresponding to the margins of uncertainty (Cremonese *et al.*, 2019)

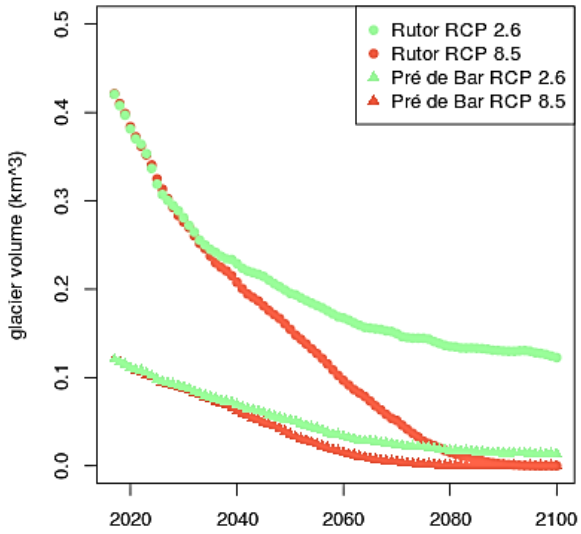

Figure 15 – Expected change in the amount of water equivalent stored in the Rutor and Pré de Bar glaciers on the Mont Blanc throughout the 21st century (Cremonese *et al.*, 2019)

6.2 EFFECTS OF CLIMATE CHANGE ON THE NATURAL SYSTEM

Mountain environment and ecosystems are built on a complex and delicate balance, and it makes them particularly vulnerable to climate change. The first effects of the described alterations in climatic conditions have already been observed during the past decades. They mainly relate to reduced water availability, declining soil fertility and land availability due to increasing soil erosion and natural hazards, and changes in plant phenology and ecosystem services (Brönnimann *et al.*, 2014; de Jong, 2015; Lavorel *et al.*, 2019).

In the following paragraph are described the cause-effect relationships that link the changes of climatic conditions to the availability and quality of natural resources and the health of animal and plant populations. A schematic overview is given in figure 16.

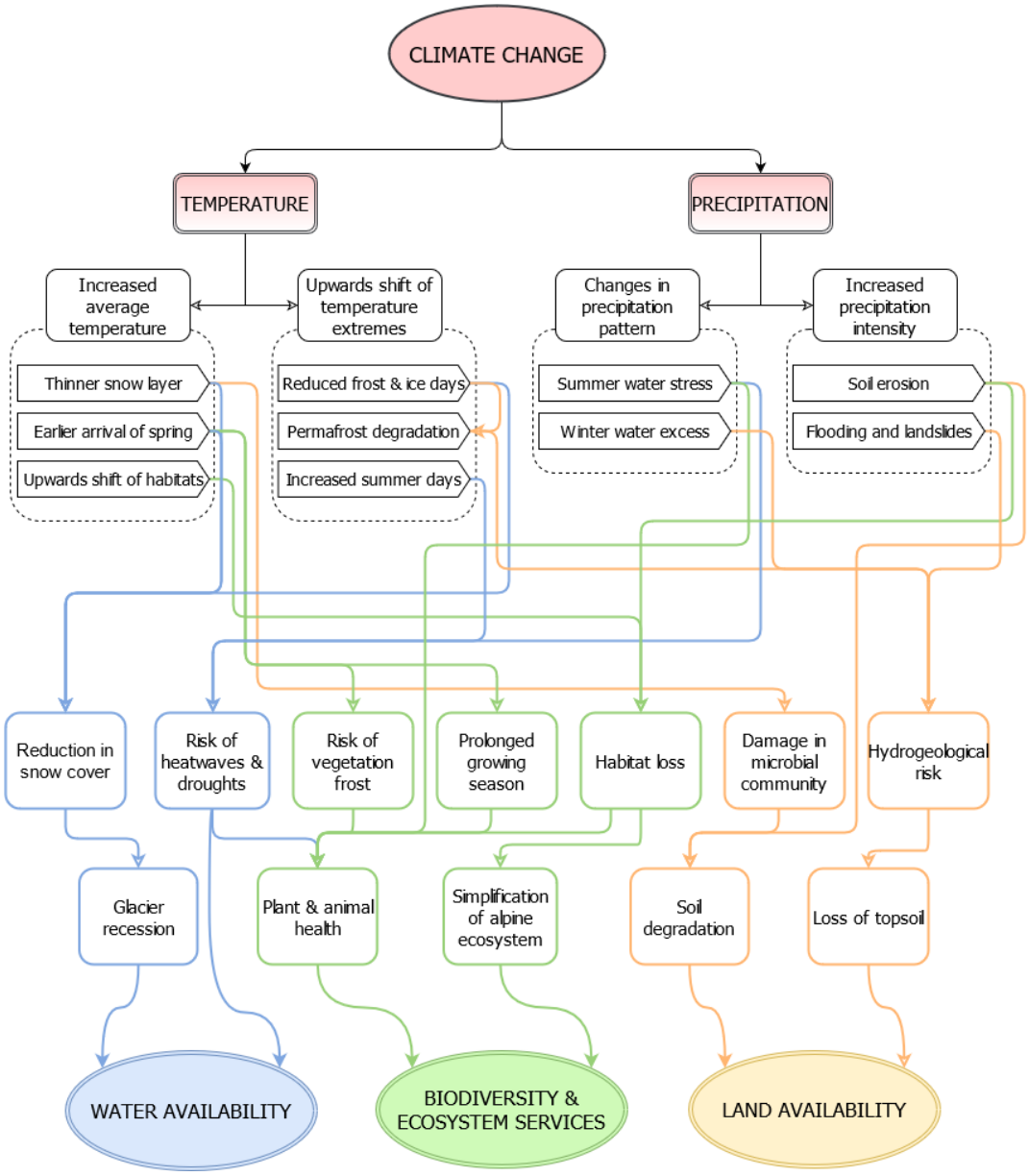

Figure 16 – Overview of climate change effects over mountain natural resources and ecosystems

6.2.1 Water availability

Availability of water can be monitored using two parameters: the snow covered area, and its relative water content, referred to as snow water equivalent. Water available in snow reservoirs is of great importance for agriculture, especially in Aosta Valley, where the irrigation network in this region almost entirely distributes water by gravity, where open canals of both historical and environmental significance convey water from the mountain streams to the fields. The origin of this water is from snowmelt and mountain sources, which in turn are recharged mostly by snowmelt during the warm seasons and by rainfall during autumn and winter.

The shrinking of glaciers is probably the most eloquent example of how hydrology in the mountains is being affected by the global rise in average temperatures: 50% of the glaciers has already been lost, while another two thirds are expected to disappear by 2100. Aosta Valley is not an exception: mass balance indicators for the Rutor and Timorion glaciers show a clear negative trend that has been monitored for the past 20 years (Figure 17) (de Jong, 2015; ARPA, 2016; EAFRD, 2020).

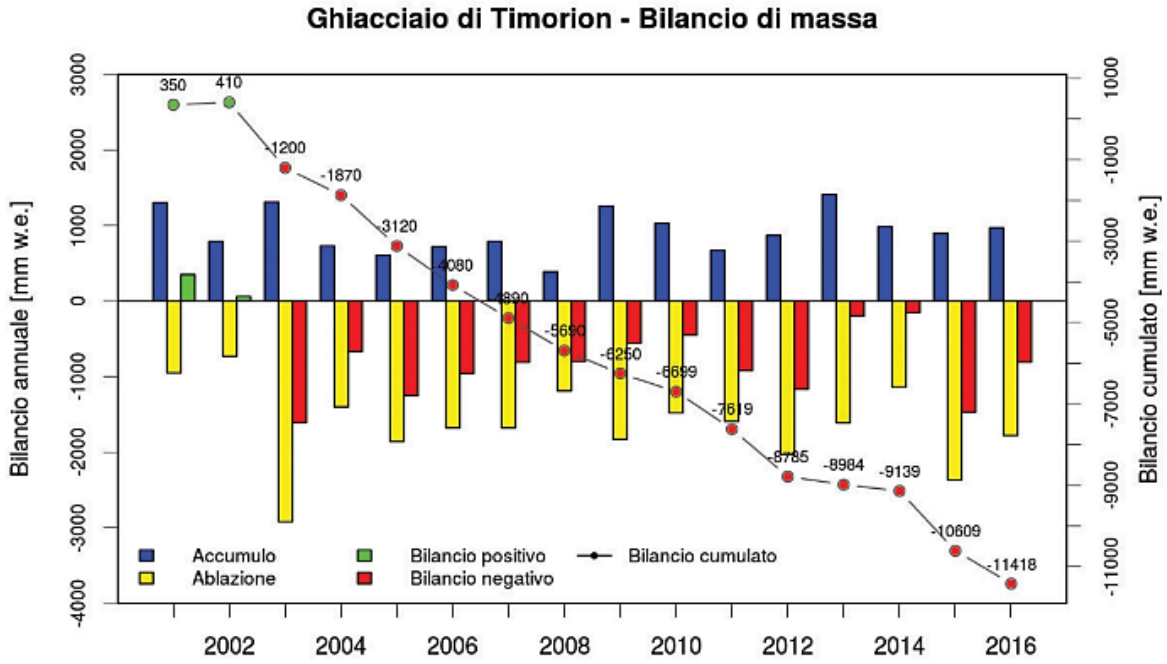

Figure 17 - Yearly and cumulative mass balance for Timorion glacier, Aosta Valley (in mm water equivalent) (ARPA, 2016)

The mass balance indicator is a measure of how much water is accumulated, or lost in this case, during a period of time, calculated as the difference between the winter accumulation of snow precipitation and the spring and summer ablation, or melting, of the snowpack. A rise in average temperatures, along with the reduction of frost and ice days, causes the accumulation of a thinner snow layer during winter, at the same time accelerating the melting of ice during spring and summer. Also, the earlier arrival of spring, coincident with the beginning of snowmelt, causes the period of snow cover to be shorter every year. Consequently, the general trend of mass balance of glaciers in the Alpine chain is highly negative, indicating a declining state of health of the mountain

cryosphere in terms of glacier regression (figure 17). De Jong reports that water reserves stored in glaciers have nearly halved in comparison to the Little Ice Age* and are expected to lose another two thirds of their volume by the end of 21st century (de Jong, 2015). This affects the water availability from a long-term perspective, as spring snowmelt has a fundamental role in groundwater recharge and could affect future spring regimes (ARPA, 2016; Cremonese *et al.*, 2019; Lucianetti *et al.*, 2020).

All these factors also have an impact on water availability in short and mid-term scenarios. Another cause for concern is represented by a higher risk of heatwaves and droughts, due to the increase in number of summer days per year combined with summer water stress caused by the shift in annual precipitation patterns. However, on a more positive note, the quantitative and qualitative state of underground waters is generally good in the whole region, as evidence that aquifers are recharging with the snowmelt waters (Brönnimann *et al.*, 2014; ARPA, 2016).

6.2.2 Biodiversity and ecosystem services

Mountains are major biodiversity hotspots: Alpine ecosystems are characterized by the presence of species which are highly specialized and have adapted to the climatic conditions of the mountain landscape. Therefore, a rise in temperatures due to climate change, coupled with the decrease in water availability that has been described, is expected to have impacts on plant and animal populations, as well as on entire ecosystems.

As it has been described, higher temperatures and lower summer precipitation entail a higher risk of heatwaves and droughts, which adversely affects ecosystems health. Increased temperatures would enhance evapotranspiration when soil moisture is less available, thus causing the senescence of the vegetation. Other species, like some insects and pests, could benefit from the warmer climate and the early arrival of spring for their survival and reproductive cycles. Therefore, plants already weakened from droughts would be also vulnerable to attacks of diseases and pests. Also, the well-being of other animal species, especially the large mammals, would be negatively impacted (Briner, Elkin and Huber, 2013; Cremonese *et al.*, 2019).

The duration of snow cover is of great importance for monitoring the health of ecosystems, as it impacts growth, phenology, and distribution of alpine plant species (Figure 28, Appendix B). In fact, plant phenology is strongly dependent on snow cover, as the beginning of the vegetative season is identified with the snowmelt, when vegetation is provided with water and nutrients and sunlight is able to reach the soils. In this sense, early arrival of spring due to shorter periods of snow cover is beneficial to some species, but for others it could represent a higher risk of being exposed to frost, which would still be common despite the rise in average temperatures (ARPA, 2016; Cremonese *et al.*, 2019; Quaglia *et al.*, 2020).

