HAL open science

Multiple aspects of wealth creation in a social-ecological system of the French Alps

Julia Grosinger

To cite this version:

Julia Grosinger. Multiple aspects of wealth creation in a social-ecological system of the French Alps. Geography. Université Grenoble Alpes [2020-..], 2021. English. NNT : 2021GRALH009 . tel-03425096

HAL Id: tel-03425096

https://theses.hal.science/tel-03425096v1

Submitted on 10 Nov 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

THÈSE

Pour obtenir le grade de

DOCTEUR DE L'UNIVERSITE GRENOBLE ALPES

Spécialité : Science du Territoire

Arrêté ministériel : 25 mai 2016

Présentée par

Julia Grosinger

Thèse dirigée par **Nicolas BUCLET, Professeur des Universités, Université Grenoble-Alpes**
et par **Sandra LAVOREL, Directrice de recherche, Laboratoire d'Ecologie Alpine-CNRS**

préparée au sein du **Laboratoire Pacte et du Laboratoire d'Ecologie Alpine**

dans **l'École Doctorale Science de L'Homme, du Politique et du Territoire**

Les multiples aspects de la création de richesse dans un système socio-écologique des Alpes Françaises

Multiple aspects of wealth creation in a social-ecological system of the French Alps

Thèse soutenue publiquement le **13 juillet 2021,**
devant le jury composé de :

M. Nicolas BUCLET
Professeur, Université Grenoble Alpes, Directeur de thèse
Mme Claire DELFOSSE
Professeur, Université 2-Lyon, Rapportrice
M. Jean-Christophe DISSART
Professeur, Université Grenoble Alpes, Président
Mme Sandra LAVOREL
Directrice de recherche, Laboratoire d'Ecologie Alpine-CNRS, Co-directrice de thèse
Mme Marianne PENKER
Professeur, University of Natural Resources and Life Sciences, Vienna, Examinatrice
M. Tobias PLIENINGER
Professeur, University of Göttingen, Rapporteur

Acknowledgements

Life doesn't just happen to us.
We happen to life; and we make it meaningful.
(Viktor Frankl)

Writing a thesis is a long process with involves many people. After this long journey, which I initially conceived as a pilgrimage, then as a relay race, subsequently as a marathon and finally a short distance race against the deadline, I want to thank the people who supported me during the last years in the most diverse ways possible. From food for thoughts and thoughts as food (I did not forget any cake ever received from any of you), countless cups of coffee and the sharing of the darkest and the brightest moments, you made this work not only a scientific, but also a human experience.

First, I extend my warmest and sincerest thank you to Sandra Lavorel and Nicolas Buclet, who were always ready to listen to and develop my frequently quite incoherent reflections, to provoke and push my way of thinking and to force me to put words on these things called thoughts. Thank you.

Another big thank you goes to the Trajectories project, which enabled me during the last four years to analyse and research the things I consider as meaningful. Without not only the material, but also especially the non-material resources, such as friendships (yes, this concerns you, Raphael), confidence, interest and openness this project would not have been possible. In addition, I would like to thank the people from the TRASSE project for their enthusiastic interest in my my work.

I am grateful for the interest of the jury not only to attend my thesis, but also their meaningful and constructive feedback.

The content of my research is mainly owed to all the people I met in the Maurienne valley. In particular, I would like to thank Caroline Glise, Chantal Daldosso, Mylene Richard and Simon Culot from the Beaufort production system for their endless patience in responding to my neverending flow of questions. Further a big thank you to Gentiane and Louis-Abel for their fast, reactive help and their seemingly endless gentleness.

For the final steps of my thesis, numerous people came along to vividly engage in any troubleshooting role possible. My warmest thank you goes to the co-authors of the published, articles, Ameline Vallet, Ignacio Palomo, Matthew Potts, Karl Grigulis and Nicolas Elleaume. I particularly highlight here not only their intellectual, but moreover the mental support they provided over the dire process of finding the meaning in my thoughts. In addition, I would like to thank Stefanie Abrial, for their invaluable aid and Bruno Locatelli in his heroic role as pretty-cow picture provider until the end!

An extremely warm thank you for the office 111 at LECA, renowned for its everboiling kettle and reliable supply of caloric feelgoodies! I had the pleasure of taking the relay from Rémy, Emilie and Coline. Together with Enora, Agnès, Nicolas, Gabin, Lionel and Océane we bravely continued this run. Marie, Titouan, Blandine and Emmanuel took over and maintain the sometimes intellectual, sometimes goofy, but always-pleasant exchanges on ecosystems, humans and chocolate. Marie-Pascale, Karl and Arnaud readily provided reliable input regarding all of these exchangew. Thank you.

I also would like to thank the administrative and technical staff that effectively and bravely manages to keep things running. In particular I would like to thank Catalina from PACTE and Florence and Oliver from LECA.

Needless to say that without my parents, my sister and my friends this thesis would never have been realised. Thank you for your understanding and particularly your patience.

Preventing me many, but yet countless times to not migrate to Antarctica as a lonely hermit without a PhD was Denis. Thank you; you know what you mean to me.

Objets inanimés, avez-vous donc une âme –
*Qui s'attache à notre âme et la force d'aimer**
(Alphonse de Lamartine)

* *Inanimate objects, do you have a soul, attached to our soul and the strength of love?*

Table of contents

Acknowledgements 1
Abstract 8
Chapter I Introduction 9
1 Context 10
2 Positioning in and within ecological economics –Territorial ecology 11
2.1. Ecological economics 11
2.2. Social-ecological systems 12
2.3. The concept of *territories* in Latin academia 13
2.4. Territorial ecology 13
3. Organisational positioning – The Trajectories project 15
4. Conceptual foundations of the thesis 17
4.1 From ecosystem services to the co-production of nature's contributions to people 17
4.2 The values of ecosystems 23
4.3. The capability approach (CA) for studying social-ecological interactions 25
4.4. Scientific objects 29
Chapter II – Social-ecological systems in the European Alps 30
1. The European Alps 32
1.1. The area 32
1.2. The people 32
1.3. Agriculture 33
1.4. The institutions 34
1.5. Challenges of Alpine agriculture 35
2. Cheese production in France 36
2.1. Importance of cheese production for identities 36
2.2. Quality labels 36
2.3. Cheese production in territorial systems 37
3. The Beaufort production system 38
4. The Maurienne valley 40
Chapter II – Social-ecological systems in the European Alps 43
1. The European Alps 45
1.1. The area 45
1.2. The people 45
1.3. Agriculture 46
1.4. The institutions 47
1.5. Challenges of Alpine agriculture 48
2. Cheese production in France 49

2.1. Importance of cheese production for identities 49
2.2. Quality labels 49
2.3. Cheese production in territorial systems 50
3. The Beaufort production system 51
4. The Maurienne valley 53
Chapter III- A conceptual framework to embed the co-production of nature's contributions to people (NCP) in social-ecological systems 56
1. Introduction 59
2. An expanded SES Framework for NCP co-production in agricultural systems 62
2.1. Social-ecological legacies and current resources 64
2.2. Activities along the NCP co-production chain 69
3. The Maurienne Beaufort cheese production system 70
3.1. Organising resources (CP0) 71
3.2. Producing fodder (CP1) 72
3.3. Mobilising ecological resources (CP2) 73
3.4. Appreciating NCP (CP3) 73
4. Discussion 74
4.1. General applications of the framework 75
4.2. Integrating social-ecological l legacies for understanding NCP co-production 77
4.3. Evolving current resources and types of appreciation 78
5. Conclusion 79
Acknowledgements 79
References 79
Annexes 90
Chapter IV- Applying collective capabilities to understand the co-production of nature's contributions to people 97
1. Introduction 100
Materials and methods 102
Study area 102
2. Materials and Methods 103
2.1. Study area 103
2.2. Overview of the approach 105
2.3. Actor selection 105
2.4. Data collection 106
3. Data analysis 107
3.1. Unravelling collective capabilities at different steps of Beaufort co-production 107
3.2. Analysing perceptions and associated sentiments about Beaufort co-production 109
3.3. Content analysis for detecting local identities 109

3.4. Comparing content and sentiment between actors' groups 110
4. Results 111
4.1. Beaufort co-production activities 111
4.2. Collective capabilities surrounding Beaufort co-production 111
4.3. Sentiments about Beaufort co-production activities 116
4.4. Highlighting local identities with terms frequency analysis 117
4.5. Sentiments differences between groups 121
5. Discussion 122
5.1. Collective capabilities contributions to NCP co-production 122
5.2. How does NCP co-production via collective capabilities contribute to local identities? 123
5.3. Local identities, relational values and contributions to good quality of life 124
5.4. Methodological considerations: Unravelling the links between NCP co-production, collective capabilities and local identities with sentiment analysis 124
6. Conclusion 125
Acknowledgements 126
References 126
Annexes 133
Chapter V- A quantitative comparison of the co-production of nature's contributions to people across a territory 149
1. Introduction 152
2. Methodology 154
2.1. Study site 154
2.2. Materials 155
2.3. Data analysis 156
3. Results 157
3.1. Key variables along the NCP co-production chain 157
3.2. Municipality archetypes 159
4. Discussion 162
4.1. The relevance of institutions along the NCP co-production chain 163
4.2. Social-ecological archetypes 163
4.3. Strengths and limitations of the study 164
5. Conclusion 164
Acknowledgements 165
References 165
Annexes 169
Chapter VI Discussion 175
1. NCP co-production and collective capabilities 177
2. Relational values along the NCP co-production chain 180

3. Contextualising collective capabilities in a territorial system 184
3.1. Collective capability 184
3.2. Territorial capability 185
3.3. Territorial capability and sustainability 185
4. Analysing cross-scale dynamics by the telecoupling framework 187
4.1. The telecoupling framework 187
4.2. Trade and tourism 190
4.3. PDO certification 190
4.4. Lifestyle 191
5. Some reflections on interdisciplinarity 192
Conclusion 196
Acronyms 198
References (chapter I, II and VI) 200
Annexes 216
Summary/ English version 216
Resumé/ version française 217
Co-authorship 220

Abstract

In this interdisciplinary thesis, I aimed to understand how the dynamic interplay of social and ecological resources and social processes underpin socioeconomic activities. For that, I combined the concept of nature's contributions to people (NCP) with the development-based capability approach. I applied this conceptual framing in the cooperative Beaufort cheese production system of the Maurienne valley, in the Northern French Alps. I suggest considering the Beaufort production system as a territorial capability structured by the complex interactions between ecosystems and society, and within society. This social dynamics combines local biophysical constraints, unique social-ecological capital and universal production factors towards an outcome that contributes to multiple aspects of quality of life and its long-term persistence. The results of this thesis support a stronger role of social sciences in interdisciplinary research on social-ecological system to fully account for their complexity.

Chapter I Introduction

Maurienne valley (credits: Bruno Locatelli/2018)

1 Context

A good quality of life is intrinsically linked to the flows of material and non-material resources between societies and surrounding ecosystems (IPBES, 2018). The academic consensus in sustainability research acknowledges good quality of life as an overarching focus. Good quality of life encompasses various dimensions, ranging from basic physical needs such as food, shelter health to more context-dependent ones such as good social relationships, cultural identity, freedom of choice and participation in society. These multiple factors are valued differently by different people (Díaz et al., 2015a; Max-Neef et al., 1989; Sen, 2000). Socioeconomic activities are crucial for a fulfilled life in modern societies, on the other hand they greatly contribute to the deterioration of ecosystems and the decrease of finite resources on the local and global scale (IPBES, 2019, 2018; IPCC, 2014; Rockström et al., 2009). This ultimately can lead to considerable (possible unequally distributed) decreases in quality of life and within societies. Technological solutions that aim to substitute ecological resources by anthropic ones frequently focus on material human needs and are insufficient to address multiple dimensions important to different people. These one-dimensional approaches threaten the longevity of ecosystems and ultimately different societies. Approaches that explicitly study the multiple, frequently subtle interdependencies between societies and ecosystems from an interdisciplinary perspective can facilitate a better understanding of how and which benefits from ecosystems can sustain various aspects contribute to a good quality of life for societies and ecosystems on a long term (Chan et al., 2018; Díaz et al., 2015a).

Based on the multidimensionality of a good quality of life the concept of nature's contributions to people (NCP) formalizes and structures these aspects that derive out of the interactions between societies and ecosystems. It acknowledges that societies and ecosystems have been jointly producing them in various ways. The concept of NCP co-production describes and acknowledges these social involvements with ecosystems through material resources (e.g. labour) and non-material resources (e.g. knowledge) (Lele et al., 2013; Palomo et al., 2016). Further, research increasingly focuses on non-material aspects such as underlying value systems between people and nature and among people to widen the understanding of societies' motivations and interrelated activities in these interactions (IPBES, 2018; Schröter et al., 2020). This view considers societies as a group of interacting beings and not as a an aggregate of self-interested, autonomously acting individuals (Vatn, 2005). At regional scale, collective structures frequently shape and govern these social-ecological interactions. The explicit integration of social structures (e.g. formal or informal institutions) in the analysis of social-

ecological interaction is thus paramount to understand the underlying subtle drivers, such as the surrounding context and associated value systems. Interdisciplinary approaches that explicitly consider humans as social beings are needed to align sustainability research with real world situations.

My PhD research is embedded in the field of territorial ecology, one research area close to the broader field of ecological economics. Ecological economics views economic activities as integral part of social-ecological systems and not as an isolated entity (Daly, 2007). This rethinking of society requires to extend the boundaries of economic production to ecosystems and to measure economic flows beyond material and monetary measures. The emerging field of territorial ecology that explicitly focuses at regional scale, proposes new valuation approaches that accounts for these multidimensional flows so as to conciliate the way people intend to live in a local context and the material consequences of human activities and puts a good quality of life in the centre of analysis (Buclet, 2021). This re-conceptualisation requires methodologies to assess these valuation systems.

In this chapter I first position my work in the academic landscape. Then I introduce the four major concepts I used. I close this chapter with the scientific objectives of my work. The aim is to provide a short overview of key concepts that can facilitate the understanding of how territorial systems can shape aspects that contribute to a good quality of life.

2 Positioning in and within ecological economics –Territorial ecology

2.1. Ecological economics

The quality of life of human societies is intrinsically linked to resources of their surrounding ecosystems (Daly, 2007; Díaz et al., 2015a). In order to better comprehend these complex linkages, I anchor my research in territorial ecology, an emerging field close to ecological economics. It addresses economic activities and the associated production modes as part of social and ecological systems where constant flows and exchanges of material and non-material resources take place at various spatial and temporal scales (Braat and de Groot, 2012). Former classical economic theories regarded ecosystems mainly as resource pools and treated related questions mainly from a utilitarian perspective of resource constraints or scarcity (e.g Adam Smith, Thomas Malthus and David Ricardo). Ecological economics challenges a radical rethinking of this perspective and questions how humans' quality of life and ecosystems can be jointly managed (Costanza, Cumberland, et al. 1997). This perspective implies that economic activities are embedded in social dynamics and ecological systems, and they cannot be regarded

as separated entities. This is in contrast to conceptions of sustainability in economic activities, such as the triple bottom line (TBL) that considers "people, planet and profit" as equally relevant dimensions (Henriques and Richardson, 2013). However, in a certain regard the TBL can be regarded as the consequence of the general view on sustainable development (Brundtland, 1987). Moreover, economic activities form the interface where society and ecosystems meet and overlap. The field of ecological economics research (its actual foundation reaching back to the 1980s) has been influenced by the work of systems ecologists and heterodox economists (Gómez-Baggethun et al., 2010; Røpke, 2004). To refine their intellectual and methodological foundations, ecological economics drew on ideas and concepts within economics (e.g. Kenneth Boulding and Hermann Daly) but it also adopted concepts well beyond its initial discipline (e.g. from the ecologist Eugene Odum and the biologist Eugene Odum) (Folke et al., 2016).