* The Little Ice Age is the name given to a climate interval that occurred approximately from 1300 to 1850, when mean annual temperatures in the Northern Hemisphere declined by 0.6°C relative to the average between AD 1000 and 2000.

Moreover, a study conducted by Rixen and colleagues demonstrates that a thinner and denser snow layer could in fact delay plant development, even by several weeks (Rixen *et al.*, 2008). Deep snow layers have a vital role in protecting soils from freezing during winter times; if climate change causes the snow cover to get thinner and denser, the insulation capacity could decrease, negatively affecting the composition and activity of the soil microbial community and damaging the fine roots of the plants. Increased nitrogen mineralization rates could counterbalance said negative effects, at least to some degree.

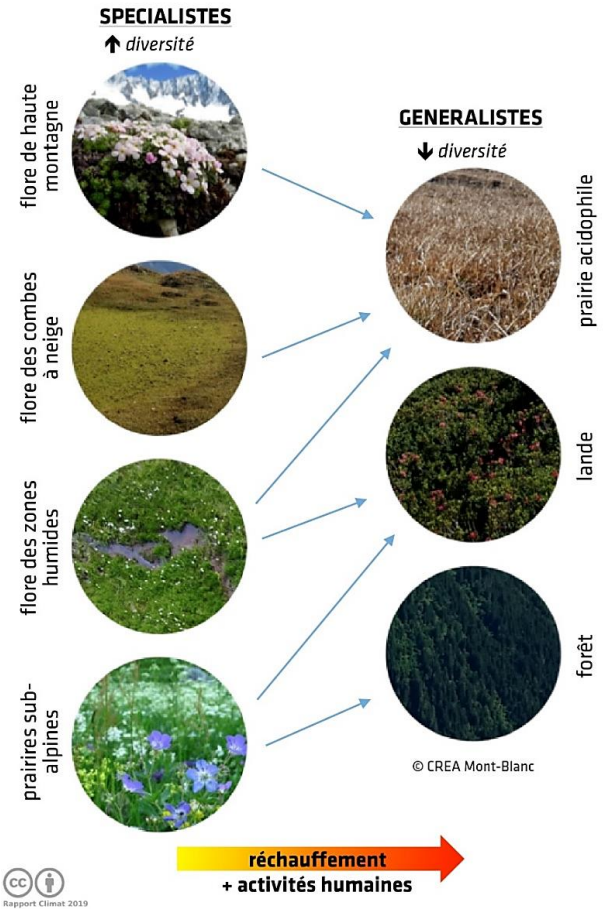

Figure 18 – Illustration of the possible simplification of alpine ecosystems in the context of climate change due to a shift from specialized species, characteristic of peculiar alpine environments such as high mountain, of snow-patch sites, humid zones and sub-alpine zones, to more generalist plant communities in acidophilic grasslands, moorlands and forests (Cremonese *et al.*, 2019)

As previously mentioned, the rise in average temperatures that has been observed since the end of the 1980s is between 0.2 and 0.5°C per decade, and it is especially marked in spring and summer. This datum roughly corresponds to the temperature deviation that is typically registered between two points at a 100 m elevation difference. As described in the Climate Report by Cremonese and his colleagues (Cremonese *et al.*, 2019), species would be forced to migrate upslope 100 m every ten years in order to meet the optimal conditions for their survival. However, given the pyramidal shape of the mountain landscape, this translates in a shrinking of the available habitat for said species, and the habitat loss for those who live at the mountain tops. Another consequence of this fact is that

the new colonizing species risk to survive at the expense of the alpine species, which are better adapted to extreme conditions but not as competitive as more generalist species with milder climates. We could then witness a simplification of alpine natural environments (Figure 18). Other studies indicate the possibility for an increase in biodiversity for vegetation growing near the valley floor, which would be more exposed to summer heatwaves and droughts; as a consequence, new species could colonize these areas, increasing biodiversity with a shift towards more drought tolerant species at lower elevations. However, this would be only a transitional effect, as the final situation is likely to be the one illustrated in figure 18 (Briner, Elkin and Huber, 2013; Cremonese *et al.*, 2019).

Another cause of habitat loss for alpine flora and fauna is the loss of habitat due to land degradation. In fact, surface erosion is likely to increment due to the increase in intensity of rain precipitations, which negatively affect soil cover as it deprives the soil of the nutrients that are fundamental for plant growth. This phenomenon, that will be further discussed in the next paragraph, impoverishes the soil thus negatively affecting plant growth (Brönnimann *et al.*, 2014).

6.2.3 Fertile land availability

Availability of productive land is a relevant issue for Aosta Valley, as 19,4% of agricultural soils are subjected to surface erosion assessed from moderate to severe (EAFRD, 2020). The availability of fertile land that is suitable for agriculture is impacted by climate change in two ways: land degradation and loss of topsoil due to increased hydrogeological instability.

As for the first, increased precipitation intensity is the main factor that contributes to eroding fertile soil by breaking soil aggregates and detaching soil particles, which are then flushed away with the excess water runoff. In addition to that, as previously mentioned, microbial communities living in the soil could be damaged by the lack of insulation that is normally provided by a thick layer of snow, thus affecting soil quality (Rixen *et al.*, 2008; Brönnimann *et al.*, 2014).

About hydrogeological instabilities, multiple determinants contribute to increase the risk of events such as landslides, avalanches, and flooding. The territory in Aosta Valley region is particularly vulnerable to natural hazards, as over 80% if its territory is subject to hydrogeological risk (Figure 27, Appendix B). Landslides and avalanches represent the main risks: the first once again prompted by the increase in intensity of precipitation, which is expected to trigger events like debris flows, while the latter would be due to the higher temperatures, especially in high mountain. Avalanche risk is likely to decrease at low elevations, as the snowline* shifts towards higher altitudes; however, phenomena like flooding from sudden burst of glacial melt pockets or glacial lakes are expected to intensify in the coming decades as glaciers melt more quickly. Another issue worth mentioning is permafrost degradation, which is caused by the rise of surface temperatures and in particular by the reduction in frost and ice days. A consequence of the melting of permafrost is slope instability, leading to rockfall and landslides.

* Imaginary line above which precipitation falls as snow rather than rain.

Changes in precipitation patterns raise concerns about the risk of flooding: with the need of conserving water for drier summers, water storage basins would be filled up during winter, making it more likely that a sudden and intense precipitation event in late winter or early spring would cause a flood wave in rivers which basins are not able to attenuate (de Jong, 2015). As a consequence, the valley floor could be affected by the flooding of the river Dora Baltea or its tributaries (Brönnimann *et al.*, 2014; Cremonese *et al.*, 2019; EAFRD, 2020).

Finally, it is important to remark that the loss of productive land means loss of habitat for a series of animal and plant species.

6.3 EFFECTS OF CLIMATE CHANGE ON THE SOCIOECONOMIC SYSTEM

Due to the intimate relationship of the local communities with the mountain environment and ecosystems, the whole socioeconomic system in Aosta Valley is expected to resent the described changes in climatic patterns. However, to effectively tackle eventual issues it is necessary to first understand the existing system and the interlinkages between economic sectors, their pressures on the environment, as well as the benefits they offer to the ecosystems. In this report, the analysis is limited to the sectors that are most reliant on the environment, either directly or indirectly: agriculture and tourism.

The causal loop diagram presented in Figure 19 aims at summarizing the interlinkages between the two sectors and the environmental and social dimensions of the system in object, which are more extensively described in the following.

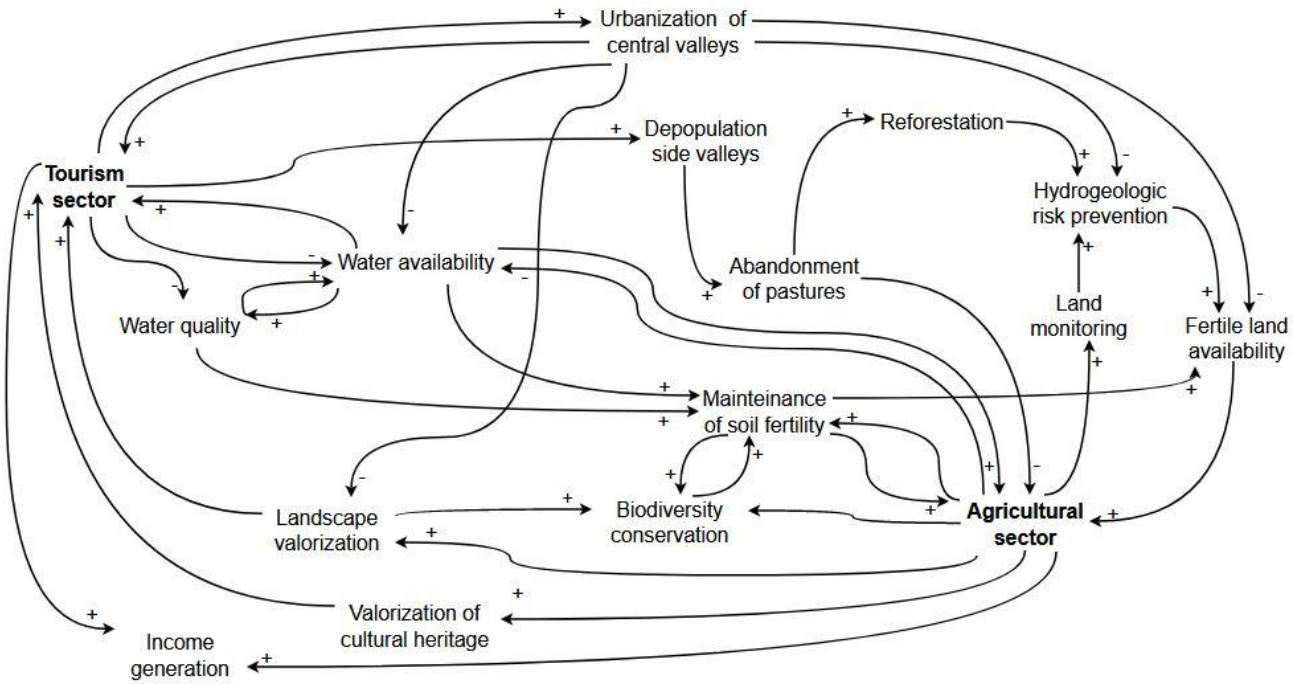

Figure 19 – Causal loop diagram describing the relationships between environment and two economic sectors: agriculture and tourism

6.3.1 Agriculture

Given its intimate relationship with the territory, agriculture profoundly influences the environment and its ability to provide ecosystem services. Besides the provisioning of food, feed and fiber, farming has a crucial role in regulating soil and water quality, supporting nutrient cycles and biodiversity, pollination, waste assimilation, pest control, carbon sequestration as well as cultural services (Yang *et al.*, 2020). For mountain landscapes, protection from hydrogeologic risk is also relevant, due to the role of the irrigation network in controlling the water flow and helping precipitation water discharge, and the action of vegetation in maintaining the soil compact thanks to the root system and preventing instabilities (Briner *et al.*, 2013).

Moreover, the presence of farmers on the territory has a key role land monitoring – in collaboration with the land improvement consortia, thus contributing to the mitigation and prevention of natural hazards like hydrogeologic instabilities. Also, agricultural practices help maintaining high soil productivity by fertilization and irrigation of the pastures, and with the building the canalizations for the rainfall waters in order to minimize soil erosion.

As previously described, traditional agricultural practices have a crucial role in the management of landscape, which naturally affects natural biodiversity, for example by creating ecological corridors and taking care of soil productivity. In this sense, healthy ecosystems are a result of good farming practices. The choice of cultivations and cattle breeds and other livestock is a consequence of the state of the pastures, too, and the environment in general, and contributes to the diversification of the species that are present on the territory. At the same time, a piece of land used for agriculture takes away vital space for forested land and habitat for wildlife; this is the reason why in Figure 19 the line connecting agricultural sector and biodiversity is the only one that is not marked as negative nor positive.

As for water use, the need for water potentially competes with that of other sectors, while the productivity of cultivated land is dependent on its availability. In fact, it is essential for growing animal feed as well as for the livestock itself, thus determining the land productivity and the number of animals that can graze over a pasture. These in turn could negatively affect the quality of waters without a proper manure management; however, data about this state that there is no relevant presence of nitrogen contaminants in water bodies in Aosta Valley, therefore the relationship between agriculture and water quality can be neglected.

Higher land availability and productivity translates in increased production of milk and therefore that of the traditional food products, keeping the traditional activities alive and at the same time enhance the cultural heritage of Aosta Valley farmers. Moreover, it generates revenue for the farmers' livelihoods, also since these traditional productions encourage enogastronomic tourism. Also landscape management is largely entrusted to farmers, who bring water to the land and make it fertile and productive, for the joy of the tourists that savor the sight and that of all the animal and plant species that find nourishment and shelter in it.

6.3.2 Tourism

As described in previous chapters, tourism is one of the major sources of income for the citizens of Aosta Valley. The environment is the main attraction for tourists in the area, due to the of beauty and quietness of the mountain landscape, the search for spiritual connection with nature, its uncontaminated air and water bodies, but also for the products that nature offers in the form of food.

A notable characteristic of tourism in Aosta Valley is its concentration, both in time, during winter and summer seasons, and in space, with the almost totality of attractions located in the central valley. This has a double effect: while said areas are going through to economic development and urbanization, a slow but constant abandonment of the settlements and the pastures is observed in the side valleys. The scale of the touristic and economic attractiveness of said areas is relevant, considering that some mountain communities register a higher number of accommodation facilities than citizens themselves: for instance, in the Valdigne Mont Blanc area are present almost 1350 hotels for every 1000 residents (ISTAT; IMONT, 2007). On one hand, building new accommodation facilities and infrastructure helps the development of the sector and encourages the arrival of more vacationers, thus reinforcing this loop and increasing the overall income generation opportunities. On the other hand, it could also ruin the landscape, which is what most tourists came looking for in the first place. Furthermore, urbanization is responsible for the impermeabilization of land surfaces, causing faster runoff to water streams and preventing water from draining into the aquifers. This issue is coupled with the consequences of the use of terrains for winter sports: they often undergo soil compaction, which makes them impermeable and unproductive. Both described phenomena cause faster runoff into rivers and canalization, thus increasing the risk of flooding in the river valley, as well as adding up to the loss of productive land.

Urban concreting due to the development of the touristic sector is also a major cause of land consumption and habitat loss for several species. Winter sports also create disturbances for wildlife, because of noise and night lighting of ski lift facilities, deforestation for the creation of ski slopes and the consequent fragmentation of habitats. Winter sports are also notably reliant on water resources, in the form of snow cover or water to be utilized to produce artificial snow. This practice is recognized to be highly water intense, thereby affecting the access to this natural resource to other parties (de Jong, 2015).

As just mentioned, if touristic areas attract visitors – and capital, secondary valleys are deserted by young people in pursuit of opportunities and workers who find themselves in a condition of increasing isolation. Pastures are abandoned and often recolonized by shrubs and forests. If the constant work or land monitoring and management of agricultural activities ceases, it becomes more difficult to prevent and control hydrogeologic instabilities. The cohesive action that plant roots have on the soils could help in this sense, although for a forest to be mature it takes up to a century.

6.3.3 Effects of climate change on the economy

As described in chapter 6.2, the main effects of climate change in the Alpine environment concern the availability of water and fertile land in the long term and the conservation of native biodiversity. Changes in any of these are likely to affect all productive sectors, in particular tourism and agriculture.

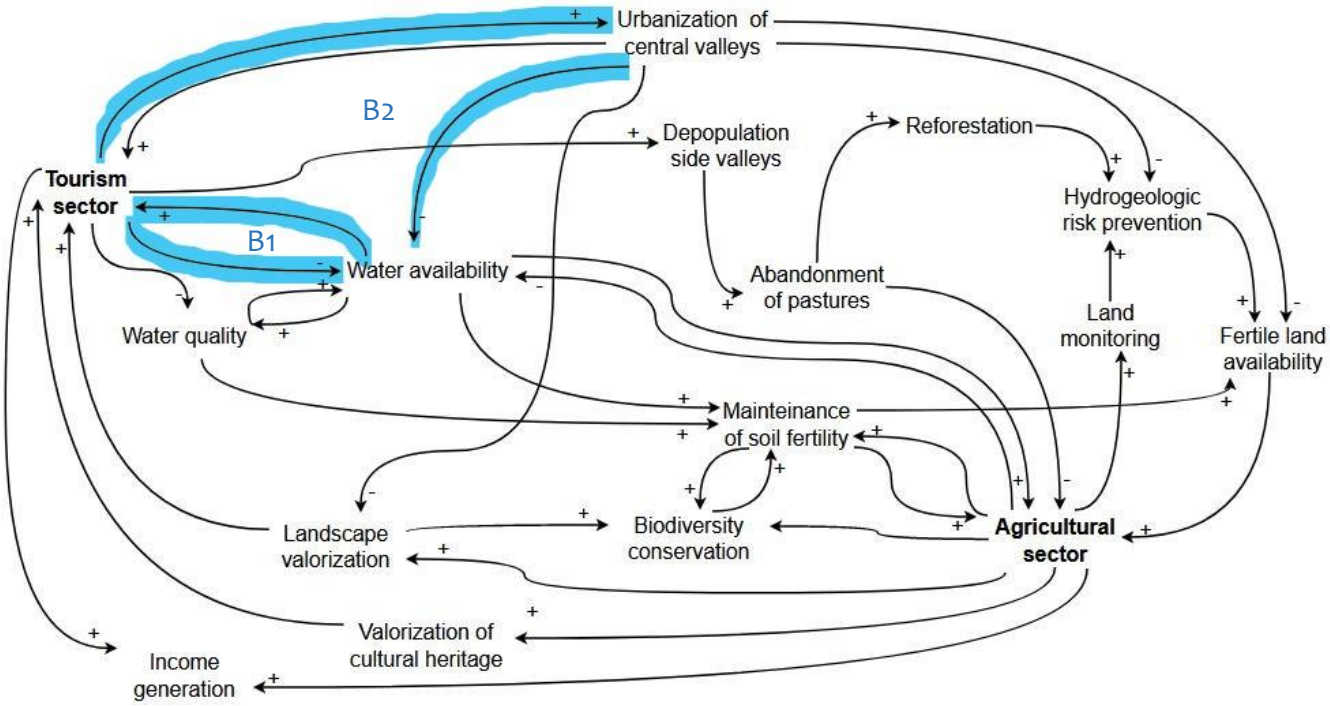

Figure 20 – Causal loop diagram describing the relationships between environment and two economic sectors: agriculture and tourism – highlight on balancing loops B1 and B2

In the first case, water scarcity would discourage visitors from choosing Aosta Valley as a destination – in winter for the lack of snow that would undermine the possibility to produce artificial snow and therefore to ski, and in summer for the degraded landscape due to the drought. This would have a positive effect in terms of water availability for the reduced need for the touristic sector. The balancing loops B1 and B2 highlighted in figure 20 are triggered. However, it can be imagined that the magnitude of the positive arrow is greater than the balancing one, causing an overall negative effect for the sector dictated by water scarcity.

Farming would suffer the consequences of the decrease in water availability, too, both directly in terms of less summer irrigation and loss of production, and indirectly due to the reinforcing loop R1 with biodiversity conversation and maintenance of soil fertility which amplifies the negative effects on the agricultural sector (Figure 21). A decrease in the ecosystem services provided by mountain biodiversity and the loss of fertile land would trigger and reinforce the same loop, thus worsening an already compromised situation.

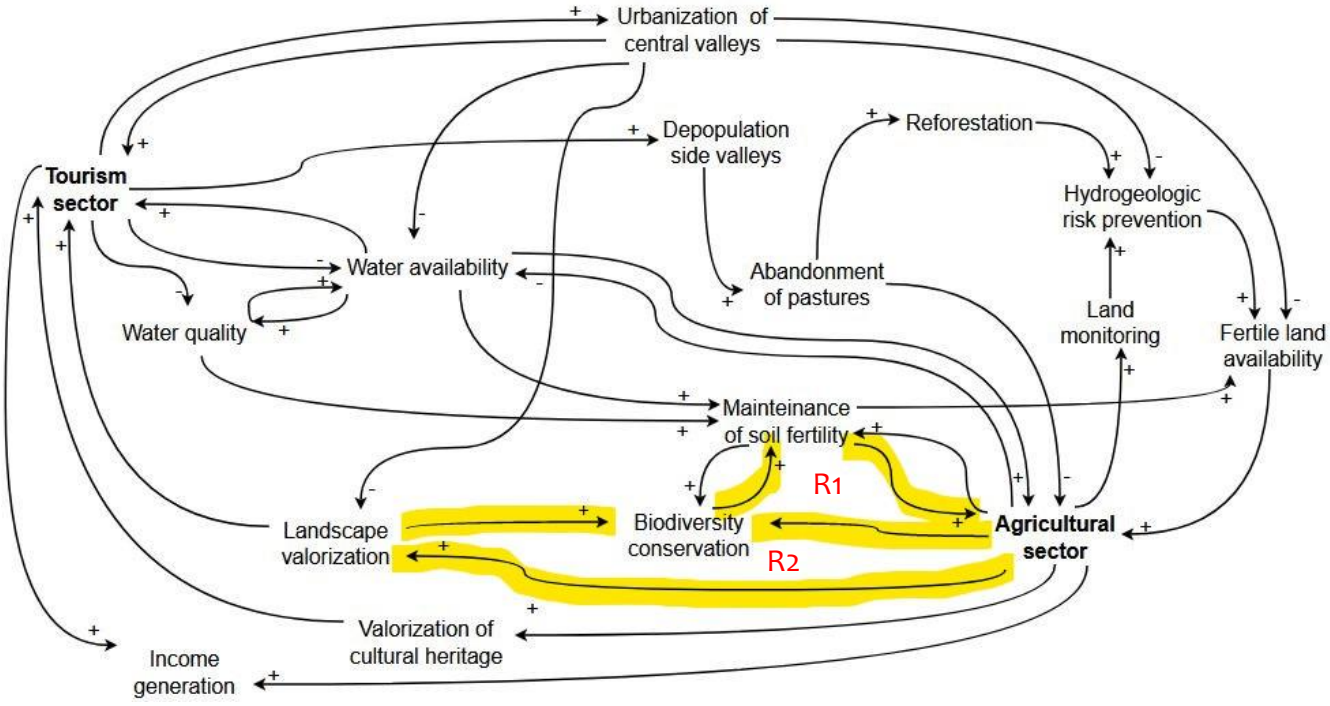

Figure 21 - Causal loop diagram describing the relationships between environment and two economic sectors: agriculture and tourism – highlight on reinforcing loops R1 and R2

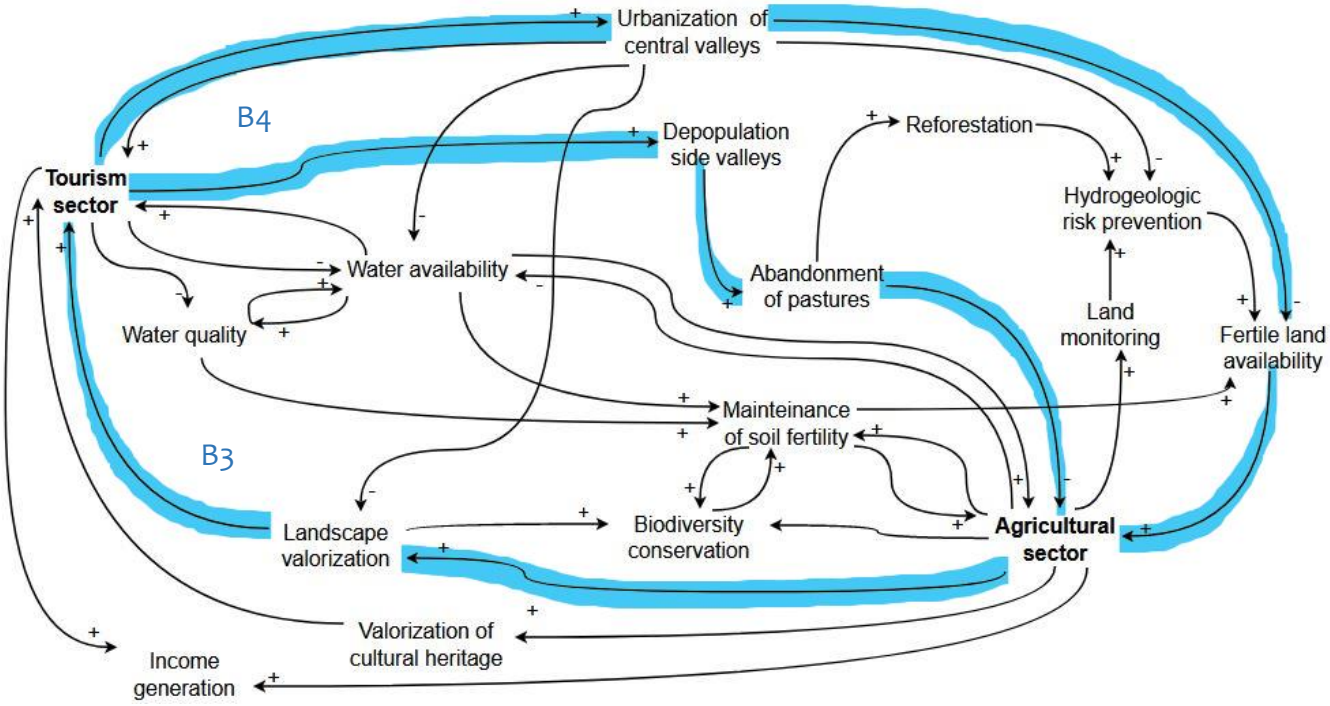

Figure 22 – Causal loop diagram describing the relationships between environment and two economic sectors: agriculture and tourism – highlight on balancing loops B3 and B4

Moreover, the negative impacts on agriculture would have consequences on the landscape, which would probably look less vital and green (R2); this indirectly harms tourism, triggering other two balancing loops: urbanization of central valleys would slow down (B4), together with the depopulation and abandonment of pastures in side valleys (B3), benefitting agriculture in the marginalized areas (figure 22).