2.2. Social-ecological systems

To position my research in ecological economics I adopted the ontological lens of social-ecological systems (SES) This lens acknowledges that society, thus also economic activities are embedded in the biosphere. Societies depend on, evolve and shape this biosphere (Folke et al., 2016). Studies on these complex coupled systems centre on the deep interlinkages of social and ecological systems. The SES perspective allows considering and including impacts, feedbacks on various spatial and temporal scales. In contrast to the above described TBL the SES concept of sustainability views economic activities as an integral part of the interactions between the social and the ecological system. This implies that (1) societies depend on ecosystems and (2) humans are recognized as drivers in shaping the ecosystem in order to achieve aspects of a good quality of life (de Schutter et al., 2019; MEA, 2005). In addition, the SES perspective reinforces the ideal of strong sustainability in research. This view considers social and ecological resources as complementary, whereby weak sustainability argues that technological solutions can substitute ecological resources (Daly, 1997; Stiglitz, 1997). The integration of economic activities (such as the modes of production) into the SES perspective leads to the reasoning that societies and the ecosystems jointly produce aspects that contribute to a good quality of life. It acknowledges that social and ecological processes have co-evolved over a long period of time and are thus embedded in a social-ecological context (McGinnis and Ostrom, 2014). In my thesis I side with Berkes (2017) and favour the term "social-ecological" over "socio-ecological' to underline that these two subsystems and their internal dynamics are equally relevant in an analysis of social-ecological interactions. The term "socio" could be regarded as a mere

supplement that is attached to an ecological system (Colding and Barthel, 2019). The concept of social–ecological systems is not rigid but research has developed over the years multiple frameworks to analyse these relations at various scales and with various focal points (Fischer et al., 2015; Scholz, 2011).

2.3. The concept of *territories* in Latin academia

"Territoire" (English: territory) is a central concept in human geography, urban planning and regional development in Latin countries, mostly in Italy and France. For example, one of the precursors, an Italian economist analysed the textile industry in the Italian city of Prato (Becattini et al., 2003). Subsequently the t*erritoire* concept was advanced to other socioeconomic areas. The French economist Bernard Pecqueur applied it to rural areas analysing the valorisation of agricultural products (Pecqueur, 2001). French academia views territory as the linkages between space and its cultural and social uses. In this research I align with the definition of previous research and define the territory "a space that is socially constructed, culturally marketed and institutionally regulated." (Lopéz and Muchnik, 1997). It thus encompasses the material and the non-material dimensions of a spatially defined area (Di Méo, 2017). Anglophone research rarely applies the approach. The French term *territoire* is frequently loosely translated with "place" (Del Biaggio, 2015), whereby the literal English translation "territory" commonly relates to political demarcation lines (Barreteau et al., 2016). However, in the following I use the term "territorial system" emphasizing that this refers in this work explicitly to a space constructed by actors and their activities at regional scale (Moine, 2006). I use the term SES when I refer to these coupled human-ecosystems from a broader perspective.

2.4. Territorial ecology

Territorial ecology links ecological questions to territorial issues (Buclet, 2021). The emerging interdisciplinary field originating in France strives to understand the organisation of human activities and the observable interactions with their natural environment (Buclet, 2021). Territorial ecology is one of the dynamic fields close to ecological economics designed to address social-ecological interactions at regional scale. Territorial ecology deliberately includes the social dimension when measuring social-ecological interactions based on material flow analysis. Initially this field of research was related with industrial ecology and therefore focused on industrial activities (Erkman, 2004). While sharing fundamental communalities with the SES approach, the concept territory emphasizes non-material dimensions deriving out of social-ecological interactions, such as the notion of sense of place and identities. Further the ability of local actors to coordinate and control their system is a recurrent research focus (Barreteau et

al., 2016). Actors are interacting with the objects within a space and shaping it. By this they modify their own social interaction and produce a territorial system with its own cultural specificities. The territory is the result of actors' interaction sharing a common geographical space which specificities are the result of such interactions (Buclet, 2021). This dynamic creation leads consequently to the situation that multiple territories can exist simultaneously (Kebir and Crevoisier, 2004). This means the approach assigns a crucial role to actors, their activities and the ways how they conceive their territorial system. The concept of territory can focus on certain specific (e.g. economic) activities relevant only for some parts of the population and differs in that regard from conventional SES approaches. In order to understand these dynamics territorial ecology uses the concept of metabolism to assess and understand flows which make up a territory (Buclet and Barles, 2011). In this context metabolism describes an exchange of matter between an organism and its environment. In modern societies, this is best exemplified by the flow of materials and energy by management, mobilisation, production, consumption and disposal of resources. From the early 19th century social sciences (among them Karl Marx and Friedrich Engels) occasionally borrowed the concept "metabolism" from biology and biochemistry to describe labour processes within societies (Fischer-Kowalski and Hüttler, 1998; Foster, 1999). Advancing the idea of metabolism some researchers such as Herbert Spencer and Wilhelm Oswald concluded that social process is related to energy surplus which allows social differentiation (Fischer-Kowalski and Hüttler, 1998). Other material resource dimensions of social-ecological interactions remained largely unnoticed until the 1960s for social sciences apart from some notable applications in anthropology (e.g. Julian Stewart) and social geography (e.g. Lewis Mumford). The early works of the physicist Robert Ayres and the economist Allen Kneese in 1969 eventually led to what have become known as material flow analysis (Fischer-Kowalski and Hüttler, 1998). This approach measures the flows of natural resources (e.g. water, biomass, energy, minerals and metals) within and across national states (EC, 2018). Studies focus mostly on national level and although regional assessments exist they remain exceptions (Singh and Haas, 2016). In addition they focus on the material flows between societies and the natural system, but they focus less on non-material flows within societies (Fischer-Kowalski and Haberl, 2007). Territorial ecology builds up on the idea of metabolism and the method of material flow analysis. The field advances this analysis to the inclusion of non-material flows. It assumes that these material flows come along with non-material aspects, such as social relations (Buclet, 2021). Thus, territorial ecology contextualises resources in their social-ecological setting. By establishing the clear links

between society and resource flows, territorial ecology seeks to analyse how social-ecological interactions contribute to good quality of life.

Inspired by territorial economy, territorial ecology favours the term “resource” over “capital” when investigating the flows and stocks in the SES. The notable epistemological difference between these two terms explains this insistence. The Cambridge Dictionary defines resources as a “a useful or valuable possession or quality of a country, organisation, or person”, while capital is defined as “money and possessions, especially a large amount of money used for producing more wealth or for starting a new business” (CD, 2021). Both terms follow an anthropocentric perspective; yet the definition of capital not only implies monetary quantification but also a tendency to accumulate. Research on social-ecological interactions frequently applies capital-based approaches, distinguishing between natural, social, human, manufactured and financial capitals. While it is easy to quantify material types of capital, social capital can rarely be measured. Further this approach does not consider the multiple interdependencies between different types of capitals. Some research explicitly distinguishes between these two characteristics within their analysis, and use the term resource for objects that are presently used and consumed, but the term capital for objects that are stocked for future use or consumption (Ostrom, 1999). Following this reasoning, the focus of territorial ecology on the flows within the *territoire* implies present use and consumption patterns of resources. However the strong focal point on the social-ecological context of the *territoire* implies that capital (in the meaning of accumulated stocks) is implicitly integrated. It is viewed though as a potential resource. Social choice determines how and if a resource is then valued and utilized.

Territorial ecology serves as the architecture of my research. I focus in chapter III explicitly on the social-ecological embeddedness of SES. I advocate considering social-ecological legacies as an integral part of the analysis. Chapter IV investigates the role of non-material resources, such as perceptions and values for the quality of life. Chapter V explores quantitatively the role and composition of non-material and material resources for quality of life. In chapter VI, the discussion I link these different findings and discuss their advantages and limitations.

3. Organisational positioning – The Trajectories project

My doctoral thesis is part of the Trajectories project, funded by national programme for university excellence (ANR-IDEX) of University Grenoble Alpes. The Trajectories cross disciplinary project (CDP) assembled over the duration of three years (2017-2020) over 100 researchers from social and natural sciences. As the name Trajectories already implies the aim of the project was to explore and understand social-ecological interactions at various time scales

in mountain areas. The approach of territorial ecology to perceive these mountain areas as territorial systems featuring unique characteristics allowed to further integrate the social dimension into social-ecological research. Three research areas with pre-existing social-ecological research on global change impacts and temporal dynamics were selected, the Arve valley, the Maurienne valley and the Meije region.

During my thesis I was part of a self-organised group of around 15 PhD students and postdoctoral researchers that aimed to apply the principles of interdisciplinary and transdisciplinary methods in the Maurienne valley and the Meije region. The first case study was based on an interdisciplinary approach. We reconstructed the social-ecological trajectory of the Meije region (that is composed of two municipalities) from 1800-2050. We communicated the results with a poster presentation at the international mountain conference in August 2019 in Innsbruck/Austria. The second case study focused on transdisciplinarity and took place in Villarodin-Bouget, a municipality in the Maurienne valley. During one week we elicited with local stakeholders their most relevant questions about climatic change impacts at local scale. Following the reasoning of transdisciplinarity we opted for an unconventional way of formalising our results. An external team of film students filmed the scientific process and condensed it to a 24-minute documentary. In collaboration with the municipality we organised a public screening. Currently (May 2021) some members of the group plan to summarize the findings of our three-year collaboration as a hands-on-practice article in a scientific journal in 2021.

My doctoral thesis contributes in various ways to the overarching objective of the Trajectories project. By the conceptual integration of legacies in a social-ecological systems framework, I highlighted the relevance of temporal scales in these interactions (see chapter III). More broadly, I translated the term ‘trajectories’ into an analytical component for further reflections. I further anchored the social dimension in social-ecological research, a discipline frequently underrepresented in interdisciplinary research (see chapter IV). From a broader perspective, my research project also highlighted the challenges in communication, because the terminologies across disciplines can greatly vary or sometimes don’t even exist. I present in chapter VI, section 5 a certainly not exhaustive overview of these still existing communication barriers.

4. Conceptual foundations of the thesis

4.1 From ecosystem services to the co-production of nature's contributions to people

The good quality of life of society depends intrinsically on ecosystems. In the last decades, sustainability research has started to formalise and structure these different types of flows by various concepts and evolving recognition of societies' active role in these interactions. This section briefly outlines and describes the conceptual journey from the beginning of ecosystem service research to the current state of the art – the IPBES framework.

4.1.1. The historical background

The ecosystem service (ES) concept provides the foundation to conceptualise material and non-material flows to and from ecosystems that contribute to a good quality of life. In the broadest possible manner, these flows are different benefits (such as clean air, food, safety) that people obtain from ecosystems with varying inputs such as labour, technology or infrastructure (MEA 2005; Palomo et al. 2016). Research dates the idea that ecosystems contribute to a good quality of life up to the accounts of Plato describing the impacts of deforestation on soil erosion. But the term and its conceptual implication was only coined in the 1980s by Ehrlich and Ehrlich (Ehrlich and Ehrlich, 1981; Gómez-Baggethun et al., 2010). From the beginning research framed ecosystem services as a strong communication and policy tool. Initially the field of conservation biology aimed to raise public awareness about ecosystem degradation (Ehrlich and Ehrlich 1981; Braat and de Groot 2012). Subsequently ecological economics adopted the idea in the 1990s. Some researchers attempted to internalise externalities (broadly defined as the uncompensated environmental costs of trade mechanisms) into the conventional market system. For that, they consequently adapted the ecosystem service concept to integrate ecological benefits to society (Gómez-Baggethun et al. 2010). Following the publication of the seminal Millennium Ecosystem Assessment (MEA) the concept gained a wider political audience in 2005 (MEA, 2005). However, the wide uptake in multiple disciplines and by different publics led some research to dilute the initial concept and its philosophical and theoretical implications to a more broadly formulated approach. The MEA affirmed the role of ecosystems for various constituents that contribute to a good quality of life (MEA, 2005). The MEA had an important role in communicating and mainstreaming social-ecological approaches (Folke et al., 2016). In 2010 the economics of ecosystem and biodiversity project, commonly known as TEEB specifically aimed to include public and private decision makers in their audience (TEEB, 2010). The explicit monetary valuation of benefits derived from ecosystems prompted mixed feelings in the research community. Some cherished the fact that the universal

valuation showed the true costs of ecosystem services in conventional economics, others rejected the concept due to methodological and ethical considerations (Kallis et al., 2013; Spash, 2008) (see chapter I, section 4.2. on valuation systems). The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) built on the MEA framework and published an evolved concept in 2015 (Díaz et al., 2018). This widely circulated and hotly debated article called for the redefinition of ecosystem services as "nature's contributions to people (NCP)". These are "all contributions, beneficial or harmful, that individuals, communities, societies, nations or humanity as a whole derive from nature" (Díaz et al., 2018). This characterization encompasses a variety of material (e.g. food), regulating (e.g. water provision) and non-material (e.g. identities) aspects that different people value differently. In particular it emphasizes the profoundly context-dependent character of these flows between people and ecosystems (Díaz et al., 2018). This re-specification fortifies inter- and possible transdisciplinary approaches by accommodating varying stakeholder interests and world views on ecosystems and its associated benefits (Díaz et al., 2018).

4.1.2. The power of conceptual frameworks

Research on social-ecological interactions frequently relies on graphic conceptual frameworks. These serve as visual communication supports within and across science and society. Researchers need to communicate results in a transparent and intuitively easy to understand manner. Conceptual frameworks summarize in words or pictures social-ecological interactions and their changes over time (Potschin-Young et al., 2018). They provide the basic vocabulary of terms and concepts which facilitates the development of causal explanations of a theory (McGinnis and Ostrom, 2014). They support the understanding or even operationalizing of complex real-world phenomena by simplification and provide a checklist for supposedly relevant variables (Meyfroidt et al., 2018; Schlager, 2019). From an analytical perspective, frameworks provide a meta-language that is useful to compare theories (McGinnis/Ostrom, 2014). All these facts together mean that prominent frameworks can become important factors for the shaping of research agendas (Carney et al., 2003).