This analysis evidences the need for an urgent and decisive action to counteract these effects of climate change. Moreover, in the current situation the development of tourism is essential for the income generation within the region, but at high social and environmental cost which are not sustainable in the long run.

However, all these factors are not only regulated by climate change: human interventions have a major role in landscape management. If tourism displays several reasons for being careful, mountain farming is a powerful instrument for land monitoring and management, and it can help control environmental conditions, such as water scarcity through irrigation and soil degradation with fertilization (Deléglise *et al.*, 2019).

7 ONGOING AND PLANNED INTERVENTIONS

In light of what has been described and analyzed so far, a mix of actions has been taken or is being planned in order to reach the region's objectives: conservation of its environment and natural resources, and development of economic activities. The different actions were classified according to their principal purpose: the improvement of water availability, the conservation of biodiversity and ecosystem services, the increase of fertile land availability, and the valorization of the cultural heritage of Aosta Valley.

7.1 INTERVENTIONS FOR IMPROVING WATER AVAILABILITY

As discussed throughout the report, uncertainty over future water availability is one of the main concerns posed by climate change for Aosta Valley. Interventions can be carried out for trying to mitigate the risk of water shortage in the future scenarios.

7.1.1 Construction of water storage reservoirs

Several studies, including the previously mentioned report by Cremonese and colleagues, present the construction of water storage reservoirs as a possible solution for ensuring water availability in the mid and long term as glaciers shrink (Cremonese *et al.*, 2019).

Just like glaciers, reservoirs would allow the accumulation of snowmelt to be used for irrigation during summer, as well as for civil use and in other activities like hydroelectric power production and summer and winter tourism, as described in chapter 6. Moreover, artificial reservoirs are regulated storage facilities, thus allowing for the design of a management policy that responds to the particular needs of the people and sectors served by it. The water flow over time is regulated with daily, weekly or monthly policies, depending on the storage capacity of the single reservoir.

Although the benefits are evident, this action raises issues regarding the impacts damming would have on the environment, stemming from construction and management of the reservoir. First of all, the building of a dam on a watercourse has major impacts on its hydrology, causing the erosion of the riverbanks and altering its natural flow and flooding cycles, its sedimentation and silting phenomena, as well as increasing evaporative losses due to the presence of the basin. Water quality is also affected: water chemistry changes due to the accumulation of chemicals and nutrients, in addition to the water stagnation that facilitates bacterial and viral proliferation. Moreover, hydrogeological and seismic risks must not be underestimated.

Biodiversity and wildlife can suffer consequences of the construction of a dam, too: upstream, areas that serve as habitat for several animal and plant species are flooded, also causing the emission greenhouse gases due to the rotten vegetation underwater, and the cumulative impacts on water quality undermine the survival of water life. However, the formation of new wetland is an opportunity to create a new habitat for water species. Downstream, problems are caused to aquatic biodiversity, as the transfer of water, sediments and nutrients is disrupted. The introduction of a

*minimum environmental flow** (MEF) in the dam management policy usually serves the purpose of guaranteeing at least the minimum water flow for the survival of downstream species.

However, the creation of a water storage reservoir can be an opportunity to enhance the landscape, making it become a touristic attraction. The arrival of more visitors could also be promoted by the new fishing and recreational opportunities introduced by the presence of the water body.

7.2 INTERVENTIONS FOR CONSERVING BIODIVERSITY AND ECOSYSTEM SERVICES

The safeguard of wildlife and landscape is among the priorities for Aosta Valley's agenda. The following initiatives aim at conserving the richness of the mountain biodiversity and the ecosystem services that nature provides to the region.

7.2.1 Protected areas

Introducing protected areas is a regulatory action that can be decided at a national or regional level. In a national context of preservation of the landscape and cultural heritage (see chapter 4.2), 87,71% of Aosta Valley's territory is protected by law: this means that around 80 areas within the region have been recognized of particular interest from a landscape point of view and are protected with initiatives that take into account the specificity of each site (Regione autonoma Valle d'Aosta, 2021).

In practical terms, the denomination of protected areas is deeply connected with land use and building regulations. The region's Landscape and Territorial Plan speaks about three main directives (Regione Autonoma Valle d'Aosta, 1998):

1. *The preservation of the visibility and recognizability of the « structural » components of the landscape (from the great geomorphological configurations, to the hydrographic network, to the pastures and woods system, to the peculiar traits of the rural landscape, to the architectural elements, isolated or agglomerated);*
2. *The discipline of the uses and interventions on the areas and on the resources that are particularly sensitive (such as pastures, woods, fluvial areas, or areas of specific cultural or environmental interest);*
3. *Protection and valorization of the visual relations that characterize the landscape units (with particular reference to the scenic value).*

As it emerges from the landscape plan, not only unspoiled nature and forested areas are protected, but also mountain pastures and elements of the manmade rural landscape, as habitats that can host a different variety of species but also in reason of their importance for the human-nature interaction.

* It is "*the minimum flow that must be released to the river downstream from a reservoir whenever the inflow exceeds the MEF*" (Soncini-Sessa, Weber and Castelletti, 2007)

7.2.2 Alternative farm management systems

Alternative farming strategies represent an opportunity for the agricultural sector in Aosta Valley, as they bring along multiple benefits in terms of conservation of the alpine landscape as well as environmental protection, especially from soil erosion (Cremonese *et al.*, 2019).

Examples of new management strategies for farms are:

- Agrisilviculture: is the land use system which integrates the presence of trees within the agricultural setting, with the aim of reinforcing the resilience of the productive activity in several ways: the diversification of the production, the prevention of soil erosion due to extreme meteorological events, and the increase of water infiltration. Three main configuration exist, which can also coexist:
  - Cultivation of perennials spaced by parcels of agricultural land;
  - Cultivation of crops (perennial or not) in clearings or thin forest;
  - Silvi-pastoral systems, which allows the coexistence of trees and livestock.

  Studies show that the presence of agricultural land between the trees favors plant growth, thanks to the irrigation and fertilization practices which also benefit the trees and to the optimal lighting that enables photosynthesis. Plants in turn have a protective effect on the cultivations: they protect the soil from intense precipitation and excessive insolation, and also serve as excellent windbreak barriers. The deep roots also facilitate the infiltration of water in the soil, while taking up nitrates from the from the deeper soil layers thus limiting the contamination of aquifers. Finally, the distance between the trees would limit the spread of diseases (Dupraz *et al.*, 2005).
- Agroecology: is the sustainable farming concept that seeks to enhance agricultural production systems making use of the biological interactions offered by ecosystems. The aim is to improve production quality by increasing biological diversity and interaction without depending on chemical inputs. Besides reducing the needs for fertilizers and pesticides, the benefits of this practice are the control of soil erosion and greenhouse gas emissions, along with the preservation of other resources like water and energy. Organic farming is a particular form of agroecology (see next paragraph).
- The diversification of the crops, the adoption of crop rotation techniques or the shift of the production at higher altitudes.
- The choice of more heat and drought resistant varieties.

Despite the multiple benefits provided by the described systems, different problems can be encountered in their implementation. First of all, the conversion of a conventionally farmed field to a new system is very costly, and the pay back times are generally long and not guaranteed.

Moreover, the benefits in terms of ecologic services have not been quantified – also in economic terms, which makes it difficult to estimate a proper compensation for the farmers from the public agencies.

Lastly, the successful management of this kind of farms requires a series of technical competences and special training, so that this kind of work cannot be improvised.

7.2.3 Organic farming

Organic farming is a system of farm management and food production whose aim is to combine the best environmental and climate action practices while preserving the health of plants, animals, and humans. In fact, the preservation of the environment from soil and water contamination goes hand in hand with the improvement of food and farm products safety and quality.

Organic production system does not allow the use of synthetic pesticides and fertilizers, herbicides, plant growth regulators, genetically-modified organisms, and prophylactic use of antibiotics and hormones for zootechnical use (CREA, 2019b). This is in line with EU's objectives concerning agricultural development. In fact, the EU set the goal of 25% of total farmland dedicated to organic farming by 2030, as part of the Farm to Fork initiative, together with other ambitious targets (European Commission, 2020):

- A 50% reduction of the use of chemical pesticides by 2030;
- A 50% reduction of nutrient loss and a 20% reduction of the use of fertilizers by 2030;
- A 50% reduction of the sales of antimicrobials for farmed animals and in aquaculture by 2030.

The EU provides financial support for both the conversion to organic farming and for maintaining the organic status, thus recognizing the potential benefits of this production method, and also offering advisory services for allowing farmers to adopt the best practices and improve efficiency (European Parliament and European Council, 2018).

Despite the benefits of this farm management system, currently the percentage of agricultural land farmed organically in Aosta Valley is only 6% of the total, a datum that is far from the EU targets but also from the national average, which is around 15% (CREA, 2019b).

7.3 INTERVENTIONS FOR INCREASING FERTILE LAND AVAILABILITY

Soil degradation and loss of agricultural land are another predictable effect of climate change and of socio-economic transformations. A series of solutions are being designed and implemented for tackling this issue, with the purpose of improving marginalized areas and guiding a more efficient use of the land.

7.3.1 Conservation and upgrading of the rural context

The revival of marginal areas could start with structural investments in the degraded and abandoned areas, bringing benefits in terms of both environmental and landscape quality. A series of actions could contribute to the region's development in this sense, starting from initiatives like environmental remediation of contaminated sites along with the restoration of degraded land. These first interventions would be aimed at restoring the soil quality and the ensuring the maintenance of the permanent Alpine pastures. Also, great attention should be given to the

connected pastoral constructions and the rural urban centers, which are fundamental elements of the mountain landscape.

This would contribute to, and at the same time depend on, the redevelopment of the agro-pastoral system in the side valleys, with interventions aimed at preserving the territory and the cultivated landscapes, as well as the historical and cultural heritage. This would be made possible by adopting measures for the restoration and development of the farming activities and the related services (Regione Autonoma Valle d'Aosta, 1998).

Said actions could be followed by the construction of new roads and infrastructure: residents would benefit from them as much as visitors, who would have increased access to areas that today are the less frequented. In addition to this, the realization of tourist circuits would encourage vacationers to explore said places, thus distributing their environmental impact on a larger area without overburdening the current touristic zones.

7.3.2 Diffusion of tourism

As just mentioned, Aosta Valley's strategy of conservation and development can not only address the most dynamic and economically performing areas located in the central valley: the objective is to reduce the existing local disparities and promote the development of the region as a whole.

One way to implement this strategy is to stimulate the diffusion of tourism in the lateral valleys, with the purpose to avoid the problems that mass tourism brings in terms of environmental and social costs, and encourage a more sustainable and responsible enjoyment of the region's nature.

Besides the structural interventions presented in the previous paragraph, this could be done with several initiatives that involve the promotion of a better use of the environment. For example, protected natural areas could be created and opened to the public, thus preserving wildlife and at the same time providing enjoyment for tourists (Regione Autonoma Valle d'Aosta, 1998).

Also, it is interesting how the offer of differentiated forms of use of the territory is being promoted: sports activities, relax and well-being, enogastronomic experiences and so on, just to name a few.

7.3.3 Grazing plans

The Gran Paradiso national park, together with the Ecrins national park in France, has been chosen as study area for the Life Pastoralp project. The purpose of this project is to define the vulnerability of pastures to climate change in the Alps and then assess and test possible adaptation strategies. The programme, financed by the EU, was started in October 2017, and will conclude by March 2022. For the studies, it integrates data from field surveys, modeling, remote sensing, socio-economic and biodiversity analyses (Pastoralp, 2021). The two national parks were chosen as examples of Alpine environment on which to study climate scenarios for six pasture typologies, with twenty datasets of climate data and ten socio-economic indicators. The expected outcome of this project is the creation of a document that provides guidelines and recommendations regarding pastures management in a climate change scenario (CINEA, 2017).

Another transboundary initiative is Espace Mont Blanc, which involves the three neighbouring regions around the highest peak in Europe: Aosta Valley in Italy, Haute Savoie and Savoie in France, and Valais in Switzerland. The aim is to protect and enhance these territories and to harmonize their development. Within this context the AdaPT Mont Blanc project was carried out and completed in 2020, with the aim of tackling the adaptation to climate change with the land planning tools, in the belief that if mitigation of climate change effects is a global responsibility, a lot can be done locally in terms of adaptation (Espace Mont Blanc, 2014).

The tools and strategies developed within the context of the described projects could be utilized for the management of rural areas throughout the Alpine region. In particular, they could be useful for the definition of the grazing plans, which are expected to be part of the strategic plan for rural development for the years 2023-27. Satellite and remote sensing data would be useful in order to determine the density of livestock that is possible to keep on a field and dynamically define the best grazing routes by knowing the productivity of each pasture.

7.4 INTERVENTION FOR THE VALORIZATION OF THE CULTURAL HERITAGE

Here are described examples of European and national initiatives aimed at the recognition and valorization of the cultural heritage of the region, through the protection of its traditional products. Farmers in Aosta Valley can join these programs.

7.4.1 Quality schemes

Quality schemes aim at protecting the name and promote the unique characteristics of traditional products, and they are recognized as intellectual property. The reason behind this is the evidence that farmers can keep producing a variety of high-quality products only if they are rewarded fairly for their work; a label serves the purpose of communicating to the consumers the unique characteristics of the products, in a condition of fair competition.

- EU quality schemes

The two major schemes are geographical indications and traditional specialty guaranteed (European Commission, 2021).

Geographical indications include:

- PDO – Protected Designation of Origin (food and wine);
- PGI – Protected Geographical Indication (food and wine);
- GI – Geographical Indication (spirit drinks and aromatised wines).

Products that are granted PDO status must comply with strict rules, and they have the strongest link to the territory they are produced in: production, transformation and elaboration happen within the same delimited geographical area. Taking Fontina as an example, for it to be recognized as a PDO product it has to be obtained with whole cow's milk coming from only one milking, and the production, ripening and cutting area for the cheese must be the regional territory.

As mentioned in chapter 3.2.4, the typical agri-food products with a PDO status in Aosta Valley are Fontina, Formadzo, Lard d'Arnad and Jambon de Bosses (CREA, 2019b), in addition to a variety of red, rosé and white wines.

- Italian quality schemes

Additional 36 products recognized as traditional by the national government, for they are deeply tied to the customs and traditions. In this case, the limited diffusion in terms of geographical area interested and quantities produced does not justify a PDO status; hence the need for a different protection scheme arose at a national level.

The complete list of products includes alcoholic and non-alcoholic beverages, diary and meat-based products, pasta formats and bakery products, greases and oils can be found in Appendix D.

8 ANALYSIS AND DISCUSSION

After having described the variety of initiatives that have been implemented or are in a planning phase, an analysis of their relative benefits and drawbacks was carried out. This was done by assessing each alternative's coherence with the objectives of protection of the territory and economic and social development.

After that, the decision makers who have the power to take each decision were identified, leading to a new classification based on the decision-making level of intervention: national or regional administration, regional entities, single farmers, or private citizens.

The final remarks attempt to offer guiding principle for the prioritization of the solutions: their economic and technical feasibility and their compatibility with one another.

8.1 ANALYSIS AND COMPARISON OF INTERVENTIONS

The different interventions can be sorted in two main groups: protective and developmental.

Protected areas, grazing plans, organic farming, quality schemes: all these activities have *protection* as common denominator with regard of their main purpose.

Protected areas and grazing plans are intended to protect the soil and landscape from degradation respectively through planning and management of land use; organic farming aims at protecting the ecosystems besides the quality of waters and agricultural land; quality schemes safeguard the regional cultural heritage by recognizing the uniqueness of its products.

Development is the key word for the other set of interventions: conservation and upgrading of the rural context, diffusion of tourism, construction of water storage reservoirs.

Conservation and upgrading of the rural context, together with the initiative for the diffusion of tourism over the whole regional territory, are actions that actively seek to stop the degradation of marginal areas and the development of the entire region; the construction of water reservoirs would provide additional resources to be exploited in multiple sectors and for multiple purposes.

However, protection and development are not mutually exclusive: development opportunities can stem from a protection initiative, and vice versa, and they can be seen as two sides of the same coin.

As a first example of this, the preservation of the environment will be considered. As illustrated in the causal loop diagram described in chapter 6.3 (Figure 19), maintenance of soil fertility and landscape protection, that come with the implementation of protected areas, grazing plans and organic farming, are included in the same virtuous loop that reinforces itself, and that is directly related to the development of the touristic sector. In fact, the enhancement of quality of the environment and the preservation of the Alpine ecosystems typically encourage tourism by taking care of what vacationers wish for: the beauty of landscapes, the wonder of nature.

However, promoting tourism at today's conditions would only benefit certain areas, which are already crowded during seasonal peaks, at the expense of the less popular valleys, for the reasons that have been described. For a real positive impact, all these measures should be implemented in a perspective of equitable development: this is where the planning of initiatives for attracting tourists comes into play. In fact, especially for the side valleys that are typically less frequented by tourists, the arrival of visitors requires the construction and maintenance of infrastructure, the presence of receptive structures, the offer of recreational activities and a series of economic activities that would represent a new source of income for the local communities and the opportunity to benefit from their positive externalities.

Moreover, this would act as a stimulus against the abandonment of pastures, thus further contributing to the preservation of the landscapes and reinforcing the positive loop of attractiveness for tourism. The Landscape Territorial Plan recognizes how tourism can have a decisive role in the conservation and stabilization of landscapes and ecosystems which are made fragile by processes of abandonment. In the same way, a smart land planning would prevent the over-urbanization of the rural area, preserving the landscape and giving space to agriculture (Regione Autonoma Valle d'Aosta, 1998).

As a consequence, protected areas, grazing plans, organic farming and the diffusion of tourism (including the structural actions) introduce a new causal relation to the model: the one between landscape enhancement and the depopulation of side valleys (Figure 23).

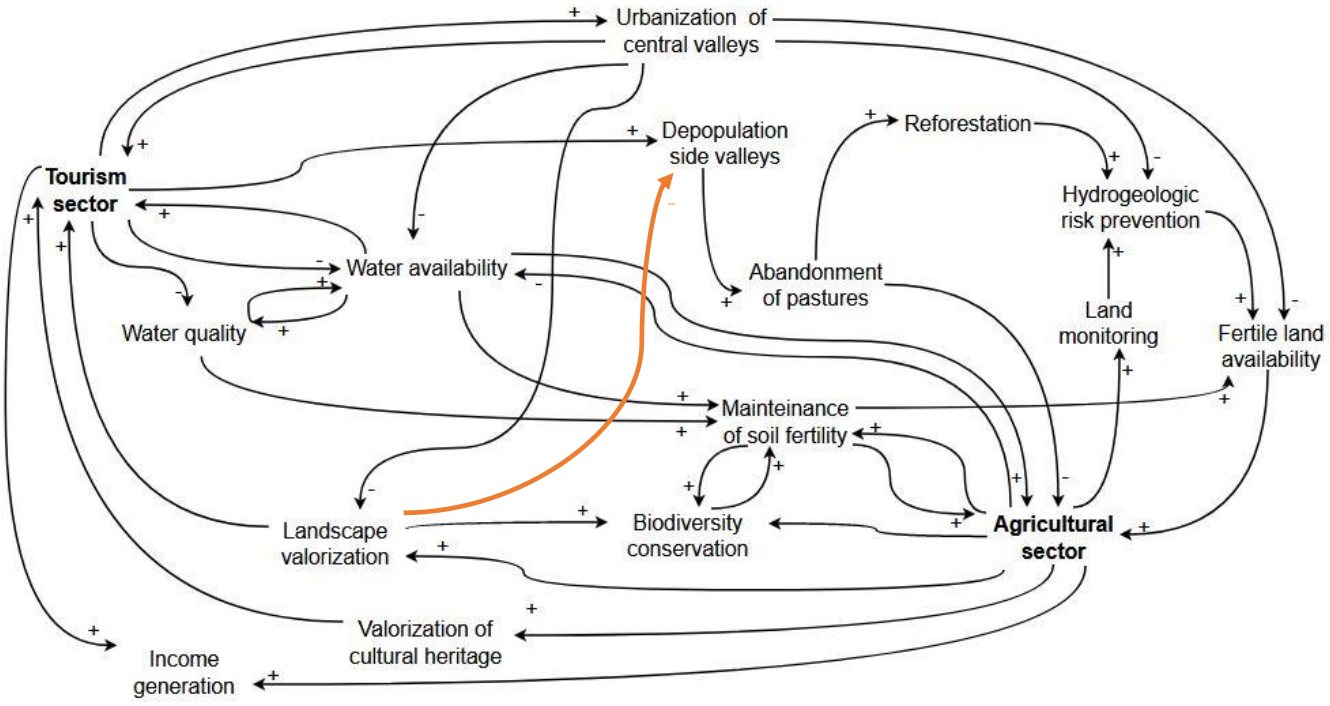

Figure 23 – Causal loop diagram underlying the causal relationship introduced by the interventions: protected areas, organic farming, quality schemes, diffusion of infrastructure and tourism.

The second example concerns the traditional agri-food products: the same diagram already underlines the positive relationship between the valorization of the cultural heritage and the tourism sector. However, the choice of producing high-quality traditional products is also made in order to increase the farmers' revenue. In this sense, quality schemes are similar to organic farming: the commitment to high-quality production or to more environmentally friendly farming techniques is not only a matter of nature conservation, but it represents a valuable income generation opportunity for the farmers. In fact, farmers would be able to obtain a price premium on both organic and DPO products, for they meet the needs of consumers who become increasingly informed and careful with their choices. Moreover, in the case of organic farming, incentives are ensured by the government or the EU for switching to organic production or to maintain it, by reason of the lower yields that usually characterize this kind of cultivations. In this case, the new causal relationships that are created are between the valorization of the cultural heritage with income generation (Figure 24).

At a closer look, a similar link can be drawn analyzing the effects of grazing plans over income generation, although the causal relationship in this case is quite different from the organic farming situation. The definition of grazing plans would allow farmers to maximize the productivity of their animals – and therefore their revenues – by choosing the best pastures at the right time. Moreover, dynamically adjusting grazing routes to the specific conditions of the year would lower the risks of overgrazing and accelerating soil erosion, which would cause permanent damage to the pastures (Deléglise *et al.*, 2019). In this sense, this practice can be seen as an investment both in the short and in the long-time perspective, and the maintenance of soil fertility, which is so closely linked to soil productivity and therefore the wellbeing of animal and plant species, once again positively impacts income generation.