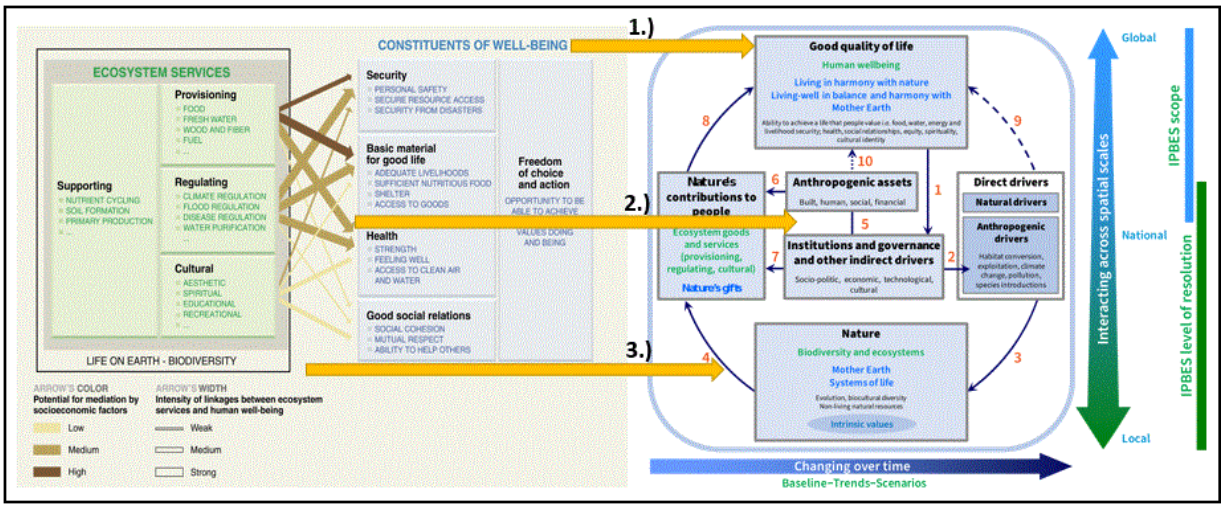


Figure 1: The graphic comparison between the ecosystem service and the nature's contributions to people framework highlights the evolution of humans as passive beneficiaries to active co-producers and the integration of spatial and temporal scales (Díaz et al., 2015a; MEA, 2005). Yellow arrows indicate the conceptual shifts from individual well-being to quality of life for all people, 2. independent flows to human interference and 3. static flows to circular flows

The conceptual shift from ecosystem services to NCP is striking when comparing the MEA framework (2005) with the IPBES framework (Díaz et al., 2015b; MEA, 2005) (Figure 1). Without going into detail, I highlight in particular three major developments that reflect the changes in current interdisciplinary research on interactions between societies and ecosystems. First, the conceptual shift from "well-being" to "good quality of life" is surprisingly little discussed in the current scientific literature within and outside research on NCP (see Figure 1, arrow 1). The human dimension in the MEA and the IPBES frameworks strongly builds on preceding theoretical concepts from development economics (Max-Neef et al., 1989; Sen, 2000). They focus on the actual outcomes of NCP to a variety of people. However, the MEA limits the definition of well-being to individual humans. The IPBES definition advances the definition of "good quality of life" to an ecological ("living in harmony with nature") and a metaphysical ("living well in balance and harmony with mother earth") dimension (Díaz et al., 2015b; MEA, 2005). The extension to these two dimensions can be considered as an attempt to reinforce more pluralistic values in scientific research. Further, by the notion of relational values, that explicit account for value construction within society the IPBES concept integrates more thoroughly the collective dimension of well-being (Chan et al., 2018). The well-being definition of the MEA appears to be quite complete, covering all areas of individual human

needs and wants, but the conceptual shift to “good quality of life” implies the recognition that NCP cannot be solely constructed at individual level but encompass social structures. Second, the IPBES framework acknowledges the crucial role of human action in generating benefits from ecosystems to people. The uni-directional concept where ecosystem services flow without explicit human interference from ecosystems to society (Haines-Young and Potschin, 2010; MEA, 2005) changed to a circular concept underlining the interconnectedness and interrelatedness of societies and ecosystems (Díaz et al., 2015b) (see Figure 1, arrow 2). This human agency implies a number of material and non-material components such as institutions and infrastructure (Díaz et al., 2015a). Some researchers have criticized that the framework has failed to sufficiently incorporate the natural, non-living components in their framework (Pandeya et al., 2016). Third, in contrast to the MEA the IPBES framework integrates an implicit temporal dimension. Thus, it at least theoretically acknowledges the possible impacts of feedback loops and legacies in SES (Turner et al., 2020). Nevertheless, the temporal dimension in the framework does not explicitly permit to account for the accumulation of different material or non-material resources that are major constituents of the context territorial systems are embedded in.

This very brief comparison of two major concepts in social-ecological research depicts the intellectual and practical efforts of interdisciplinary science to create a common thought system that permits to reflect on social-ecological interactions. Some promising novel approaches such as the co-production approach which I detail below, indicate that this radical reconceptualization has already prompted some shifts in empirical research. However, only the results of ongoing future and ongoing research will be able to compare and assess the results and draw conclusions from this shift.

4.1.3. NCP co-production

Although the MEA framework acknowledged the active human role in the generation of ecosystem services, the IPBES framework emphasized explicitly that societies create NCP in interaction with ecosystems (Díaz et al., 2018; MEA, 2005; Palomo et al., 2016). Various articles published almost in parallel pointed out the need to further investigate the active role of societies in generating NCP. Notable examples are Spangenberg et al. (2014) who underlined the role of human agency for ecosystem service production and Ernstson (2013) who advocated to integrate the social dimension in value creation. Prior to the adoption of the term “co-production” in NCP research “co-production” was used to describe the sector of public administration (Ostrom, 1996), the social context of science (Latour, 1990) and the role of

transdisciplinary knowledge creation in sustainability science (Miller and Wyborn, 2020). In ecosystem service research "co-production" has been gaining a wider audience with the publication by Lele et al (2013). The article specifically underlined that human labour along with other human-created assets and the general socio-technical context are primordial for the analysis of ecosystem services. Following this path, Palomo et al. (2016) further systemized this approach by estimating varying degrees of human intervention in ecosystems. The current literature broadly considers co-production as the mobilization of ecosystems by human assets such as infrastructure, labour, technology and knowledge at various spatial and temporal scales (Bruley et al., 2021; Fedele et al., 2017; Outeiro et al., 2017). Society's co-producing role has become current scientific consensus though no systematic, structured analysis of these contributions has been undertaken yet (Berbés-Blázquez et al., 2016; Fischer and Eastwood, 2016; Outeiro et al., 2017; Plieninger et al., 2015a).

The concept of NCP co-production corresponds well to underlying larger currents of ecological economics, such as Odum's energy flow approach. NCP require some investment of energy, be it labour or capital (Braat and de Groot, 2012; Crawley and Odum, 1984). More specifically it strongly aligns with and supports a better understanding of SES (Berkes et al., 2000; McGinnis and Ostrom, 2014). The integration of labour and capital in also bridges the gap of natural sciences to environmental justice and distributional equity issues (Lele et al., 2013). It allows society more agency but at the same time assigns more responsibility to act in light of the growing population in a world with finite resources (Spangenberg et al., 2014). The differentiation between producers and beneficiaries of NCP presented a milestone in ecosystem service science. It allowed explicitly focusing on mismatches in governance, management and benefits between stakeholders. In a next step, research further refined the roles of stakeholders along the main steps of co-production based on the cascade framework (Fedele et al., 2017; Haines-Young and Potschin, 2010).The cascade framework, published in 2010, thus prior to the IPBES framework initially aimed to render the role of ecological functionings to human well-being more understandable and to disaggregate the links of biodiversity to ecosystem services (Haines-Young and Potschin, 2010). The cascade framework structures the interactions of ecosystems and society into four interlinked mechanisms of action. The initial cascade framework indicated that biophysical processes and their consequences for society don't exist in isolation from humans but didn't specify human material and non-material assets on these steps (Haines-Young and Potschin, 2010).

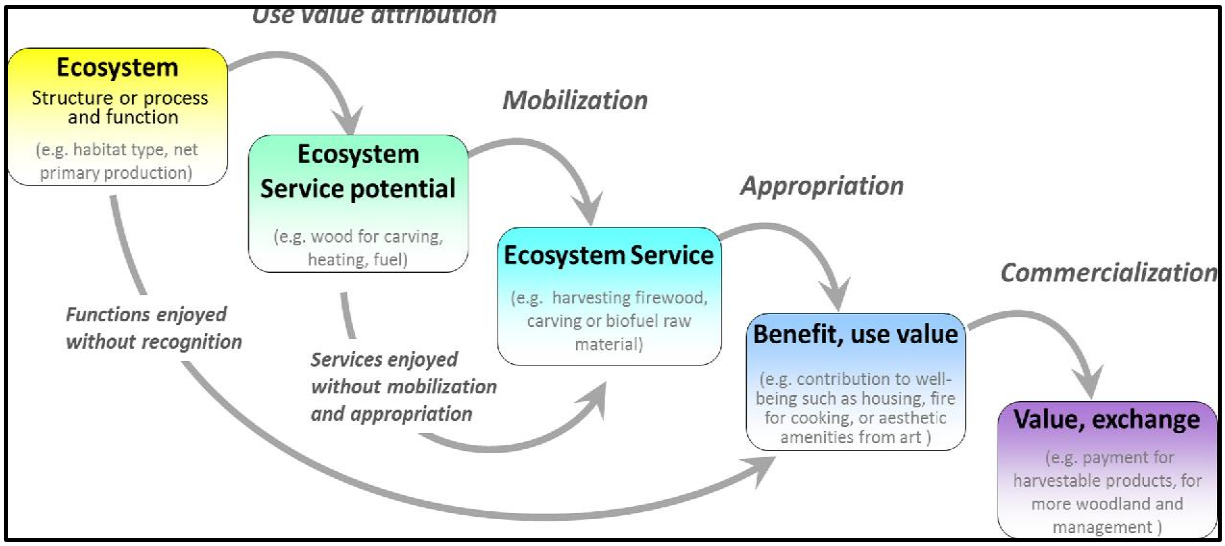


Figure 2: The advanced cascade framework by Fedele et al. (2017), based on Haines-Young and Potschin (2010)

Conceptual refinements of the framework enabled accounting explicitly for human agency in the co-production of NCP and led to account for feedbacks from society to ecosystems through management and decisions (Fedele et al., 2017). The steps differentiates not only between the physical or theoretical steps of co-production, moreover it assigns the different steps to different various stakeholders (Fedele et al., 2017; Vallet et al., 2019) (Figure 2). Basically these four steps structure the ways in which society engages with ecosystems to derive various benefits. The first step manages the ecosystem (e.g. by fertilising fields, ploughing or seeding), the second step mobilises these flows (e.g. harvesting) and the third steps translates these mobilisation to a function that is meaningful to fulfil the need of a respective society (e.g. food). The fourth step accommodates different ways of valuation and appreciation either by monetary or non-monetary means (chapter I, section 4.2. provides more information on valuation systems). Fedele et al. (2017) adopted the cascade framework and integrated specific human functions and conditions, such as values, assets, rules and space on the four mechanisms. Revisiting the cascade framework and associated studies more than a decade later, Potschin-Young et al. (2018) suggested that the framework lays out how values and benefits determine people's interaction with ecosystems. It does not deny that in particular the transition from benefits to values is a very complex process because this appreciation deeply depends on social-ecological context (Braat and de Groot, 2012). Thus, while the human role in NCP production constitutes an undeniable part of the interdisciplinary research agenda, the question of how and which value to put on ecosystems has remained a scientific battlefield with conflicting types of

valuation systems existing at the same time (Farber et al., 2002; Gomez-Baggethun and Martin-Lopez, 2015).

4.2 The values of ecosystems

Values and associated value systems are central to current discourses about social-ecological interactions. In line with the conceptual advancements described above, conceptualisations of nature's values have evolved from initially utilitarian to more holistic approaches. This section briefly summarizes the major developments and their possible implications for future research.

4.2.1. Valuation systems in ecological economics

The valuation of NCP constitutes one of the main fields in ecological economics (Pirgmaier, 2021). I base my definition on previous analysis of valuation languages and define valuation as the fact of assessing, appraising or measuring value or importance (Gomez-Baggethun and Martin-Lopez, 2015). Ecosystem valuation broadly distinguishes between systems based on exchange value and those based on use value (Pirgmaier, 2021; Schumpeter, 1954). Exchange value is defined as the "ratio between any two commodities or services"(Pirgmaier, 2021; Schumpeter, 1954) It remains the centre of classical economic analysis. Usually money constitutes the universally accepted unit of exchange. Use value on the other side means the features of an object that satisfies human needs or requirements. Those can be highly subjective, context-dependent and change over time (e.g. social norms, historical background, cultural customs or individual tastes) (Pirgmaier, 2021). NCP valuation therefore depends on the kind of value system (exchange or use). It also implies that same NCP can have different types of values for different people.

4.2.2. Valuation systems in ecosystem sciences

Two major research paths in valuation systems have evolved in ecosystem valuation since the 1990s. One research path advocates the application of ecosystem valuation based on the exchange value. This approach condenses the diversity of ecosystem service values into one, market-based (economic) value. In practice, this means the mainstreaming of ecosystem services into market-based systems (such as payment for ecosystem services schemes, www.teebweb.com). The article by Costanza et al. (1997) perhaps best exemplified this systematic application of the exchange value in ecosystem valuation. This study measured the total economic value of the global natural capital. It can be considered as one of the classic examples of the efforts to internalise ecosystems into conventional economic thinking (Braat and de Groot 2012; Costanza et al. 2017). The view on ecosystems from an instrumental angle, thus considering only aspects of ecosystems that are valuable to people was criticised as the commodification of nature. It raised a number of concerns of the potential detrimental effects

such as the replacement of ecological resources by social resources or the reinforcement of social inequalities (Gómez-Baggethun et al., 2010; Kallis et al., 2013; Kosoy and Corbera, 2010). The second research path favours the use over the exchange value and integrates social or cultural values in the concept (Braat and de Groot 2012). It implicitly encompasses the assumption that exclusively economic values lack the explanatory power to decipher the complex, subjective notions of a good quality of life. This approach was in particular exemplified by the publication of the MEA framework, which underlined the multiple dimensions of well-being despite economic considerations (MEA 2005) (see chapter 1, section 4.1.1). The evolved IPBES framework then again reaffirmed by its holistic approach the diversity of values and viewpoints of individuals and societies (Díaz et al., 2015a).

4.2.3. Valuation systems in nature's contributions to people (NCP)

The NCP approach democratizes the diversity of values and emphasizes in particular their multiple, sometimes conflicting, frequently overlapping and non-commensurable character (Gomez-Baggethun and Martin-Lopez, 2015; Pascual et al., 2017a). The IPBES framework allows to consider besides instrumental values (ecosystem provide benefits that are of value to a person) and intrinsic values (values that are inherent of the ecosystem) a third dimension - relational values (Chan et al., 2016). These are the results of social processes and social-ecological interactions (Pascual et al., 2017a; Schröter et al., 2020). Relational values subsume the entirety of social, cultural, social-cultural aspects that derive out of social-ecological interactions (Gomez-Baggethun and Martin-Lopez, 2015). What unites them is their subjectivity, their non-materiality and their strong dependence on the spatial, temporal and social context (Chan et al., 2018). In particular the recognition of the social embeddedness stands in stark contrast to the conception of neoclassical economics seeing humans as self-interested individuals who base their values on rational choice (Vatn, 2005). Broadly, relational values describe the sum of collective values derived from interactions within SES (Muraca, 2011; Riechers et al., 2020). It is relevant to add that those relationships go beyond the mere physical needs (such as food) to an end (pleasure of working in a garden) (Chan et al., 2018; Schröter et al., 2020). The focus of the IPBES framework on values that are not necessarily scientifically pre-determined requires a profound analysis of value construction of societies in social-ecological interactions.

The overlaps between the heated debates over ecosystem valuation with the ongoing discussions over new metrics to measure the good quality of life in development economics (Stiglitz et al., 2018) highlights dependence of societies on ecosystems. Apart from the *zeitgeist* and the urgency of action in view of earth system degradation, these two discourses share the same views on the multidimensionality of a good quality of life. Both agree that satisfactions of needs, the experience of freedom, health, personal security, good social relations and healthy natural environment are integral parts of a good quality of life (Alkire, 2008; Díaz et al., 2015a; Sen, 2000). However, understanding how societies collectively define and achieve socially valued outcomes in their territorial systems and at global scale remains a challenge across science, society and policymaking and can best be advanced by interdisciplinary approaches (Raworth, 2017).