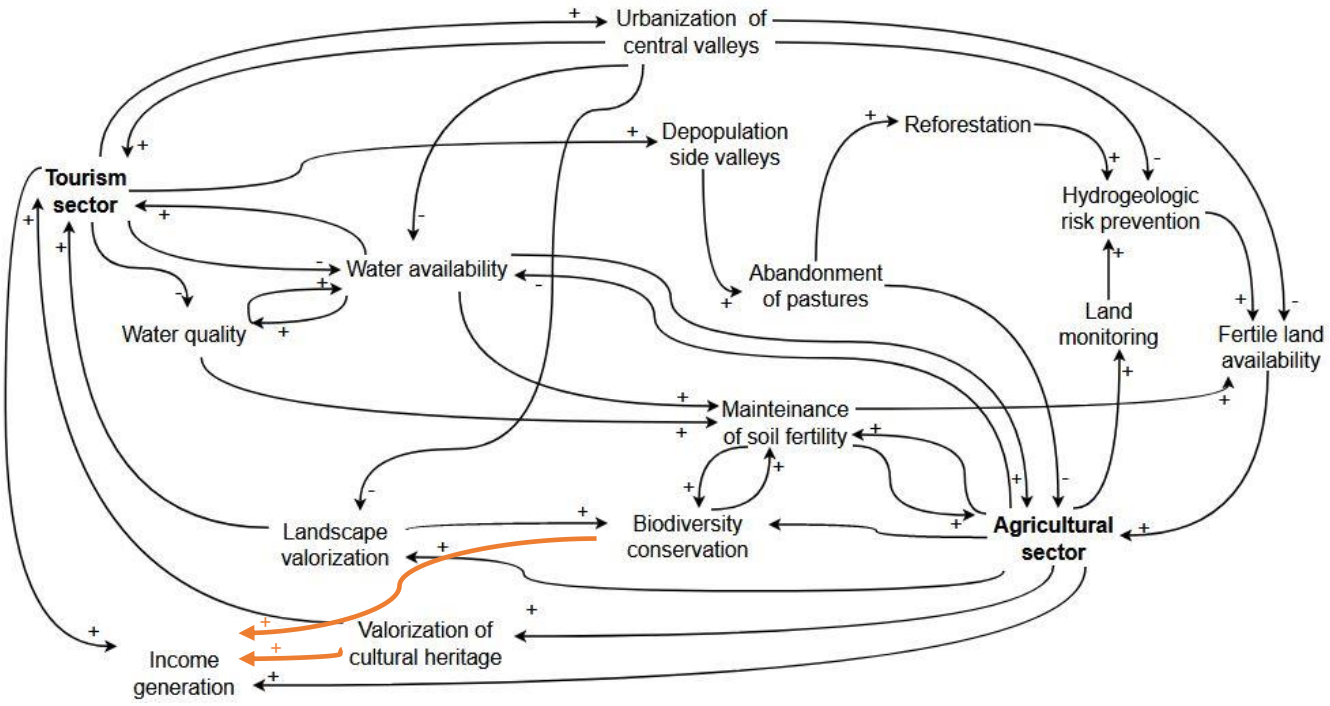

Figure 24 – Causal loop diagram underlying the causal relationship introduced by the interventions: grazing plans, organic farming, quality schemes.

The case of the water reservoirs is somewhat more complex, due to the number of implications deriving by the construction of an engineering work of this kind.

On one hand, changes in water availability in the short and long term would have a fundamental role in human economic activities, like civil and industrial use, irrigation, hydropower generation, and tourism, in particular winter sports (Rixen *et al.*, 2008; de Jong, 2015; Lucianetti *et al.*, 2020). This kind of investment could therefore benefit all sectors and turn out to be an excellent investment for the future, at the same time securing such a precious natural resource that is expected to be scarce in the future scenarios, and also give the opportunity to multiple sectors to develop.

On the other hand, as it was described, the construction of reservoirs would negatively affect the environment and potentially also the landscape. De Jong reports that climate change is affecting flood timing and magnitude as a consequence of changing precipitation patterns, and human interference impacts flood routing, timing and magnitude, to the point of outweighing the natural impacts (de Jong, 2015).

Said alterations could be detrimental for the tourism sector, as damming a watercourse causes alterations in the mountain scenery that vacationers generally look for – although some tourists could be attracted by the presence of the new water reservoir or by the presence of the dam itself.

All in all, the causal relationships introduced by the construction of water storage reservoirs in high mountain catchments, as presented in figure 25, are: the positive link to income generation, and the neutral link to landscape valorization and biodiversity conservation, as the impact of the building of a dam can have negative and positive effects.

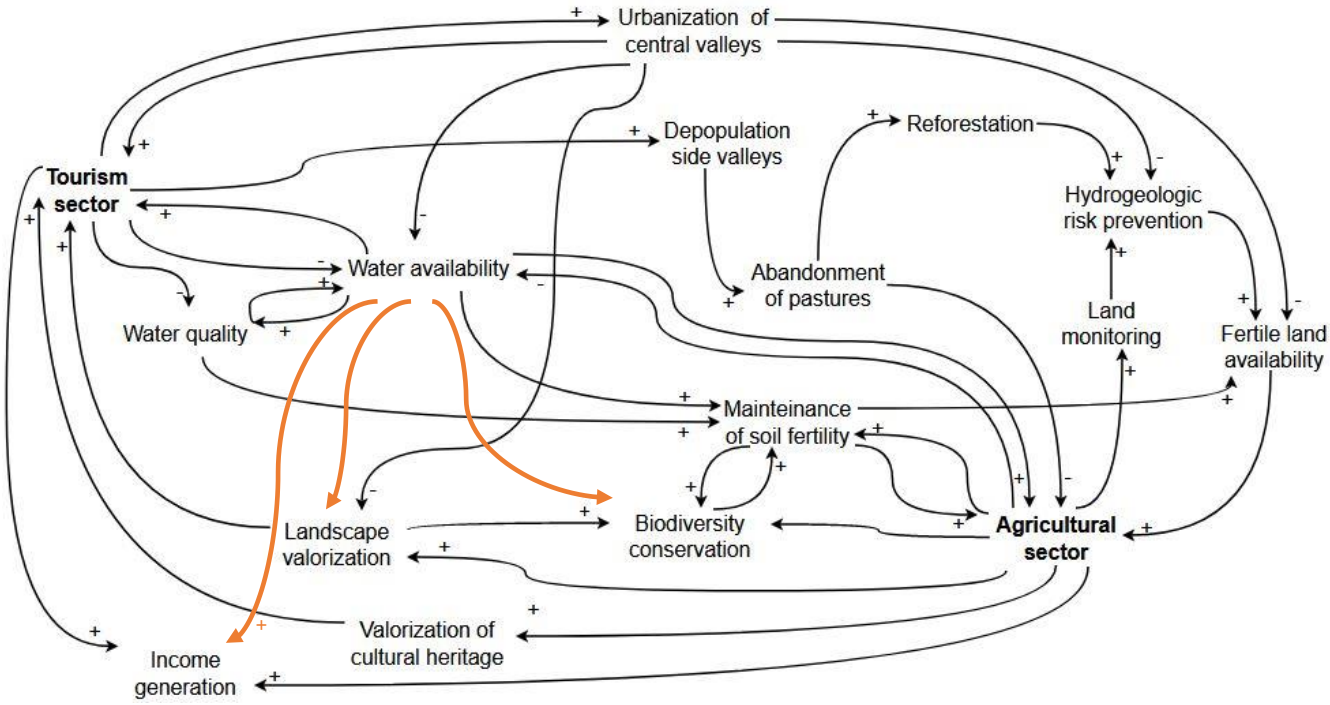

Figure 25 – Causal loop diagram underlying the causal relationship introduced by the intervention: construction of water storage reservoirs.

8.2 COMPETENCE ON THE IMPLEMENTATION OF INTERVENTIONS

For these interventions to be implemented, it is important to identify the decision makers who can take the initiative. For this purpose, the interventions have been classified based on who can take the decision: the national or regional administrations, regional entities, farmers, or private individuals amongst the citizens.

8.2.1 National and regional administration

Regulatory actions that can be taken by the national and regional administration encompass a wide range of interventions, from bans and restrictions to active proposals of incentives and funding. The interventions the public agencies have most power on are:

- Protected areas – as described, national legislation indicates certain categories of protected areas, as well as a set of criteria for introducing new areas at the discretion of the regional administration.
- Requalification & infrastructure – the central government or the region provide funding for the building of new infrastructure, or more often for the maintenance of the existing one,

depending on the dimension of the projects. The region is responsible for the remediation of degraded or polluted sites.

- Water storage reservoirs – once again, the competence over the planning and funding of this typology of intervention depends on its dimension and strategic value; the management is always entrusted to the region.

8.2.2 Regional entities

The regional entities listed in chapter 4.3 support the region in the decision making by providing science-based information or they help the definition and coordination of projects for the sustainable development of the region.

- Grazing plans –the main contributions to the design of the grazing plans are research institutions that carry out projects with the aim of helping a wise land planning making use of technological tools supported by science-based knowledge. In this context, two projects having these objectives have been mentioned: PastorAlp and AdaPT Mont Blanc.
- Diffusion of tourism – the role of the region in this initiative is to provide guideline and set shared objectives for the coordinated development of the whole region, but actors like the GAL are responsible for the coordination of the projects that aim at developing a model of sustainable tourism within Aosta Valley.

8.2.3 Farmers

The activity of farmers is strictly linked to European and national directives, whose role is, besides providing incentives, to promote campaigns for spreading information and raising awareness on issues like climate change and sustainable transition and to assist the producers with consulting services about the best practices and the cutting-edge technologies. On their side, farmers can decide to join a European program, or also to diversify or reinvent their activity trying alternative management systems.

- Organic farming – the EU provides economic support for the transition from conventional to organic farming, for a period that is set at 2 years for ruminant grazing land.
- Quality schemes – farmers have to follow the European or national specific regulations in order to join the program and label their products as DPO or traditional.
- Alternative farming management systems: the adoption of an innovating farming management system can be considered as a long-term investment for the farmers, by reason of the multiple benefits these farming methods bring to the environment and the production.

8.2.4 Citizens

Even private individuals are invited to participate to the ecologic transition of the region. They have two main ways to take action: monitoring the territory and contributing to its maintenance, or proposing new community-lead initiatives.

- Requalification and construction of infrastructure – associations like the Land Improvement Consortia are historical organizations of people who take care of the maintenance of irrigation systems and rural road infrastructure; they are not coordinated by the region, although they depend on it for funding.
- Diffusion of tourism – the Leader approach is a pillar of the implementation of the EU's Rural Development Strategy (see chapter 4.3.3). The encouragement of sustainable tourism is seen as a strategy for the local promotion and requalification of rural areas, starting with the direct involvement of the local population.

8.3 FINAL REMARKS

With the purpose of giving an idea of the possible prioritization of the analyzed interventions some final remarks are made, concerning their practical and economic feasibility and their compatibility with one another.

8.3.1 Feasibility

The feasibility of each intervention depends on both the availability of funding and the will of each actor involved.

This is particularly true for the initiatives that directly involve the farmers: as it emerged during the interviews, already today the direct payments granted to farmers by the EU are a crucial instrument for ensuring the profitability of agricultural activities. Consequently, if the willingness to transition towards a new production model starts from them, economic incentives are a conditio sine qua non for making high-quality or organic farming a viable option for their livelihoods. Currently, the maximum amount each farmer can be granted for switching to an organic production system is € 3,000.00 per year, for a maximum of 5 years (CELVA, 2018). Moreover, public authorities from the European to the local level are responsible for spreading information and raising awareness over sustainable development and the role of agriculture through information campaigns and with assistance and consulting about the best practices.

Initiatives like the grazing plans also depend on the willingness of the administrations to fund the research projects, and of the farmers' availability to join the programs. Moreover, their success and adoption in the long term depends on the quality of the results of the research plans and the attentive and efficacious application of the recommendations.

As for water storage reservoirs, the difficulty is to find a suitable location which maximizes the benefits and minimized the impacts of the construction, as the best ones in this sense have already been exploited. Moreover, this kind of civil engineering works are highly cost intensive. As mentioned in chapter 4.2, the National Recovery and Resilience Plan previews investments in water infrastructure to ensure the availability of water resources in face of the challenges posed by climate change. However, for obtaining the financing, the project must participate in an invitation to tender and be approved. If the cost of the realization of a new small water reservoir in the alps is around 10 M €, and the design of the project is estimated around 6-10% of the cost of the final project, there

would be a minimum expense of about 600,000 € to even start the process. In this sense, this intervention appears not truly economically feasible.

8.3.2 Compatibility

If it can happen that reinforcing loops are created with a combination of more than one intervention, some other couplings can be mutually exclusive, or could cancel each other's benefits out.

To start with, a wise land planning and landscape protection is always required, whatever action the region is willing to undertake.

In fact, as it has been well documented, structural interventions designed to facilitate the access of tourists to larger areas of the territory would surely help revive the economy of side valleys, bringing along new opportunities for agricultural activities and the consequent benefits derived from management of the territory. However, such structures could also lead to an excessive anthropization of areas that have so far been spared from mass tourism, thus causing unintended environmental impacts without proper regulations.

Also, the spread of tourism would potentially lead to increased urbanization in the lateral valleys, once again at the expense of fertile land that could have been used for agricultural purposes otherwise.