4.3. The capability approach (CA) for studying social-ecological interactions

The capability approach (CA) is a value-based approach that measures the good quality of life based on the freedom to choose what people consider as meaningful. Contextual factors, such as social background, but also personal conditions affect these capabilities. In order to be consistent with the premise of this work that sees humans as social beings, I extend the definition of freedom to a collective centered notion and discuss the CA from the viewpoint of collective capability. This provides the analytical support to comprehend the non-material dimensions of social-ecological interactions. I advance that the original CA who has the individual as a normative basis does not form part of this study and is therefore only briefly outlined (Ballet et al., 2018; Evans, 2002; Sen, 2000).

4.3.1 The capability approach

The capability approach (CA) developed by the economist thinker and philosopher Amartya Sen in the 1980s reshaped how science and politics consider and measure the multiple dimensions of ‘a good quality of life” (Sen, 2000). Good quality of life, rephrased in a much subtler notion as the “freedom to choose” forms the focus of his analysis. Inspired by Isaiah Berlin (Berlin, 1969) and his seminal work on freedom, Amartya Sen considers that the degree of freedom is expressed as a capability that “reflects a person’s ability to choose between different ways of living” (Sen, 2003). Thus, the capability set reflects the sum of potentials (possibilities and opportunities) of individuals to choose to achieve what they consider as meaningful (Forsyth, 2015; Sen, 2000). This is in contrast with former economic theories that were based on instrumental approaches to well-being. They assumed that good quality of life can achieved by an increase of happiness frequently quantified by economic measures (Robeyns, 2006; Sen, 2000). However, these approaches might not be able to capture the other

aspects people consider as meaningful (see chapter I, section 4.2.3.). Thus, freedom in this aspect means the capability to choose between different options that people value.

4.3.2 A modest attempt to define freedom or what is a good quality of life?

What lies behind these seven letters that compose this ideal called "freedom"? Without even attempting to dive into the multiple definitions this term has entailed for humanity since its earliest days, I very briefly introduce two starkly different conceptions of freedom. This juxtaposing allows integrating the idea of freedom into my research that is based on the premise that humans are social beings. Modern, liberal interpretations, emphasize freedom as doing what one wishes to do as long as it doesn't limit the freedom of another person. Regulations and laws mostly accomplish this type of freedom. This conception of freedom is firmly anchored in the "Declaration of the Rights of Man and of the Citizen" of the French revolution, one of the foundational documents for modern understanding of democracy. Article IV states: "Liberty consists of doing anything which does not harm others: thus, the exercise of the natural rights of each man has only those borders which assure other members of the society the fruition of these same rights. These borders can be determined only by the law" (France: Declaration of the Right of Man and the Citizen, 1789). This thus implies an underlying image of humanity as naturally evil in the sense of Thomas Hobbes (Hobbes, 1996). The opposing pole is the assumption that humans are naturally good and social beings who can organise themselves in the sense of Jean-Jacques Rousseau (Rousseau, 2009). This position consequently leads to a very different definition of freedom. The contemporary Italian philosopher Roberto Esposito, who is interested, among a multitude of other themes, in communities and how they evolve, emphasizes the collective level of freedom. He argues that the first meaning of freedom, before the modern one, was radically different. He defines freedom as "a power of connection, of aggregation, of pooling: even if it is more in the sense of belonging to a common root that grows and develops according to its internal law"(Esposito et al., 2019). Thus, while the former conception states "freedom in spite of the others", Esposito argues "freedom because of the others"(Buclet, 2021; Schröter et al., 2020). Thus, from a philosophical perspective, the construction of relational values in NCP co-production (see chapter I, section 4.2.3.) could be therefore regarded as the achieved freedoms of people, which translates to a "a good quality of life". Based on this definition, social interaction is indispensable for the achievement of freedom.

4.3.3. Collective capabilities in NCP co-production

The term 'collective capabilities' was first used by Peter Evans (Evans 2002; Rauschmayer et al. 2018) and extensively further developed by Ibrahim (2006). I broadly define collective capabilities in this study as "capabilities that can only be achieved socially … as a result of social interaction" (Comim and Carey, 2001). (Buclet, 2021) building on the collective character of freedom argues that collective action can help to empower members in a society to decide and shape activities according to their own objectives. Other research on the capability approach already stated this collective character of freedom by implicitly arguing that the adherence to a group that shares the same goals and interests represent an achievement in itself (Evans, 2002). These can be generated by social structures, place or territory and collective action (Dissart, 2012). Collective capabilities are the result of the voluntary involvement of people in a collective process (Buclet, 2021; Pelenc et al., 2015). They are not simply the sum (or average) of individual capabilities, but rather new capabilities that the individual alone would neither have nor be able to achieve without a collective structure (Ballet et al., 2007; Ibrahim, 2006). However, the overview Rosignoli (2019) provides over the variety of other versions such as group capabilities (Stewart 2013), relational capabilities (Giraud et al. 2013), external capabilities (Foster and Handy 2008) and joint capabilities (Hall 2017) reflects the ongoing discourse on finding valid characteristics of collective capabilities.

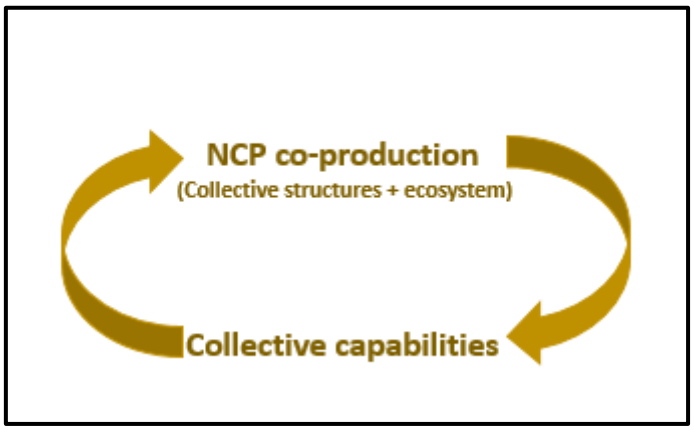


Figure 3: Simplified representation of the dynamic interaction between NCP-co production and collective capabilities

The integration of relational values emphasizes the role of these collective structures in achieving the freedom people aim to achieve in NCP co-production (Buclet, 2021; Schröter et al., 2020). Collective structures and common action are crucial for collective capabilities (Buclet, 2021). They generate in dynamic interaction collective capabilities (see Figure 3). The achievements what collective structures consider as valuable govern then the modes of NCP co-production. The coupling of collective capabilities and the associated collective character of

freedom with NCP co-production might fill out the knowledge gaps related to the dynamic interactions between institutions, value systems and ecosystems (Mastrángelo et al., 2019). It could offer an explanation why people act as they act.

However, systematic approaches that explore the interlinkages between collective capabilities and ecosystem service research have remained scarce (Ballet et al., 2018; Griewald and Rauschmayer, 2014; Pelenc et al., 2015; Polishchuk and Rauschmayer, 2012). This might be explained by the fact that the initial CA approach does not explicitly consider society-ecosystems interactions in their analysis, but it rather merges them with other external factors vaguely termed "environmental" (Sen, 2000). This might be owed to sociological conventions and humanities in general that social factors can only be explained by other social facts (Fischer-Kowalski and Erb 2016). Additionally, initial ecosystem service assessments considered ecosystem services as neutral entities and considered society only as rational individuals (Costanza et al., 1997; Vatn, 2005). Lastly, only by redefining freedom, one is able to conceptually transfer the individual based CA with the underlying principle of social justice to a collective dimension, which operates on the premise of solidarity.

This value pluralism necessitates a strong interdisciplinary approach. Initial scientific analysis in ecosystem services focused on a limited number of values, however diversifying these values can identify a larger number of leverages and pathways (Lele et al., 2013). This broader approach implies a methodological pluralism (Gomez-Baggethun and Martin-Lopez, 2015). For that, in my doctoral research I integrated quantitative and qualitative mixed methods. Those can render these multiple aspects of values visible. The deliberate integration of non-material aspects to a good quality of life in scientific analysis might eventually contribute to a democratization of these different, non-monetary value systems (Chan et al., 2018).

4.4. Scientific objects

This dissertation work aims to contribute to a better understanding of the effectiveness of further embedding NCP co-production within its social-ecological context by bringing a greater focus on the role of societies at territorial scale. Based on territorial ecology, my interest lies in particular in the non-material aspects of these social-ecological interactions that contribute to a good quality of life. Consequently, the overall research question that this work aims to answer is the following:

What are the material and non-material flows that contribute to a good quality of life in a social-ecological system at territorial scale?

In order to answer this, I analyse major components of a territorial system with the following questions:

a) What is the role of social-ecological legacies of regional systems for NCP co-production?

b) What is the role of collective capabilities in NCP co-production?

c.) What is the interplay of social-ecological resources for NCP co-production in a heterogeneous territory?

Chapter II – Social-ecological systems in the European Alps

Maurienne valley (credits: l'Atelier S.Madelon/SDB)

In this chapter, I briefly describe my study area. First, I describe the general context of the European Alps and particularly highlight the most relevant instruments through which society aims to protect the multiple values of these European landscapes. I then introduce and describe the relevance of cheese production for identity-related dimensions in France and underpinning cooperative structures in the French Alpine region. A brief illustration of the French cow cheese Beaufort that forms the study object of my thesis follows. I conclude with a description of the Maurienne valley, that forms part of the Beaufort production area.

1. The European Alps

1.1. The area

The European Alps are considered as a geographic area with an important cultural heritage influencing co-evolution between societies and ecosystems over a long period. Along with other mountain regions they contribute in various ways to the good quality of life of local and global societies (Martín-López et al., 2019) The Alps are Europe's second largest biodiversity reservoir with over 30,000 animal species and 13,000 plant species (representing over over 20% of Europe's plant species (EEA, 2010; Väre et al., 2003). They are considered as water towers providing freshwater to a wide range of ecosystems, societies and associated socioeconomic activities (EEA, 2010). Land cover and associated land use comprise largely cultural landscapes that reflect a series of complex and interacting factors over the timescales of both geological and social-ecological history (EEA, 2010). The Alps heterogeneous landscapes spread over 190,700 km² on eight countries and are characterized by extensive lowlands, deep valley and high elevations peaking at 4800 m (Gobiet et al., 2014).

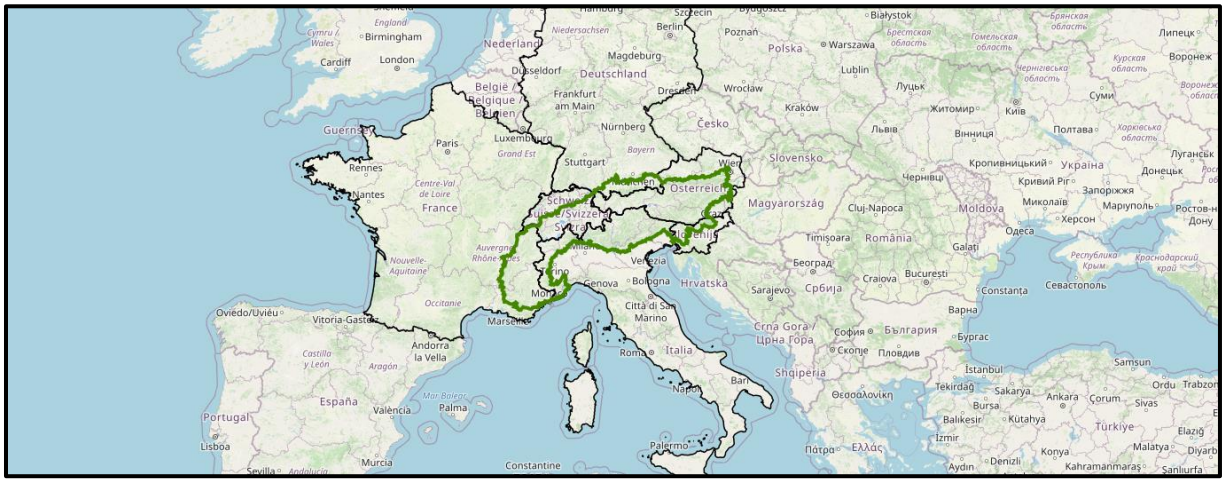


Figure 1: Overview of the Alpine Convention area. The map shows the position of the Alpine convention area extending 190,700 km² on eight countries in Europe

1.2. The people

The Alpine Convention area hosts 14. 2 million people (74.6 inhabitants/km²) in over 5,700 municipalities in an overall rural setting (Elmi, 2018)). Settlements are found in the most accessible areas, notable the valleys, while more remote areas experience depopulation (Elmi, 2018). Along with the general European aging trend the Alpine area's population has a share of 19.5% of residents over 65 years. However, there are large differences between the different countries that largely align with the national average age. For example, in the French Alps, where my study area is found, 16.9% of residents are over 65 years, which corresponds well to

the national average (17%) (Permanent Secretariat of the Alpine Convention, 2015). In line with the economic structures of industrialized countries, the service sector (includes tourism) presents the largest income generating sector with a share ranging from below 50% to 75% of total labour force. The secondary sector linked to industry still represented 36% of jobs in the early 2000 but is- again corresponding to the general European trend- decreasing (Price et al., 2012). Despite the relative low direct share of agriculture on total work force (2-3%), agriculture is crucial for the maintenance of landscapes and identities and in economic terms closely linked to tourism and forestry (Elmi, 2018). Further many people pursue agriculture as a second income generating activity (Schermer et al., 2016; Tappeiner et al., 2008). In contrast to urban areas, these economic activities are frequently closely tied to and intrinsically depend on the surrounding ecosystems.

Local and global societies' values for the European Alps vary widely and underline the multifunctionality of the region. Instrumental values are frequently tied to agricultural production, wood fuel and timber, water quality and risks of regulations; intrinsic values are related to endemic species and overall biodiversity, relational values can encompass the appreciation of landscape appearance, sense of place or other attachments (Bruley et al., 2021; Klein et al., 2019; Lavorel et al., 2019; Martín-López et al., 2019).

1.3. Agriculture

Alpine farming shares a number of communalities with other mountain farming system, such as biophysical constraints, lower production levels and extensive farming practices (FAO, 2013). European Alpine farming systems features several distinctive characteristics that render comparisons at global scale challenging. The region is embedded in a number of highly developed and (post)industrialised countries with agriculture playing a minor role in conventional economic terms and hosts a mostly urbanized population (Flury et al., 2013). Additionally, changing lifestyle patterns coupled with urbanisation led to a reduction of the production factors of labour and land. As noted above, Alpine agriculture depends on subsidies that aim to combat the ongoing trend of decreasing farms. Further, agricultural production mainly focusses on high-value added, premium products, such as quality labelled dairy products and to a lesser extent on food security (Flury et al., 2013; Santini et al., 2013). Lastly, as exemplified above, agriculture takes place in a highly institutionalized setting effective at various scales and is considered as an integral part of the European cultural heritage (Egarter Vigl et al., 2016). Agricultural practices have been influenced by market pressures and

economic policies, however climate change can become another crucial factor governing the future dynamics in agricultural systems (Lavorel et al., 2019).

1.4. The institutions

At institutional level various treaties, conventions and policies with varying objectives administer these multiple values. The following, certainly not exhaustive listing shall exemplify the relevance society allocates to the multiple values of this region. The more than 1,000 protected areas aim to preserve these landscapes and the associated biological biodiversity and encompass 28% of the Alpine convention area (Elmi, 2018). At global level, notable recognition of the value of the European Alps include 14 listings as World Heritage Sites(UNESCO, 2020a) and a number of biosphere reserves (UNESCO, 2020b), and sites designated under the Ramsar Convention on Wetlands (Ramsar, 2020). At European Union (EU)-policy level values deriving from social-ecological interactions such as high biodiversity and landscapes are recognised through the Natura 2000 sites which cover 19.7% of the total Alpine area (EEA, 2010). At macro-regional scale, the Alpine Convention was signed by the eight Alpine states (Austria, France, Germany, Italy, Liechtenstein, Switzerland, Slovenia and Monaco) and the European Community, and in 1991 and is the legally binding regional agreement and was preceded by the International Commission for the Protection of Alpine Regions from 1952 (EEA, 2010). Its overall aim encompasses the protection of the fragile ecosystems but it also explicitly names the maintenance of associated cultural identities in its protocol for mountain farming(AC, 2006). The environmental non-governmental organisation (NGO) CIPRA unites more than 100 national and local associations to foster awareness of these crucial social-ecological systems (CIPRA, 2020). In addition, states within the Alpine region host in total 13 national parks and a number of regional parks with varying environmental protections. At territorial level, there is a number of collective structures with varying objectives and foci such as pastoral land associations, agricultural cooperatives, and agricultural development. At municipal level the “Alliance in the Alps”, an association of over 300 member municipalities and communities implements some of these targets (Alliance in the Alps, 2020).

Regarding agriculture, the European Alpine area comprises of over 20% of High Nature Value (HNV) area of utilized agricultural area (Oppermann et al., 2012). The EU and its member states support and maintain in particular through Rural Development Programmes (EEA, 2010). These farming systems are characterized by mainly extensive practices, Alpine meadows and pastures, smaller than the national average farm sizes (Santini et al., 2013). The EU Common Agricultural Policy (CAP) and notably its second pillar, the Rural Development Policy,

formalised by the directive on mountain and hill-farming (Directive 75/268 OJ No L128) has been an indispensable support for the maintenance of Alpine agriculture since 1975.

1.5. Challenges of Alpine agriculture

The Alpine area and in particular agriculture faces in line with other mountain system a number of challenges in the next decades, with rural abandonment, land use and climate as major drivers (Martín-López et al., 2019). In terms of landscape, physical space constraints have resulted in intensive land use in the bottom of the valleys, while less accessible parts face land abandonment. In addition, the number of agricultural holdings in the Alpine region has almost halved from 1980 to 2010, with probably less than 260,00 farms left today (Elmi, 2018). Frequently cited reasons for the decline of Alpine farming are individual preferences for other income generating activities; at a general level, the increasing densification of economic activities; at institutional level the impact of varying policies and subsidy schemes, spatial planning and municipal budgets; and in economic terms soaring land costs and land (EEA, 2010; Elmi, 2018). The multiple, partly interrelated major activities such as tourism, agriculture and industry coupled with a relatively high population density and exacerbated by the risk of natural hazards frequently result in conflicts over land use in the valleys (EEA, 2010). On the other hand, less accessible areas experience depopulation and associated land abandonment ultimately leading to the closing of aesthetically highly appreciated pastureland. In addition current climate change scenarios predict that the Alpine region will be considerable affected by rising temperatures, greater variability in precipitation, and temperatures and associated impacts like floods, droughts, snow cover and other natural hazards (Gobiet et al., 2014). Temperatures in the Alps have increased by 2ºC since the end of the 19th century, since the annual mean decadal temperature records a augmentation of 0.5ºC (Gobiet et al., 2014). This will have impacts on biodiversity, the fundamental base for NCP co-production (Lavorel et al., 2019) . On the other hand, mountain regions have been known for their large adaptive capacities when encountering new challenges, for example the marketing of agricultural products by geographical indications (GI) has proved to be an effective response to combat land abandonment in the 1960s in various French regions (Lamarque and Lambin, 2015; Lavorel et al., 2019).

2. Cheese production in France

2.1. Importance of cheese production for identities

In France, cheese is an iconic product with many small differences, such as the use of local livestock breeds, local fodder, the adherence to non pasteurised transformation techniques which have evolved frequently by collective structures in social-ecological interactions over a long time (Ricard, 2015). Research on local French cheese products frequently underlines the identity related dimensions of these production systems (Bérard et al., 2008; Delfosse, 2007). In a very anecdotal way, the importance of cheese for local identities is exemplified by the brief and shallow comparison of the Wikipedia entry for the word “cheese” in the English and French version. The English entry has a total word quantity of around 6,200, whereby the French entry hosts more than double, with 15,000 words (Cheese, 2021; Fromage, 2021). However, it is also necessary to point out that GIs in general can play a crucial role for identities and maintain or revive local agricultural systems all over the world (Delfosse, 2012; Gervais, 2015; Pachoud et al., 2020).

2.2. Quality labels

Local French cheese production systems are - in contrast to other more quantity oriented production regimes (such as Dutch Edam cheese) - frequently tied to the respective territories (Bérard et al., 2008). In today’s economic global market system Geographical indications (GI) play an important role to legally protect these linkages between products, place and production (Quiñones Ruiz et al., 2018). The best-known GI within the European Union is the label “protected designation of origin (PDO)” (see Figure 2). Further, in mountain agriculture, the quality label “mountain products” acknowledges the specificity of these products since 2012 (Santini et al., 2013). Currently, France has registered 45 different types of cheese under these labels (CNAOL, 2016). A department of the French ministry of agriculture, the *institut national de l'origine et de la qualité* (national institut of origin and quality/INAO) is responsible for the regulation of these products. At European scale, the European commission and the associated administrative bodies oversee these products.

Figure 2: The EU-PDO label links the product to its place of origin

2.3. Cheese production in territorial systems

In the French mountains, Ricard (2015) identified well over 200 cooperative dairy systems. In the French Alps the precursor of today's cooperative systems was the "*fruitière*", dating back as early as 1800 (Ricard, 2015). Pull factors, such as the improved accessibility, new production techniques coupled with the demand of an increasing urban population led to the emergence of new types of dairy cooperatives after the World War II (Delfosse, 2007; Ricard, 2015). On the other hand, these collective structures were also a reaction to combat agricultural decline and to maintain agricultural production and more broadly mountain territories in general (Buclet, 2021). The heterogeneous characteristics of these products are intrinsically tied to their territories and their own specific governance sets was partly summed up by a (not confirmed) quote of the former French president General Charles de Gaulle "How to rule a country where there are 258 types of cheese?" (Ozouf-Marignier, 2008). Despite my focus on these regional cheese production systems the industrial player are present in French cheese production since the beginning of the 1960s (Delfosse, 2007). For example, the largest dairy product group in the world, the French company Lactalis has a major influence on the well-known French quality labelled cheeses such as Camembert and Roquefort (Léraud and Kronlund, 2020).

I used as the main entry point for my thesis about social-ecological interactions French cheese for various reasons. First, it presents an iconic product frequently deeply related to the surrounding ecosystems and collective structures and cannot dislocated to another territory. Second, it presents the stocked, condensed, value-added (and economically viable) result of social-ecological legacies derived through specific farming, management and transformation practices. Third, I see mountain cheese production as a multibeneficial activity contributing in various aspects to a good quality of life.

3. The Beaufort production system

My thesis focuses on the nationally well-known raw milk cow cheese Beaufort. Compared with other French quality cheeses, Beaufort production with a comparable small production quantity of 5,000 t/yr is lower than neighbouring PDO cheeses such *reblochon* (15,000 t/yr) or Saint-Nectaire (14,000 t/yr), not to mention the French PDO leader in cow milk cheese *comté* (55,000 T/yr) (CNAOL, 2016). In the Savoy department where Beaufort production takes place there are eight high quality labelled types of cheese, and many less structured, private producers.

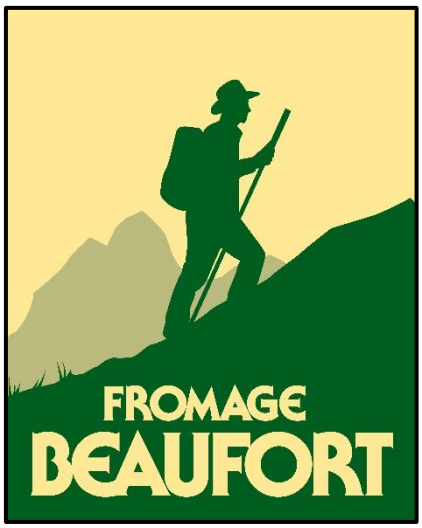


Figure 3: The logo of the Beaufort cheese (credits: L'Atelier S.Madelon/SDB)

The origin of the institutionalized Beaufort production system dates back to the 1960s in the adjacent Beaufortain valley. The omnipresent "rural exodus" coupled with mounting pressure on land due to the development of ski resorts and hydropower led to a decline of Alpine French agriculture(Faure, 1999). The leading founding figure Maxime Viallet challenged this trend by involving actors from all scales such as scientific research, local agricultural organisations and municipalities to engage in a collectively organised cheese production system(Lynch and Harvois, 2016). The idea to unite farmers and share resources, notable by task division and collective transformation facilities was considered as a "local revolution" (Faure, 1999). The PDO label Beaufort was formally registered in 1968.

Figure 4: The Beaufort cheese loaf has a weight of around 40 kg. Characteristic is the concave heel (credits: l'Atelier S.Madelon/SDB)

Fourteen cooperatives in three adjacent valleys, the Beaufortain valley, the Tarentaise valley and the Maurienne valley compose today's production system. The consortium (Syndicat de défense du Beaufort/SDB) offers and regulates legal and technical assistance and control of Beaufort specifications. The marketing of the Beaufort cheese particularly emphasize the role of the mountainous environment (see Figure 3). There are various specifications, however my work focused on the three main rules that shape the type of agriculture and the associated resource use along the NCP co-production steps (INAO, 2015). The first rule links production quantity to the territory (grassland covers 26% of total area) by requiring that 75% of fodder is regionally sourced. The second rule limits production through absolute milk quota at both the livestock unit, farm and cooperative levels. This keeps farm size at a moderate level (average: 32 ha). The third rule requires that low yielding, regional cattle breeds ('Abondance' and 'Tarine') constitute 100% of livestock. The Beaufort production system started in the early 1970s. It has been predominantly catering to local winter tourism. Initially conceived as a "crazy" idea, these direct sales succeeded to circumvent less profitable whole sale and contribute in monetary and non-material values to the maintenance of collective identities and their associated values (Lynch and Harvois, 2016). In the following work the term Beaufort production system is exclusively used for the Beaufort production system in the Maurienne valley. I specifically highlight when referring to the entire production Beaufort production that encompasses the three valleys.

4. The Maurienne valley

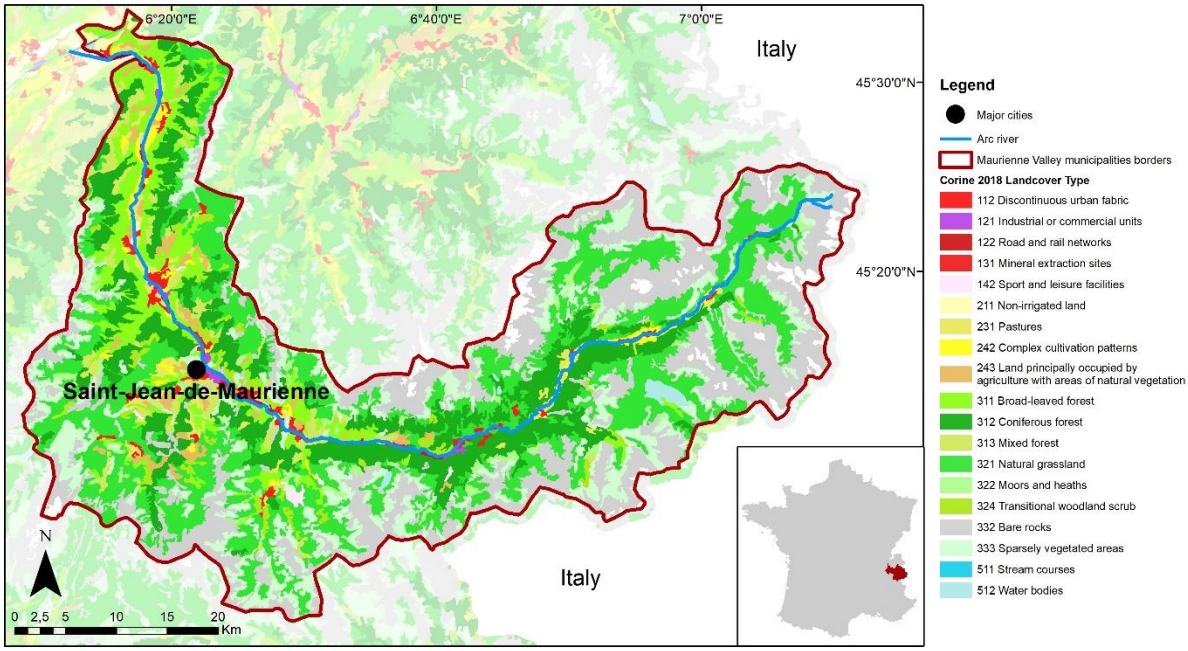


Figure 5: Land use cover map and location of Maurienne valley (Copernicus Land Monitoring Service, 2018; IGN-F, 2006, 2019).

The Maurienne valley falls within the boundaries of the PDO Beaufort production. Situated in the department Savoy it is the longest valley (120 km long) in the French Alps shaped by the river Arc. The area hosts over 100 summits over 3000 meters. The land use classes with e.g. a share of 30% pasture land correspond to the average land use features of the Alps (EEA, 2010; SPM, 2020). The climate ranges from a humid pre-alpine climate in the west to a continental alpine climate in the east. The 40,000 inhabitants live in 62 municipalities in an overall rural setting. Three urban centres at the bottom of the valley have a population of more than 2,000 inhabitants. With a density of 22 inhabitants/km² it is well below average in the Alps (75/km²) (Elmi, 2018; SPM, 2020). No significant changes in population numbers in the last 20 years are noted. A large part of the work force (25%) links to winter tourism, with around 20 skiing resorts; the industrial sector constitutes an income source for 19% of the working population (SPM 2020). Livestock farming is the prevalent farming activity and represents with around 350 farms 2% of the total workforce (SPM, 2020).