A different example involves the construction of water storage reservoirs, which is not compatible with the creation of protected areas or natural reserves, although either have the potential to attract visitors: both are valid actions, but with different purposes and effects. The national and regional administration would have to choose which one to go for over a defined area, based on the priorities dictated by the specificity of each zone.

Other initiatives, as the choice of innovative management systems like agrisilviculture or agroecology are compatible; moreover, their environmental benefits would combine and reinforce one another.

Lastly, using the technologies experimented for the grazing plans for the planning and management of organic or diversified production systems would increase the environmental benefits of these practices, too, at the same time making the agricultural sector more efficient and sustainable and allowing the use of innovative techniques like precision farming for reducing inputs of water and natural fertilizers.

9 CONCLUSION

Due to the intimate relationships between the environment, economy and society that characterize Alpine regions, climate change will have not only consequences on Aosta Valley's landscape and climate, but also on the use of the territory and the two fundamental economic sectors that depend on it: agriculture and tourism.

Climate change is expected to alter temperature and precipitation patterns in Aosta Valley during the coming decades, thus affecting the availability of water resources and fertile land, as well as the region's biodiversity and the ecosystem services provided by its natural environments. However, it is also important to point out that environmental problems derive not only from natural factors, but they are increasingly determined by innovations in the local economy and in the territory dynamics. Moreover, if changes dictated by the climate are foreseeable to some extent, the control other factors like urbanization and the diffusion of tourism over the territory present a twofold difficulty: it is not easy to foresee the future developments of the cited phenomena in the coming decades without a careful regulation, and it is almost impossible to provide a quantitative description of the consequences of changes in that sense.

The same way, human control over the territory can both strive for the mitigation of climate change and, at a local level, even more for adapting to its inevitable consequences, and steer the economy by means of initiatives and policies.

In this sense, Alpine farming has a crucial role in the monitoring, regulation and preservation of the territory, and it provides multiple ecosystem services that benefit the environment and wildlife as much as the local population. The provision of these positive externalities can be promoted or discouraged by the design of policies at all scales, from European to local, as well as land planning.

As the present study demonstrates, action is necessary for reaching the goal of a prosperous and sustainable future of the agricultural sector in Aosta Valley.

One example of this is the need for maintaining the current protected areas and possibly introduce new ones, in order to preserve valuable landscapes and protect the historical heritage of the rural tradition. This could be done with a view to contain the urbanization of the most exploited areas and to prevent the same issues in the zones that are expected to be developed for tourism in the coming years.

The building of infrastructure and the promotion of tourism should therefore be carefully planned and regulated in order for tourism to be a resource rather than a threat for the environment, for example limiting the access to a certain area to a specific number of visitors or impose penalties for irresponsible behaviors like littering or damaging natural sites.

Organic farming could be promoted by reason of their environmental benefits in terms of resource efficiency and ecologic services, especially in a biodiversity hotspot like the Alpine chain. Moreover,

being the farming system extensive in the whole region, the ambition level could go beyond the 20% proposed by the European Union. This transition can be accompanied by the introduction of alternative management systems, like agrisilviculture, which would bring along environmental benefits like increased infiltration which are fundamental for mountain environments. Adequate incentives need to be granted to the farmers in order to make the transition economically feasible for them, who already face difficulties in making profits in their activity.

Lastly, a synergy between agricultural and tourism sector could be created, thanks to bottom-up initiatives like the ones promoted by the Leader programme which favor the development of sustainable tourism and agritourism in the less-favored rural areas of Aosta Valley.

To conclude, in a global context of climate change, where cattle farming is responsible of 8 to 9% of the global GHG emissions (Gerber *et al.*, 2013), it is important to reflect on the role of an extensive, traditional farming system in the provision of ecosystem services, in the conservation of the territory and in the preservation of the identity and culture of a people. Instead of stigmatizing an entire sector, it could be possible to recognize that sustainable pastoral practices are a reality on which the health and economy of entire regions depend, and that can turn into a resource for tackling climate change through mitigation and adaptation plans.

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APPENDICES

9.1 APPENDIX A

The interview guides that have been prepared for the semi-structured interviews are reported below.

- **General interview structure**
  1. Greetings and giving thanks for interviewee availability
  2. Presentation of interviewer
  3. Summary and explanation of the aims of the project
  4. Clarification of specific reasons why the interviewee was contacted
  5. Questions/dialogue time
  6. Ask if the interviewee has any (further) questions for the interviewer
  7. Asking for availability for an eventual follow-up interview
  8. Conclusion

- **Interview guide for ARPA Aosta Valley**
  1. Amidst the current global pandemic, is there still discussion about climate change:
     - In research institutes?
     - In the dialogue with the public?
     - In the dialogue with public administrations?
  2. With reference to the study you have conducted in collaboration with the regional administration of Aosta Valley:
     - Which sectors have been analyzed?
     - What type of model has been used?
     - Is it possible to have access to said information?
  3. About current situation:
     - Is agricultural sector in good health?
     - Which are the major problematics today?
     - What are expected to be the major challenges for the coming decades?
  4. On what terms and to what extent climate change can impact:
     - The availability of natural resources (such as water, soils, …)?
     - The quality of said resources?
  5. To what extent can farming adapt to cope with the negative effects of climate change through a proper land management?
  6. Which indicators have been chosen to describe the change in alpine climate?
     - How are they chosen?
     - How significant are they?
  7. Besides the Region, do you have an open dialogue about climate change and agriculture with other agencies or sectors?
  8. Do you have any suggestions for me about another third party who could be interested in being involved in this research project?

- **Interview guide for the Management Authority for the Agricultural and Natural Resources Council of Aosta Valley**
    1. About current situation:
        - Is agricultural sector in good health?
        - Which are the major problematics today?
    2. Which policies have been implemented in the past years?
        - What has been successful?
        - What needs improvement? Why?
    3. With reference to the study ARPA has conducted in collaboration with you:
        - What are expected to be the major challenges for the coming decades?
        - Are they more linked to the availability or the quality of natural resources?
    4. To what extent do you believe farming can adapt to cope with the negative effects of climate change through a proper land management?
    5. What is your vision of agricultural sector for the next 30 years?
    6. What is your role in the development of the new CAP (Common Agricultural Policy) now that the objectives are likely to be national rather than regional?
    7. How does the dialogue with farmers work?
        - What was the purpose of last summer's consultation?
        - What have you learnt?
    8. Do you have any suggestions for me about another third party who could be interested in being involved in this research project?

- **Interview guide for the Bureau of land improvements – agricultural department**
    1. What is the role of the land improvement consortia in the land management of Aosta Valley?
    2. Who is part of these organizations?
    3. Is it a traditional activity? Since when?
    4. What is the role of agriculture in the preservation of the environment?
    5. What are the expected consequences of the abandoning of mountain pastures?
        - Do you see it as a positive or negative perspective for the future?
    6. Is there some level of coordination between the activities of the various consortia?
    7. How does the dialogue between the consortia and the regional administration work?

9.2 APPENDIX B

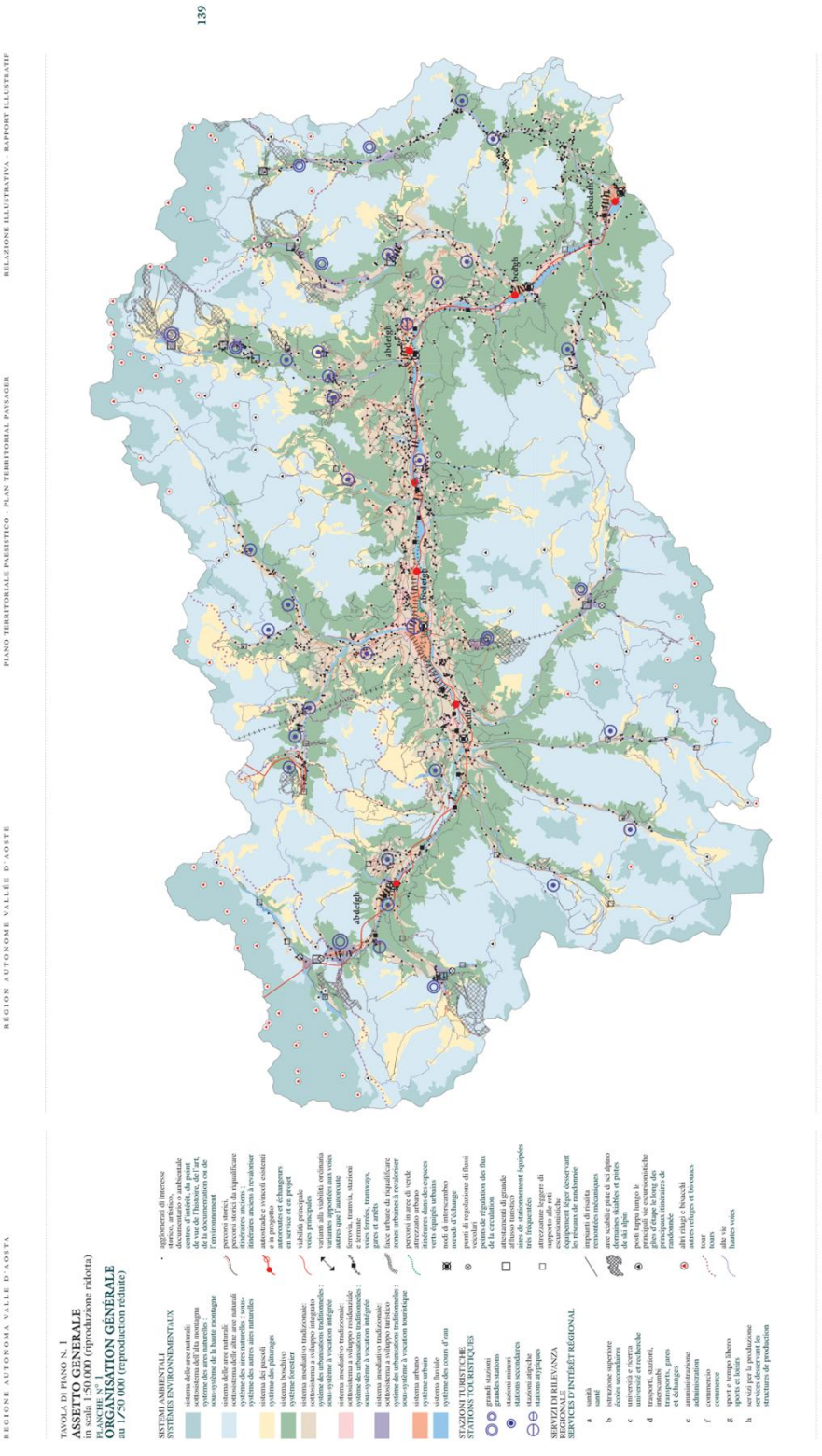

Figure 26 – Land cover classification for Aosta Valley (Regione Autonoma Valle d'Aosta, 1998)