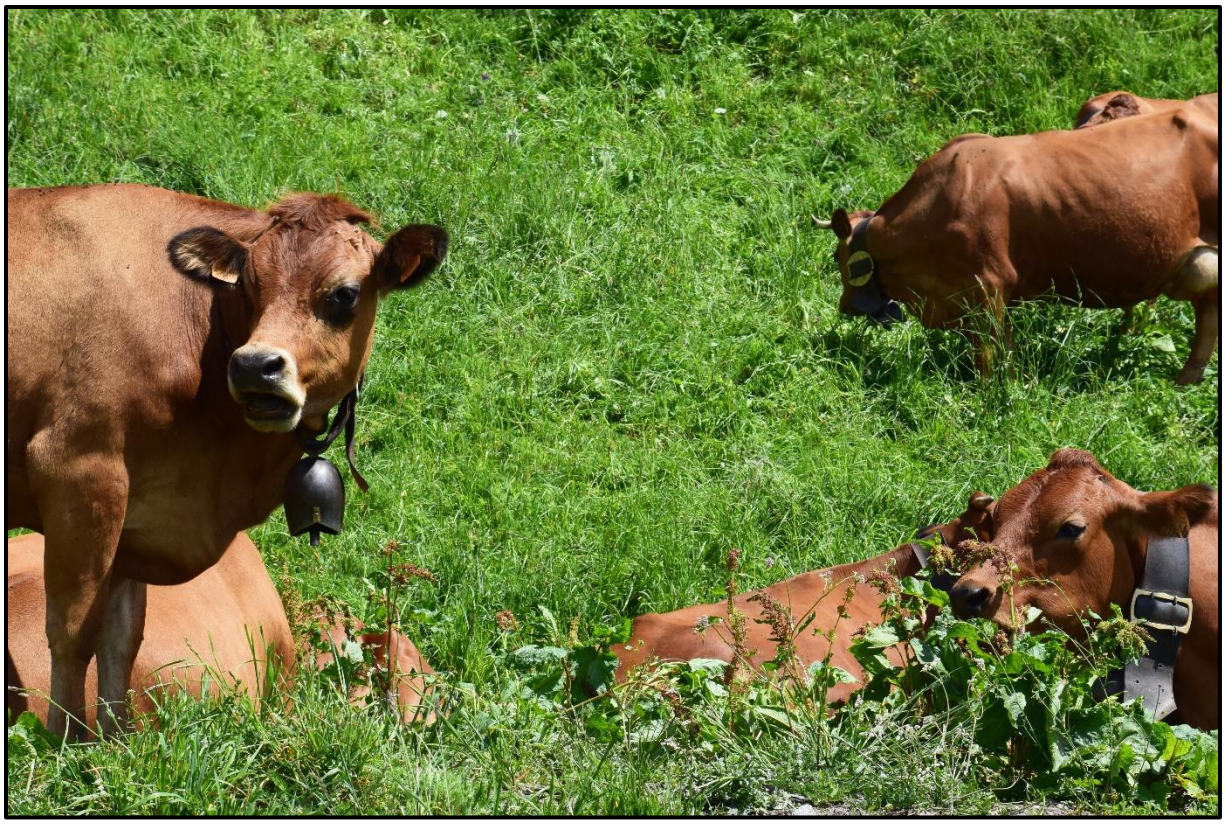


Figure 5: Grazing Tarine cows are a common sight in the Maurienne valley (credits: Bruno Locatelli)

Agriculture is based on livestock farming, where the Beaufort production system unites 38% of the 350 agricultural holdings. 25% of agricultural holdings focus on small livestock and 10% of holdings produce beef. Diversified production (e.g. beekeeping, vegetable production) has a shared of 19%. Transhumant activities play a major role, whereby 66% of small livestock grazing is coming from the outside of the valley (SPM, 2020). At territorial scale, agricultural activities are organised around various institutions. Three Beaufort cooperatives that unite 80 producers are spread evenly across the valley with historically evolved collection areas. There is no comparable structure for other livestock farming activities within the Maurienne valley. Two agricultural associations assemble according to their own statements 80% of economically relevant agricultural holdings. At municipal scale 22 pastoral land association with the aim to consolidate the historically evolved land fragmentation provide easier access to land for farming activities. While irrigation systems have been in place since the 18th century, local actors have established five irrigation associations in the Eastern part of the valley since 2015. The latest central territorial planning instrument the "schéma de coherence territorial" (SCOT) emphasizes explicitly the relevance to maintain primary cropland around municipalities for agriculture and introduced guidelines. In a broader context, some agricultural activities are affected by the regulations of the National Park Vanoise that encompasses a large part of the

Eastern part of the valley. Further there are 18 Natura 2000 sites, two regional parks and well over 340 zones of faunistic or floristic interests ((SMB, 2020)..

Along with the above-mentioned challenges common across the Alpine Convention area, the Maurienne valley might encounter more localized future questions to solve. In particular, the currently ongoing large infrastructure project, the Turin-Lyon high-speed railway link might affect the territory in the long term by modifying the accessibility of valley. Some worry about the associated closure of smaller train stations and expect negative impacts on the ecosystem, others are favourable in view of the better connectivity to urban centres (SPM, 2020). Further, the liberalisation of the European electricity market prompts mixed reactions regarding the possible establishment of micro-scale hydroelectric energy by private investors.

Within the Trajectories project several Phd-students have been working in the Maurienne valley from a social-science perspective. Bevione, (2021) currently analyses the Beaufort production system by the metabolism approach. Jaume, (2019) compiled an extensive overview over different types of legacies in the Maurienne. Sheperd, (2020) analysed the social-ecological vulnerability to climate change based on the collective capability approach. In the discipline history .Lachello (2021) works on the social-ecological history of forests from 1815-1940.

Chapter II – Social-ecological systems in the European Alps

Maurienne valley (credits: l'Atelier S.Madelon/SDB)

In this chapter, I briefly describe my study area. First, I describe the general context of the European Alps and particularly highlight the most relevant instruments through which society aims to protect the multiple values of these European landscapes. I then introduce and describe the relevance of cheese production for identity-related dimensions in France and underpinning cooperative structures in the French Alpine region. A brief illustration of the French cow cheese Beaufort that forms the study object of my thesis follows. I conclude with a description of the Maurienne valley, that forms part of the Beaufort production area.

1. The European Alps

1.1. The area

The European Alps are considered as a geographic area with an important cultural heritage influencing co-evolution between societies and ecosystems over a long period. Along with other mountain regions they contribute in various ways to the good quality of life of local and global societies (Martín-López et al., 2019) The Alps are Europe's second largest biodiversity reservoir with over 30,000 animal species and 13,000 plant species (representing over over 20% of Europe's plant species (EEA, 2010; Väre et al., 2003). They are considered as water towers providing freshwater to a wide range of ecosystems, societies and associated socioeconomic activities (EEA, 2010). Land cover and associated land use comprise largely cultural landscapes that reflect a series of complex and interacting factors over the timescales of both geological and social-ecological history (EEA, 2010). The Alps heterogeneous landscapes spread over 190,700 km² on eight countries and are characterized by extensive lowlands, deep valley and high elevations peaking at 4800 m (Gobiet et al., 2014).

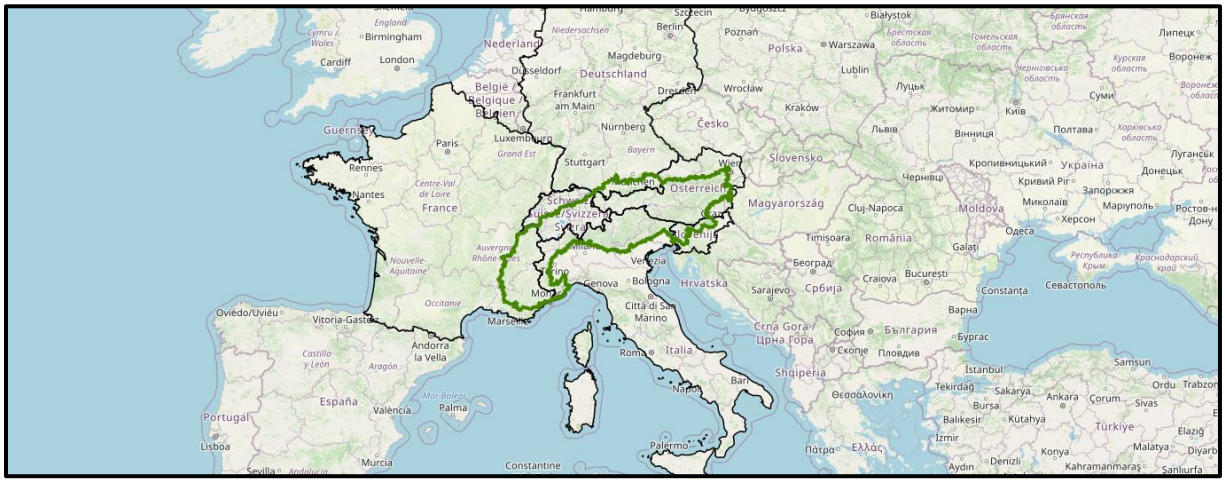


Figure 1: Overview of the Alpine Convention area. The map shows the position of the Alpine convention area extending 190,700 km² on eight countries in Europe

1.2. The people

The Alpine Convention area hosts 14. 2 million people (74.6 inhabitants/km²) in over 5,700 municipalities in an overall rural setting (Elmi, 2018)). Settlements are found in the most accessible areas, notable the valleys, while more remote areas experience depopulation (Elmi, 2018). Along with the general European aging trend the Alpine area's population has a share of 19.5% of residents over 65 years. However, there are large differences between the different countries that largely align with the national average age. For example, in the French Alps, where my study area is found, 16.9% of residents are over 65 years, which corresponds well to

the national average (17%) (Permanent Secretariat of the Alpine Convention, 2015). In line with the economic structures of industrialized countries, the service sector (includes tourism) presents the largest income generating sector with a share ranging from below 50% to 75% of total labour force. The secondary sector linked to industry still represented 36% of jobs in the early 2000 but is- again corresponding to the general European trend- decreasing (Price et al., 2012). Despite the relative low direct share of agriculture on total work force (2-3%), agriculture is crucial for the maintenance of landscapes and identities and in economic terms closely linked to tourism and forestry (Elmi, 2018). Further many people pursue agriculture as a second income generating activity (Schermer et al., 2016; Tappeiner et al., 2008). In contrast to urban areas, these economic activities are frequently closely tied to and intrinsically depend on the surrounding ecosystems.

Local and global societies' values for the European Alps vary widely and underline the multifunctionality of the region. Instrumental values are frequently tied to agricultural production, wood fuel and timber, water quality and risks of regulations; intrinsic values are related to endemic species and overall biodiversity, relational values can encompass the appreciation of landscape appearance, sense of place or other attachments (Bruley et al., 2021; Klein et al., 2019; Lavorel et al., 2019; Martín-López et al., 2019).

1.3. Agriculture

Alpine farming shares a number of communalities with other mountain farming system, such as biophysical constraints, lower production levels and extensive farming practices (FAO, 2013). European Alpine farming systems features several distinctive characteristics that render comparisons at global scale challenging. The region is embedded in a number of highly developed and (post)industrialised countries with agriculture playing a minor role in conventional economic terms and hosts a mostly urbanized population (Flury et al., 2013). Additionally, changing lifestyle patterns coupled with urbanisation led to a reduction of the production factors of labour and land. As noted above, Alpine agriculture depends on subsidies that aim to combat the ongoing trend of decreasing farms. Further, agricultural production mainly focusses on high-value added, premium products, such as quality labelled dairy products and to a lesser extent on food security (Flury et al., 2013; Santini et al., 2013). Lastly, as exemplified above, agriculture takes place in a highly institutionalized setting effective at various scales and is considered as an integral part of the European cultural heritage (Egarter Vigl et al., 2016). Agricultural practices have been influenced by market pressures and

economic policies, however climate change can become another crucial factor governing the future dynamics in agricultural systems (Lavorel et al., 2019).

1.4. The institutions

At institutional level various treaties, conventions and policies with varying objectives administer these multiple values. The following, certainly not exhaustive listing shall exemplify the relevance society allocates to the multiple values of this region. The more than 1,000 protected areas aim to preserve these landscapes and the associated biological biodiversity and encompass 28% of the Alpine convention area (Elmi, 2018). At global level, notable recognition of the value of the European Alps include 14 listings as World Heritage Sites(UNESCO, 2020a) and a number of biosphere reserves (UNESCO, 2020b), and sites designated under the Ramsar Convention on Wetlands (Ramsar, 2020). At European Union (EU)-policy level values deriving from social-ecological interactions such as high biodiversity and landscapes are recognised through the Natura 2000 sites which cover 19.7% of the total Alpine area (EEA, 2010). At macro-regional scale, the Alpine Convention was signed by the eight Alpine states (Austria, France, Germany, Italy, Liechtenstein, Switzerland, Slovenia and Monaco) and the European Community, and in 1991 and is the legally binding regional agreement and was preceded by the International Commission for the Protection of Alpine Regions from 1952 (EEA, 2010). Its overall aim encompasses the protection of the fragile ecosystems but it also explicitly names the maintenance of associated cultural identities in its protocol for mountain farming(AC, 2006). The environmental non-governmental organisation (NGO) CIPRA unites more than 100 national and local associations to foster awareness of these crucial social-ecological systems (CIPRA, 2020). In addition, states within the Alpine region host in total 13 national parks and a number of regional parks with varying environmental protections. At territorial level, there is a number of collective structures with varying objectives and foci such as pastoral land associations, agricultural cooperatives, and agricultural development. At municipal level the “Alliance in the Alps”, an association of over 300 member municipalities and communities implements some of these targets (Alliance in the Alps, 2020).

Regarding agriculture, the European Alpine area comprises of over 20% of High Nature Value (HNV) area of utilized agricultural area (Oppermann et al., 2012). The EU and its member states support and maintain in particular through Rural Development Programmes (EEA, 2010). These farming systems are characterized by mainly extensive practices, Alpine meadows and pastures, smaller than the national average farm sizes (Santini et al., 2013). The EU Common Agricultural Policy (CAP) and notably its second pillar, the Rural Development Policy,

formalised by the directive on mountain and hill-farming (Directive 75/268 OJ No L128) has been an indispensable support for the maintenance of Alpine agriculture since 1975.

1.5. Challenges of Alpine agriculture

The Alpine area and in particular agriculture faces in line with other mountain system a number of challenges in the next decades, with rural abandonment, land use and climate as major drivers (Martín-López et al., 2019). In terms of landscape, physical space constraints have resulted in intensive land use in the bottom of the valleys, while less accessible parts face land abandonment. In addition, the number of agricultural holdings in the Alpine region has almost halved from 1980 to 2010, with probably less than 260,00 farms left today (Elmi, 2018). Frequently cited reasons for the decline of Alpine farming are individual preferences for other income generating activities; at a general level, the increasing densification of economic activities; at institutional level the impact of varying policies and subsidy schemes, spatial planning and municipal budgets; and in economic terms soaring land costs and land (EEA, 2010; Elmi, 2018). The multiple, partly interrelated major activities such as tourism, agriculture and industry coupled with a relatively high population density and exacerbated by the risk of natural hazards frequently result in conflicts over land use in the valleys (EEA, 2010). On the other hand, less accessible areas experience depopulation and associated land abandonment ultimately leading to the closing of aesthetically highly appreciated pastureland. In addition current climate change scenarios predict that the Alpine region will be considerable affected by rising temperatures, greater variability in precipitation, and temperatures and associated impacts like floods, droughts, snow cover and other natural hazards (Gobiet et al., 2014). Temperatures in the Alps have increased by 2ºC since the end of the 19th century, since the annual mean decadal temperature records a augmentation of 0.5ºC (Gobiet et al., 2014). This will have impacts on biodiversity, the fundamental base for NCP co-production (Lavorel et al., 2019) . On the other hand, mountain regions have been known for their large adaptive capacities when encountering new challenges, for example the marketing of agricultural products by geographical indications (GI) has proved to be an effective response to combat land abandonment in the 1960s in various French regions (Lamarque and Lambin, 2015; Lavorel et al., 2019).

2. Cheese production in France

2.1. Importance of cheese production for identities

In France, cheese is an iconic product with many small differences, such as the use of local livestock breeds, local fodder, the adherence to non pasteurised transformation techniques which have evolved frequently by collective structures in social-ecological interactions over a long time (Ricard, 2015). Research on local French cheese products frequently underlines the identity related dimensions of these production systems (Bérard et al., 2008; Delfosse, 2007). In the French context, in a very anecdotal way, the importance for cheese as a symbol of local identities is partly exemplified by the brief and shallow comparison of the Wikipedia entry for the word “cheese” in the English and French version. The English entry has a total word quantity of around 6,200, whereby the French entry hosts more than double, with 15,000 words (Cheese, 2021; Fromage, 2021). However, it is also necessary to point out that GIs in general can play a crucial role for identities and maintain or revive local agricultural systems all over the world (Delfosse, 2012; Gervais, 2015; Pachoud et al., 2020).

2.2. Quality labels

Local French cheese production systems are - in contrast to other more quantity oriented production regimes (such as Dutch edam cheese) - frequently tied to the respective territories (Bérard et al., 2008). In today’s economic global market system Geographical indications (GI) play an important role to legally protect these linkages between products, place and production (Quiñones Ruiz et al., 2018). The best-known GI within the European Union is the label “protected designation of origin (PDO)” (see Figure 2). Further, in mountain agriculture, the quality label “mountain products” acknowledges the specificity of these products since 2012 (Santini et al., 2013). Currently, France has registered 45 different types of cheese under these labels (CNAOL, 2016). A department of the French ministry of Agriculture, the institut national de l'origine et de la qualité (national institut for origin and quality/INAO) is charged with the regulation of these products. At European scale, the European commission and the associated administrative bodies oversee these products.

Figure 2: The EU-PDO label links the product to its place of origin

2.3. Cheese production in territorial systems

In the French mountains, Ricard (2015) identified well over 200 cooperative dairy systems. In the French Alps the precursor of today's cooperative systems was the "*fruitière*", dating back as early as 1800 (Ricard, 2015). Pull factors, such as the improved accessibility, new production techniques coupled with the demand of an increasing urban population led to the emergence of new types of dairy cooperatives after the World War II (Delfosse, 2007; Ricard, 2015). On the other hand, these collective structures were also a reaction to combat agricultural decline and to maintain agricultural production and more broadly mountain territories in general (Buclet, 2021). The heterogeneous characteristics of these products are intrinsically tied to their territories and their own specific governance sets was partly summed up by a (not confirmed) quote of the former French president General Charles de Gaulle "How to rule a country where there are 258 types of cheese?" (Ozouf-Marignier, 2008) Despite my focus on these regional cheese production systems the industrial player are present in French cheese production since the beginning of the 1960s (Delfosse, 2007). For example, the largest dairy product group in the world, the French company Lactalis has a major influence on the well-known French quality labelled cheeses such as *camembert* and *roquefort* (Léraud and Kronlund, 2020).

I used as the main entry point for my thesis about social-ecological interactions French cheese for various reasons. First, it presents an iconic product frequently deeply related to the surrounding ecosystems and collective structures and cannot dislocated to another territory. Second, it presents the stocked, condensed, value-added (and economically viable) result of social-ecological legacies derived through specific farming, management and transformation practices. Third, I see mountain cheese production as a multibeneficial activity contributing in various aspects to a good quality of life.

3. The Beaufort production system

My thesis focuses on the nationally well-known raw milk cow cheese Beaufort. Compared with other French quality cheeses, Beaufort production with a comparable small production quantity of 5,000 t/yr is lower than neighbouring PDO cheeses such r*eblochon* (15,000 t/yr) or Saint-Nectaire (14,000 t/yr), not to mention the French PDO leader in cow milk cheese *comté* (55,000 T/yr) (CNAOL, 2016). In the Savoy department where Beaufort production takes place there are eight high quality labelled types of cheese, and many less structured, private producers.

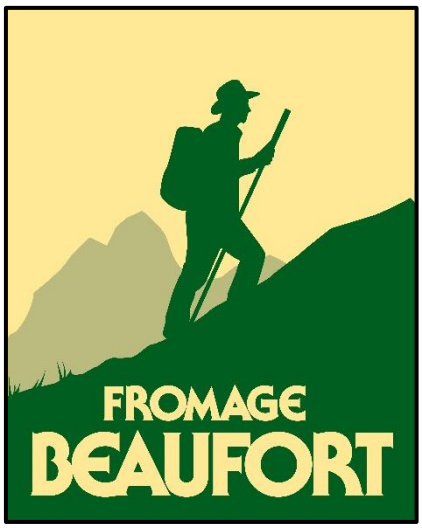


Figure 3: The logo of the Beaufort cheese (credits: L'Atelier S.Madelon/SDB)

The origin of the institutionalized Beaufort production system dates back to the 1960s in the adjacent Beaufortain valley. The omnipresent "rural exodus" coupled with mounting pressure on land due to the development of ski resorts and hydropower led to a decline of Alpine French agriculture (Faure, 1999). The leading founding figure Maxime Viallet challenged this trend by involving actors from all scales such as scientific research, local agricultural organisations and municipalities to engage in a collectively organised cheese production system (Lynch and Harvois, 2016). The idea to unite farmers and share resources, notable by task division and collective transformation facilities was considered as a "local revolution" (Faure, 1999). The PDO label Beaufort was formally registered in 1968.

Figure 4: The Beaufort cheese loaf has a weight of around 40 kg. Characteristic is the concave heel (credits: l'Atelier S.Madelon/SDB)

Today's production system is based on 14 cooperatives in three adjacent valleys, the Beaufortain valley, the Tarentaise valley and the Maurienne valley. The consortium (Syndicat de défense du Beaufort/SDB) offers and regulates legal and technical assistance and control of Beaufort specifications. The marketing of the Beaufort cheese particularly emphasize the role of the mountainous environment (see Figure 3). There are various specifications, however my work focused on the three main rules that shape the type of agriculture and the associated resource use along the NCP co-production steps (INAO, 2015). The first rule links production quantity to the territory (grassland covers 26% of total area) by requiring that 75% of fodder is regionally sourced. The second rule limits production through absolute milk quota at both the livestock unit, farm and cooperative levels. This keeps farm size at a moderate level (average: 32 ha). The third rule requires that low yielding, regional cattle breeds ('Abondance' and 'Tarine') constitute 100% of livestock. The Beaufort production system started in the early 1970s. It has been focussing on direct sale and caters mostly to the local winter tourism sector. Initially conceived as a "crazy" idea, these direct sales succeeded to circumvent less profitable whole sale and contribute in monetary and non-material values to the maintenance of collective identities and their associated values (Lynch and Harvois, 2016). In the following, work the term Beaufort production system is exclusively used for the Beaufort production system in the Maurienne valley. I specifically highlight when referring to the entire production Beaufort production that encompass the three valleys.

4. The Maurienne valley

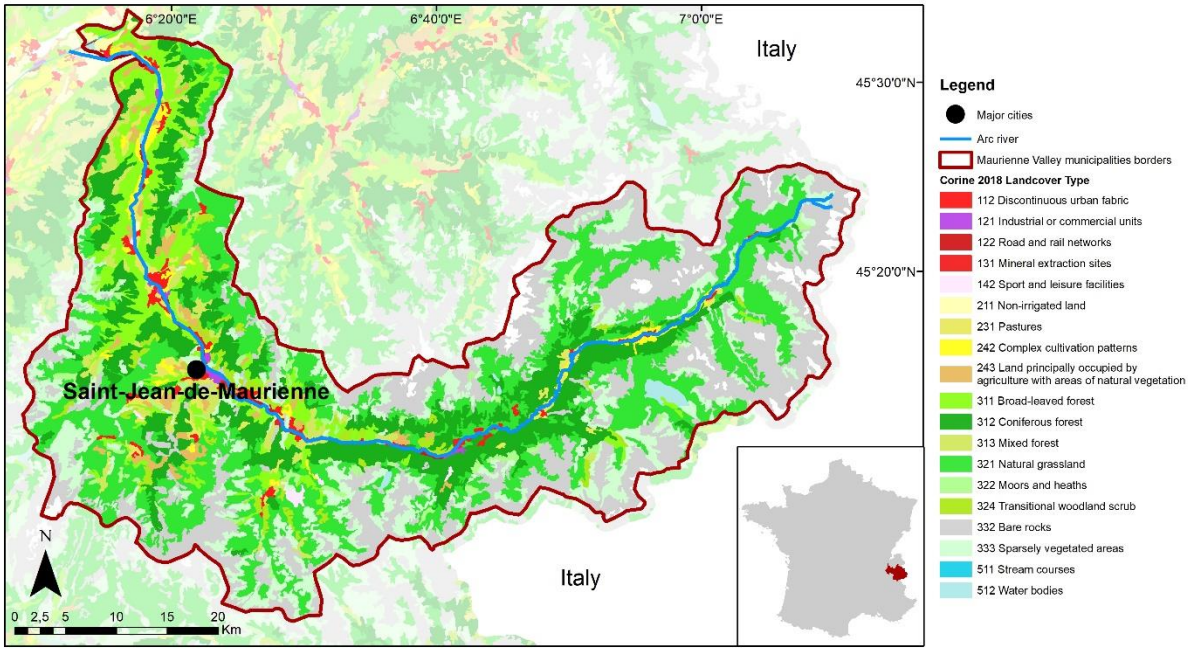


Figure 5: Land use cover map and location of Maurienne valley (Copernicus Land Monitoring Service, 2018; IGN-F, 2006, 2019).

The Maurienne valley falls within the boundaries of the PDO Beaufort production. Situated in the department Savoy it is considered as the longest valley (120 km long) in the French Alps shaped by the river Arce. The area hosts over 100 summits over 3000 meters. The land use classes with e.g. a share of 30% pasture land correspond to the average land use features of the Alps (EEA, 2010; SPM, 2020). The climate ranges from a humid pre-alpine climate in the west to a continental alpine climate in the east. The 40,000 inhabitants live in 62 municipalities in an overall rural setting. Three urban centres at the bottom of the valley have a population of more than 2,000 inhabitants. With a density of 22 inhabitants/km² it is well below average in the Alps (75/km²) (Elmi, 2018; SPM, 2020). No significant changes in population numbers in the last 20 years are noted. A large part of the work force (25%) is linked to winter tourism, with around 20 skiing resorts; the industrial sector constitutes an income source for 19% of the working population (SPM 2020). Livestock farming is the prevalent farming activity and represents with around 350 farms 2% of the total workforce (SPM, 2020).

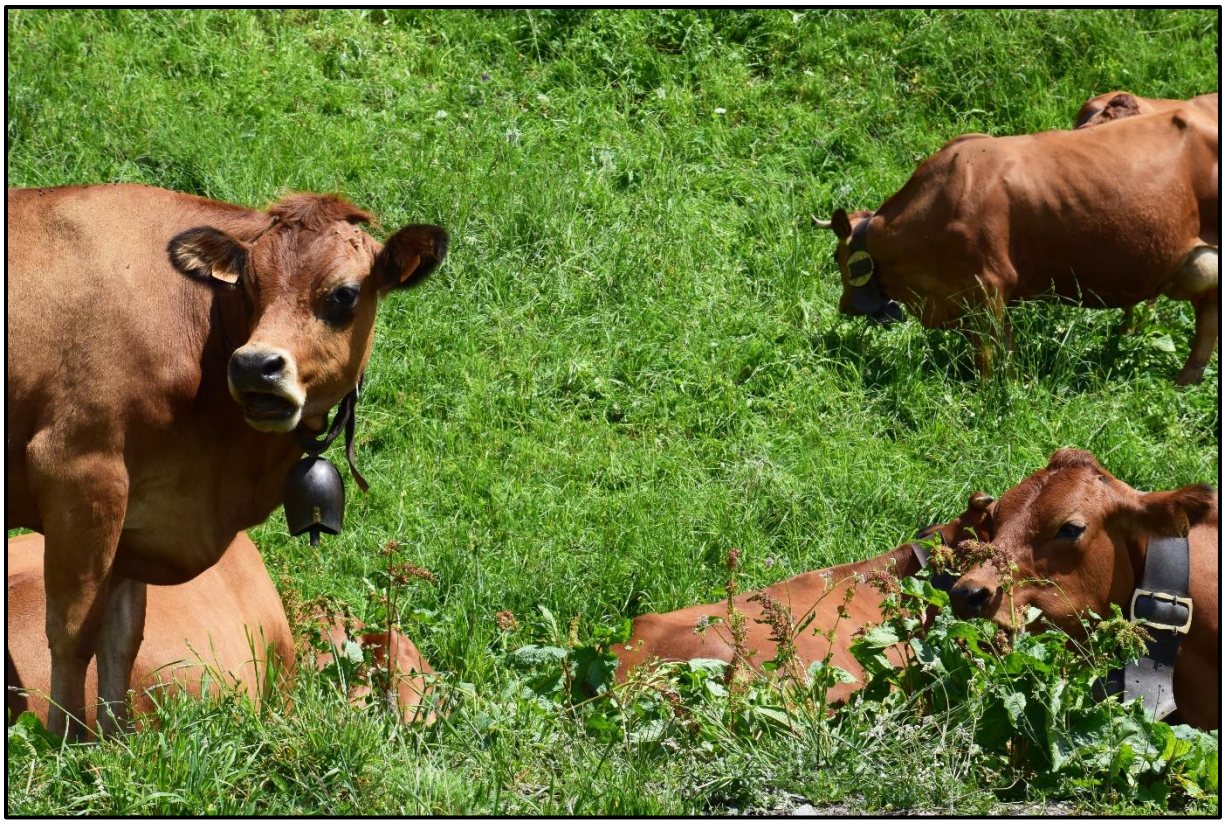


Figure 5: Grazing Tarine cows are a common sight in the Maurienne valley (credits: Bruno Locatelli)