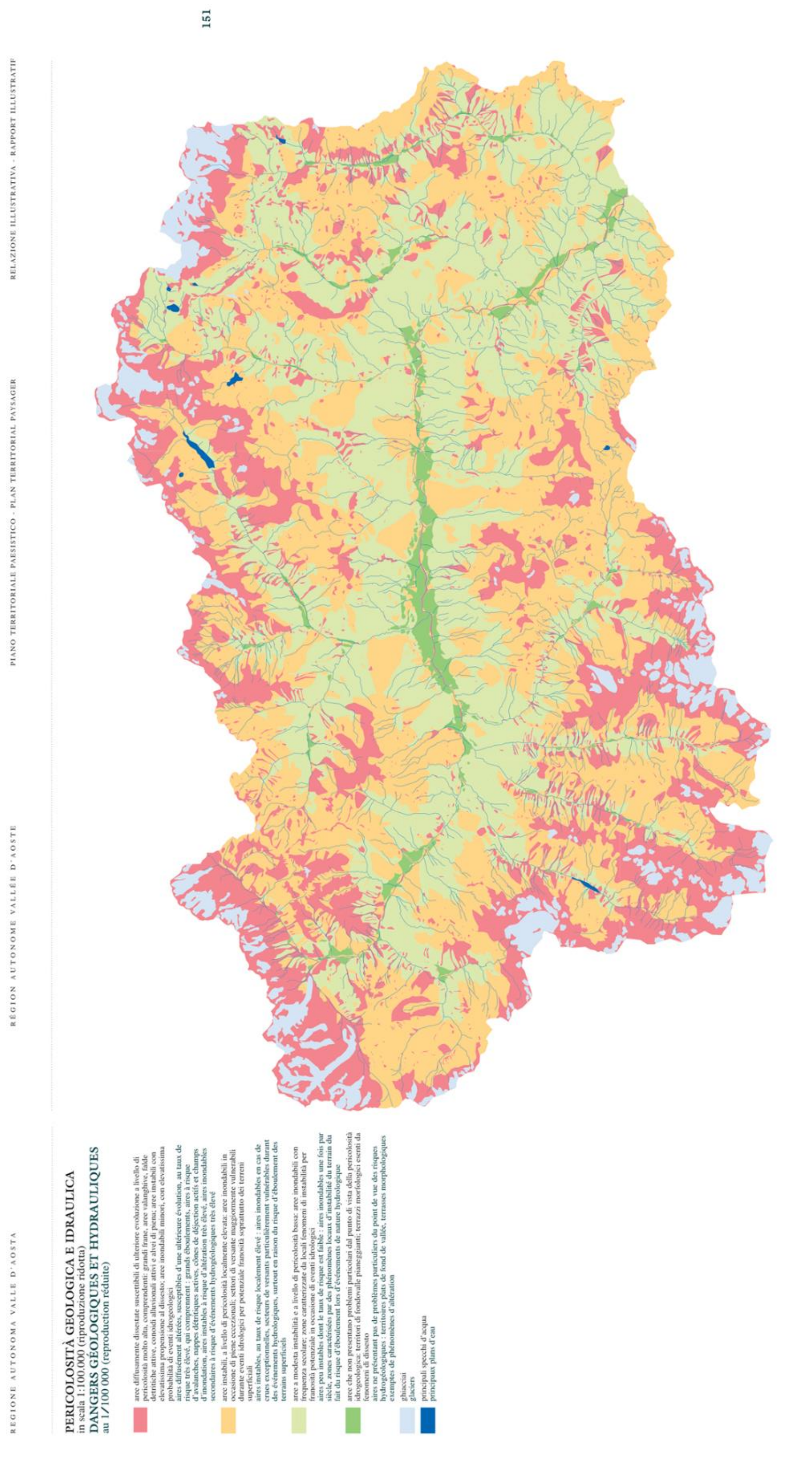

Figure 27 – Land classification for hydraulic and geologic danger (Regione Autonoma Valle d'Aosta, 1998)

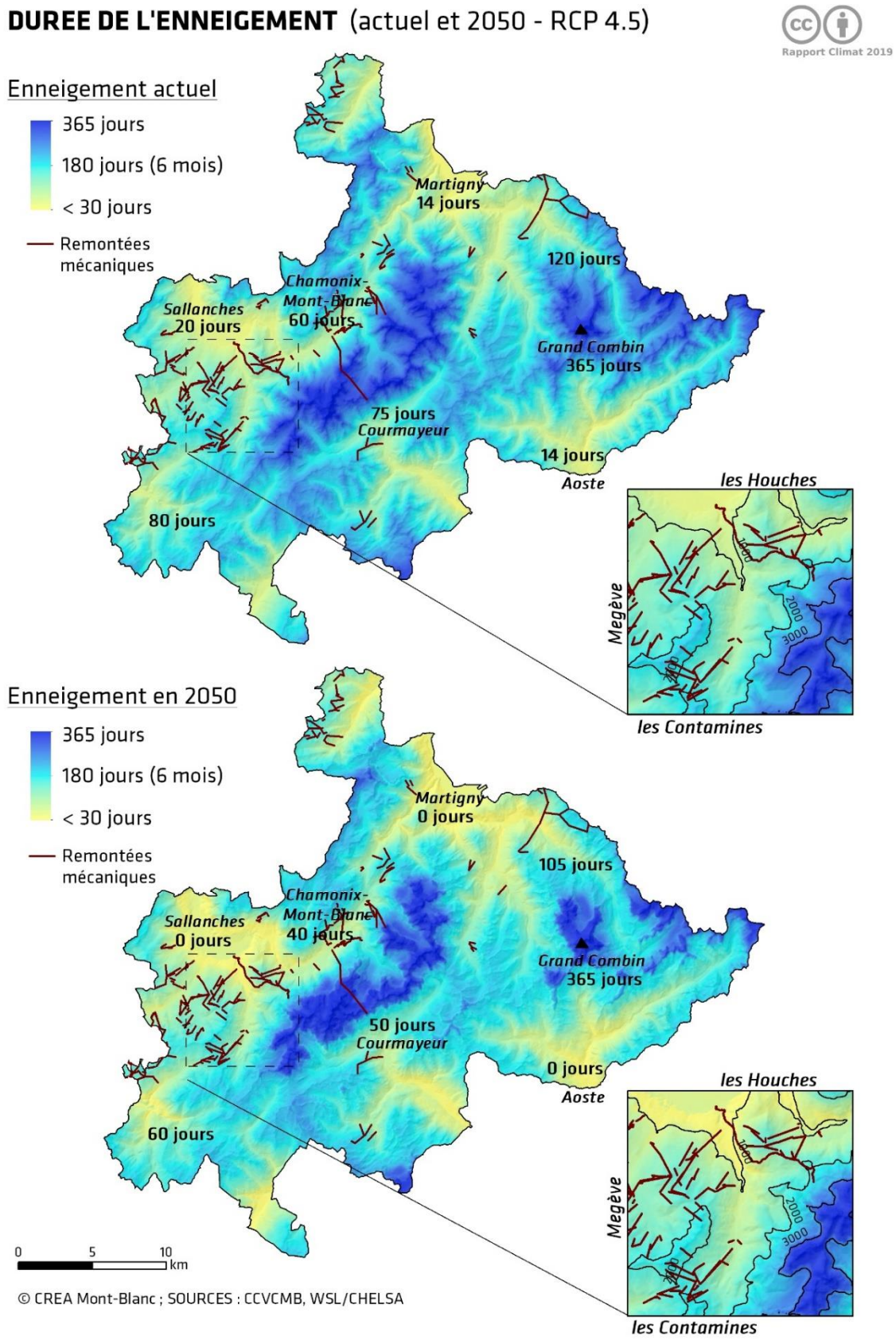

Figure 28 – Expected duration of snow cover, defined as number of days with snow on the ground, today and in 2050, in the Mont Blanc massif area (Cremonese *et al.*, 2019)

9.3 APPENDIX C

The Intergovernmental Panel for Climate Change (IPCC) has projected multiple greenhouse gas emission scenarios, depending on future trends in socio-economic development, such as population size, economic activity, energy use, lifestyle, land use and technology, as well as climate policy.

The Representative Concentration Pathways (RCPs) describe four different emission scenarios for 21st century, which take into account emissions and atmospheric concentrations of GHGs, emissions of other air pollutants, and land use (IPCC, 2014). Said scenarios are:

- RCP2.6: stringent mitigation scenario; radiative forcing peaks at approximately 2.6 W/m² before 2100 and then declines. Representative of a scenario that aims to keep global warming below 2°C above pre-industrial temperatures.
- RCP4.5: intermediate mitigation scenario; radiative forcing is stabilized at approximately 4.5 W/m² after 2100. Increase* in global mean surface temperature of 1.1° to 2.6°C.
- RCP6.0: intermediate mitigation scenario; radiative forcing is stabilized at approximately 6.0 W/m² after 2100. Increase* in global mean surface temperature of 1.4° to 3.1°C.
- RCP8.5: high GHG emissions scenario; radiative forcing reaches >8.5 W/m² by 2100 and continues to rise for some time. Increase* in global mean surface temperature of 2.6° to 4.1°C.

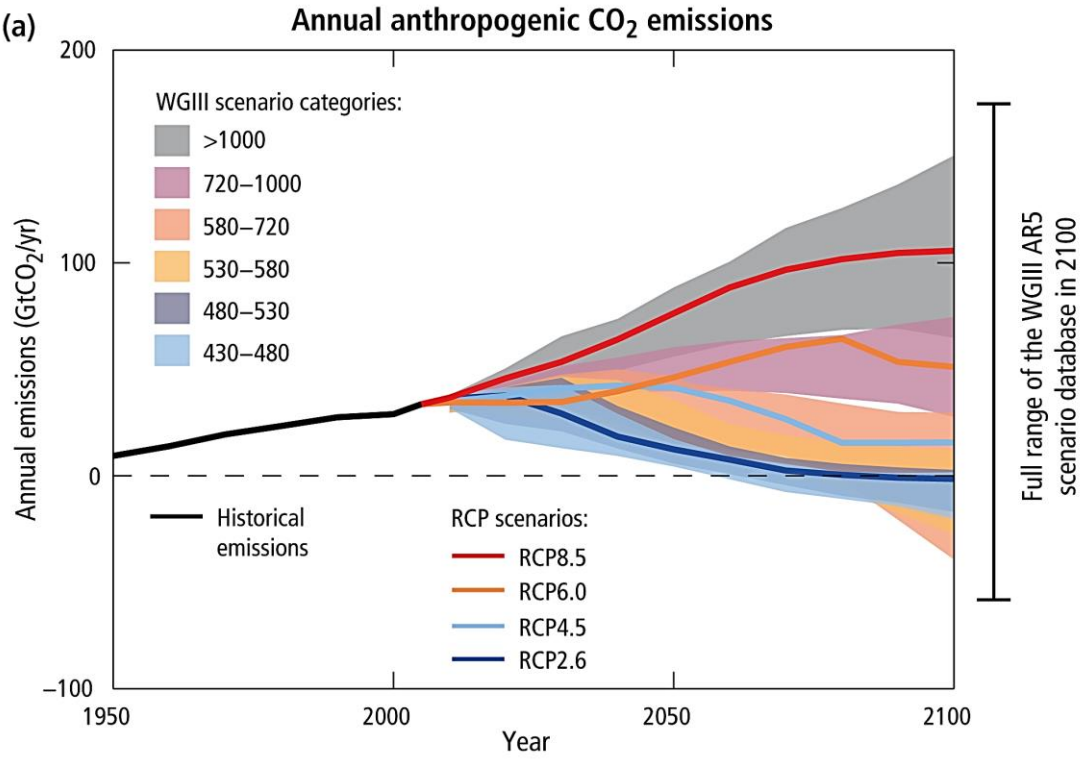

Figure 29 – Projections of future emission trends for the 21st century, defined in CO2-eq concentration levels in ppm. The colored lines represent the RCPs, and the plumes show the associated 5 to 95% range.

* Relative to 1986-2005. This period is approximately 0.61 [0.55 to 0.67] °C warmer than 1850–1900.

9.4 APPENDIX D

List of traditional agri-food products, 21st review (Ministero delle politiche agricole alimentari e forestali, 2016).

REGIONE AUTONOMA VALLE d'AOSTA		
Tipologia	***N°***	***Prodotto***
Bevande analcoliche, distillati e liquori	1	Grappa
	2	Ratafià
Carni (e frattaglie) fresche e loro preparazione	3	Boudin
	4	Mocetta
	5	Motsetta - Motzetta (Mocetta di carne valdostana)
	6	Prosciutto alla brace Saint- Oyen (Jambon à la braise Saint- Oyen)
	7	Saouseusse
	8	Teteun
	9	Tseur achétaye
Formaggi	10	Brossa
	11	Formaggio di capra a pasta molle
	12	Formaggio di pecora o capra a pasta pressata
	13	Formaggio misto
	14	Reblec
	15	Reblec de crama
	16	Salignoùn
	17	Séras
	18	Toma di Gressoney
Prodotti vegetali allo stato naturale o trasformati	19	Golden Delicious della Valle d'Aosta
	20	Renetta della Valle d'Aosta
Paste fresche e prodotti della panetteria, della biscotteria, della pasticceria e della confetteria	21	Crèichèn, Créchén
	22	Flantse e Flantsón
	23	Micóoula
	24	Mécoulén, Mécoula e Pan de Cogne
	25	Piata di Issogne
	26	Pan ner, Pane nero
Grassi (burro, margarina, oli)	27	Beuro (Burro di affioramento)
	28	Beuro coló
	29	Beuro de brossa
	30	Burro centrifugato di siero
	31	Olio di noci, Huile de noix
Prodotti della gastronomia	32	Seupa à la vapelenentze
Prodotti d'origine animale (miele, prodotti lattiero caseari di vario tipo, escluso il burro)	33	Miele di castagno (Mi de tsatagnì)
	34	Miele di rododendro (Mi de framiclio)
	35	Miele millefiori di montagna (Mi de fleur de montagne)
	36	Lasé

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