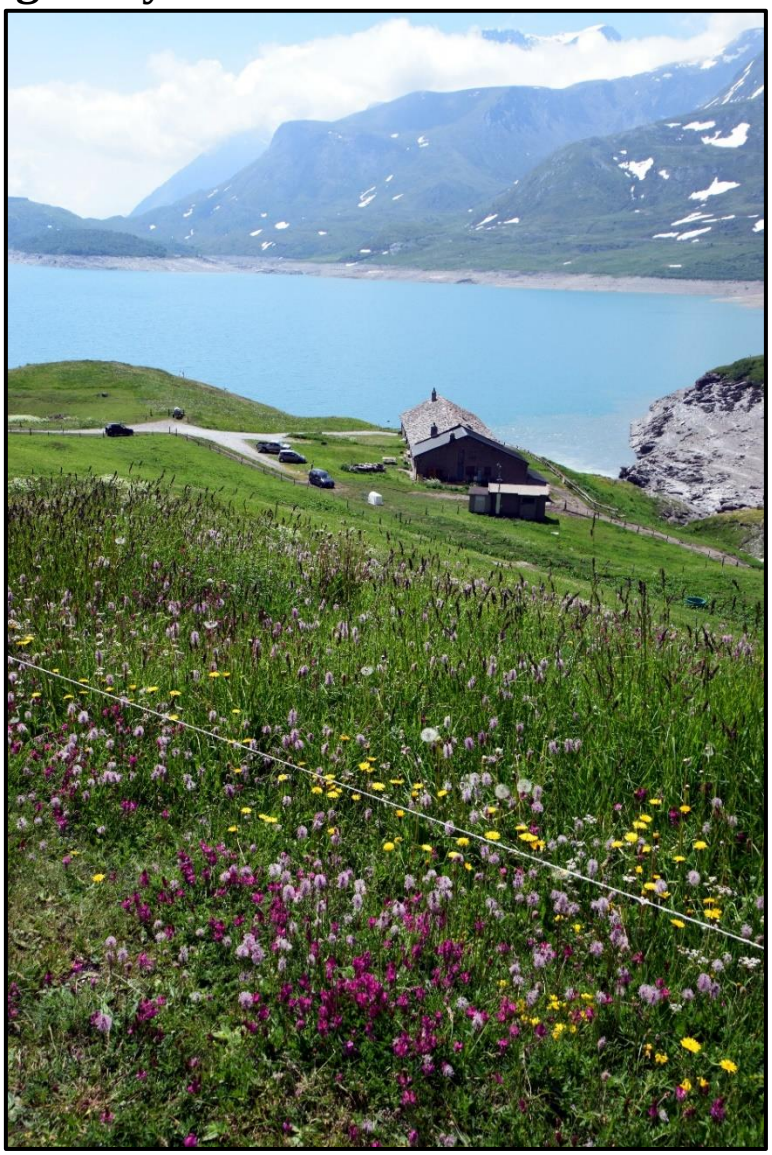
Agriculture is based on livestock farming, where the Beaufort production system unites 38% of the 355 agricultural holdings. 25% of agricultural holdings focus on small livestock and 10% of holdings produce beef. Diversified production (e.g. beekeeping, vegetable production) has a shared of 19%. Transhumant activities play a major role, whereby 66% of small livestock grazing is coming from the outside of the valley (SPM, 2020). At territorial scale, agricultural activities are organised around various institutions. Three Beaufort cooperatives that unite 80 producers are spread evenly across the valley with historically evolved collection areas. There is no comparable structure for other livestock farming activities within the Maurienne valley. Two agricultural associations assemble according to their own statements 80% of economically relevant agricultural holdings. At municipal scale, 22 pastoral land association with the aim to consolidate the historically evolved land fragmentation provide easier access to land for farming activities. While irrigation systems have been in place since the 18th century, local actors have established five irrigation associations in the Eastern part of the valley since 2015. The latest central territorial planning instrument the "schéma de coherence territorial" (SCOT) emphasizes explicitly the relevance to maintain primary cropland around municipalities for agriculture and introduced guidelines. In a broader context, some agricultural activities are affected by the regulations of the National Park Vanoise that encompasses a large part of the

Eastern part of the valley. Further there are 18 Natura 2000 sites, two regional parks and well over 340 zones of faunistic or floristic interests ((SMB, 2020)..

Along with the above-mentioned challenges common across the Alpine Convention area, the Maurienne valley might encounter more localized future questions to solve. In particular, the currently ongoing large infrastructure project, the Turin-Lyon high-speed railway link might affect the territory in the long term by modifying the accessibility of valley. Some worry about the associated closure of smaller train stations and expect negative impacts on the ecosystem, others are favourable in view of the better connectivity to urban centres (SPM, 2020). Further, the liberalisation of the European electricity market prompts mixed reactions regarding the possible establishment of micro-scale hydroelectric energy by private investors.

Within the Trajectories project several (Phd) students have been working in the Maurienne valley from a social-science perspective. Bevione, (2021) currently analyses the Beaufort production system by the metabolism approach. Jaume, (2019) compiled an extensive overview over different types of legacies in the Maurienne. Sheperd, (2020) analysed the social-ecological vulnerability to climate change based on the collective capability approach. In the discipline history .Lachello (2021) works on the social-ecological history of forests from 1815-1940.

Chapter III- A conceptual framework to embed the co-production of nature's contributions to people (NCP) in social-ecological systems



The Mont Cenis water reservoir is a typical example of social-ecological legacies in the Maurienne valley (credits: Bruno Locatelli/2018))

In order to understand the various flows between societies and ecosystems for NCP co-production I considered it crucial to embed these interactions in the territorial system. For this, based on previous research on NCP co-production and inspired by the IPBES framework, we developed a conceptual framework to answer the following question: “What is the role of social-ecological legacies of regional systems for NCP co-production?” We illustrated its relevance through the analysis of the Beaufort production system. In particular, we were interested in the role of the broader social-ecological context, that we defined by social-ecological legacies, social dynamics and current resources for NCP co-production.

In this chapter, we addressed the following specific questions:

- What defines/are social-ecological legacies?
- What are the temporal, organisational spatial system boundaries of social-ecological legacies and current resources?
- What is the role of social dynamics in the organisation of social-ecological legacies for NCP co-production

This conceptual approach structured my further research by providing the analytical base to understand major components of a social-ecological system at territorial scale.

This chapter is presented in the form of an article in the journal Sustainability Science.

Grosinger, J.; Potts M.D.; Buclet, N.; Lavorel S. Memory over matter? – A conceptual framework to integrate social- ecological l legacies in agricultural NCP co-production. Sustainability Science (in revision)

Memory over matter? – A conceptual framework to integrate social-ecological l legacies in agricultural NCP co-production

Grosinger Julia[12], Potts Matthew D.[3], Buclet Nicolas[1], Lavorel Sandra [24]

Submitted to *Sustainability Science* : accepted

[1]Université Grenoble Alpes, CNRS, Sciences Po Grenoble, PACTE, 38000 Grenoble, France
[2]Laboratoire d'Ecologie Alpine, CNRS – Université Grenoble Alpes – Université Savoie 9 Mont-Blanc, 6 38000 Grenoble, France.
[3]Department of Environmental Science, Policy, and Management, University of California, 9 Berkeley, 130 Mulford Hall #3114, Berkeley, CA 94720, USA.
[4]Manaaki Whenua – Landcare Research, Lincoln, New Zealand

Abstract

To better account for how social-ecological legacies of social and ecological systems jointly shape the current composition, quality and quantity of Nature's contribution to People (NCPs), we integrate the concept of NCP co-production into social-ecological system thinking. Our expanded framework highlights how NCP co-production is frequently entangled within its social-ecological context, such as legacies, current resources and social activities. Additionally, we underline the relevance of non-material and material dimensions of resources in NCP co-production. To illustrate the potential of this expanded framework, we explore its application to an agricultural system of the French Northern Alps. We conclude that this framework (1) facilitates the understanding of society-ecosystem interactions in a specific regional social-ecological context; (2) helps to better conceptualise the interdependencies between resources and social activities; (3) demonstrates how current rule sets to organise social-ecological legacies affect the entire NCP co-production chain. The framework's further implementation requires more research to better understand the complex interlinkages between the social and the ecological subsystems that underpin socioeconomic activities.

Keywords: social-ecological legacies, nature's contributions to people (NCP), social-ecological systems, co-production

1. Introduction

Societies and surrounding ecosystems have co-evolved over a long period in their various interdependent material and non-material aspects. In order to support pathways to sustainability, there is a critical need to understand how this interplay of resources and social dynamics underpins current socioeconomic activities in their specific social-ecological context (Ostrom 2009; Meyfroidt et al. 2018; Mastrángelo et al. 2019). To explain these dynamic interrelationships, we use the multidimensional concept of "co-production" of "nature's contributions to people" (NCP). Broadly defined, NCP encompass "all contributions, beneficial or harmful, that individuals, communities, societies, nations or humanity as a whole derive from nature" (Díaz et al. 2018). Expanding on the ecosystem service concept, the NCP concept explicitly acknowledges that flows from nature can have not only different qualities (material, non-material and regulating) but also offer different aspects of appreciation to people (MEA 2005; Díaz et al. 2018; Pascual et al. 2021 Mar 25). In addition, the NCP approach acknowledges that the material and non-material categories are fluid, thus e.g. a material NCP such as milk, can also have a non-material aspect such as the maintenance of identities (Díaz et al. 2015). The co-production concept as applied to NCP describes how people use different resources in diverse ways to generate with ecological systems outcomes that people consider as meaningful(Barnaud et al. 2018; Muhar et al. 2018). Palomo et al. (2016) and Jones et al. (2016) initiated the formalisation of NCP co-production (CP); they defined NCP co-production as the process by which societies and individuals organise and manage resources to mobilise material and non-material flows from nature to contributions to people's good quality of life. The hyphen in 'co-production' stresses that these social activities for the production of NCP can vary to different extents (Palomo et al. 2016). For example, some NCP can benefit society without social intervention, such as some regulating NCP like soil erosion reduction, regulation of hydrological flows and nutrient cycling. However material NCP (e.g. food production) require in most cases some minimum human intervention (Bruley, Locatelli, and Lavorel 2021).

Research has yet to fully integrate NCP co-production in its social-ecological context. This means considering the diverse surrounding material and non-material resources and the associated social activities (Díaz et al. 2015). Research that has targeted the society-ecosystem interface has often analysed NCP co-production using a capital-based approach (Guerry et al. 2015; Jones et al. 2016). This approach distinguishes between social capital and manufactured capital, but neglects that non-material and material resources are mutually dependent (Chaigneau et al. 2019). For example, a material resource, such as a farm or other physical

infrastructure can also be the carrier of non-material aspects such as knowledge, habits or the feeling of belonging for different people (Winner 1980).The integration of social activities can facilitate understanding these multiple dimensions. As an example, co-production was used to evaluate the impact of varying degrees of human input (technology, infrastructure, etc.) in different Portuguese small-scale fisheries on one material NCP (Outeiro et al. 2017). In the French Alps, research suggests that material NCP require potentially more human intervention than non-material or regulating NCP (Bruley, Locatelli, and Lavorel 2021). (Fedele et al. 2017) applied the concept of co-production along the different mechanisms of the ecosystem service cascade framework (Haines-Young and Potschin 2010). What unites these various approaches is the explicit or implicit acknowledgement of non-material aspects such as traditional knowledge (Outeiro et al. 2017), identities (Fischer and Eastwood 2016), shared values (Bruley, Locatelli, and Lavorel 2021), value articulation (Ernstson 2013) or other cognitive dimensions (Palomo et al. 2016) to co-produce NCP. A systematic interpretation of co-production that accounts how societies apply these non-material and material dimensions in NCP-co-production has yet to come (Bennett et al. 2015; Mastrángelo et al. 2019). We assert that the perspective of regional coupled social-ecological systems (SES) provides a means to contextualise and explain NCP co-production (Reyers et al. 2013).

The SES approach considers social (e.g. institutions) and ecological (ecosystems) factors as deeply interlinked (Berkes et al. 2000; McGinnis and Ostrom 2014; Colding and Barthel 2019). They are composed of multiple subsystems with overlapping processes (such as farms, municipalities or pasture land) that interact across scales (Folke 2006; Ostrom 2009). From a spatial and organisational perspective, they are nested in or are linked to other political, socioeconomic, technological, cultural and biophysical structures (Folke 2006; Plieninger et al. 2015). The drawing of system boundaries can be challenging (Walker et al. 2002). Frequently research designs them based on political or administrative units (Dearing et al. 2014; Hanspach et al. 2016), biophysical measures (Martín-López et al. 2017), institutional management divisions (Ostrom 2009), or broad concepts such as resilience (Alessa et al. 2009). Social-ecological system studies often do not appropriately address the definition of system boundaries (Colding and Barthel 2019).

SES are embedded in social-ecological legacies that continue to influence current types and forms of NCP co-production. These social and ecological memories are the result of numerous interactions between and within social and ecological processes for centuries to millennia (Cook et al. 2012). We consider social-ecological legacies as resources that contain social and

ecological elements that co-evolved in time and space, resulting in integrated entities. These can be places like alpine pastures (Quétier et al. 2010; Egarter Vigl et al. 2016), cultural landscapes (Tengberg et al. 2012; Plieninger et al. 2015) or resources for management, like local livestock breeds (Vilá and Arzamendia 2020 Oct 26) or agricultural knowledge (Berkes et al. 2000; Kim et al. 2017). Legacy effects of past society-ecosystem interactions such as modified ecosystems, altered ecosystem functions or social path dependencies have shaped and will continue to shape the type and modes of NCP co-production (Renard et al. 2015; Wu et al. 2020; Bruley, Locatelli, Vendel, et al. 2021). Current resources may become legacies if their material or non-material forms and functions continue to influence future processes (Foster et al. 2003). For example, pasture fertility is a current material, ecological resource supporting fodder production, which will carry over to future soil nutrient status due to slow biogeochemical dynamics (Spiegelberger et al. 2006; Quétier et al. 2007). The same holds true for social resources such as cultural specificities or attachments to places that can transform into common value sets, institutional settings and routinized behaviour (Upton 2008). Non-material dimensions such as knowledge (Hernández-Morcillo et al. 2014) or collective identities (Pachoud 2019) depend on the type of social activities. They are frequently linked to visible social-ecological legacies such genetic diversity (Essl et al. 2015) and regional cultural landscapes (Oppermann et al. 2012; Plieninger et al. 2015). Policies related to agricultural land use have recognised these historically evolved co-production processes in more or less explicit ways. A notable example in Europe is the classification of farmland as High Nature Value (HNV) (Feranec et al. 2016) or regulations for protected areas that require sustained human intervention (Europarc 2018). The European food quality label "Protected Designation of Origin" (PDO) promotes distinct regional agricultural products, and can be regarded as an attempt to preserve social-ecological legacies through economic mechanisms (Quiñones Ruiz et al. 2018). Still, the role of social-ecological legacies for NCP co-production remains underexplored in conceptual and empirical research (Herrero-Jáuregui et al. 2018; Mastrángelo et al. 2019). In order to fill this knowledge gap we propose a conceptual framework that links NCP co-production to the SES approach. This allows us to effectively integrate social-ecological legacies and more robustly distinguish between social (infrastructure, knowledge, etc.) and ecological (biomass, livestock, etc.) resources (Anderies et al. 2004; McGinnis 2011).

The rest of the paper is organised as follows: First, we present an expanded SES framework to fully account for the role of social-ecological legacies and social activities in the NCP co-production. In particular, we discuss the challenges regarding the delineation of system

boundaries within these frameworks between the organisational (social, ecological), temporal (legacies, current resources) and spatial (biophysical, economic) dimensions. In the subsequent section, we apply this framework to a regional SES. In Europe, agricultural mountain production systems rely on social-ecological legacies to ensure the maintenance of regional rural economies. The integration of social-ecological legacies and interlinked social activities can explain varying transformation strategies of the same products (Madelrieux et al. 2018) or entirely different agricultural production systems in adjacent regions with similar physical endowments (Bruley, Locatelli, Vendel, et al. 2021). It allows us to show how different trajectories are based on the previous experiences of a system and how they are linked to different appreciations and values of NCP co-production. Specifically, we illustrate the applicability of our framework for a regional mountain SES and its cheese production.

2. An expanded SES Framework for NCP co-production in agricultural systems

We present a framework to embed NCP co-production in its social-ecological context. We defined the social-ecological context as social-ecological legacies, current resources and social activities. We separated the social from the ecological subsystem (Fig. 1, boxes) following previous epistemological and analytical considerations on NCP co-production (Díaz et al. 2015; Palomo et al. 2016; Bruley, Locatelli, and Lavorel 2021) and the current IPBES framework (Díaz et al. 2015). We decided on this delineation because social activities are widely considered as dominant drivers of change in SES (Folke 2006; Kofinas and Chapin 2009; Spangenberg et al. 2014). Further, the two systems exhibit their own processes that can (1) act independently (Anderies et al. 2004; Colding and Barthel 2019), (2) have different rates of change, (Ostrom 2000; Foster et al. 2003; Walker et al. 2006) and (3) imply different understandings of scale (Winkler et al. 2021 Mar 16). We link these two subsystems with four subsequent steps (Fig. 1, black arrows) that describe social activities.

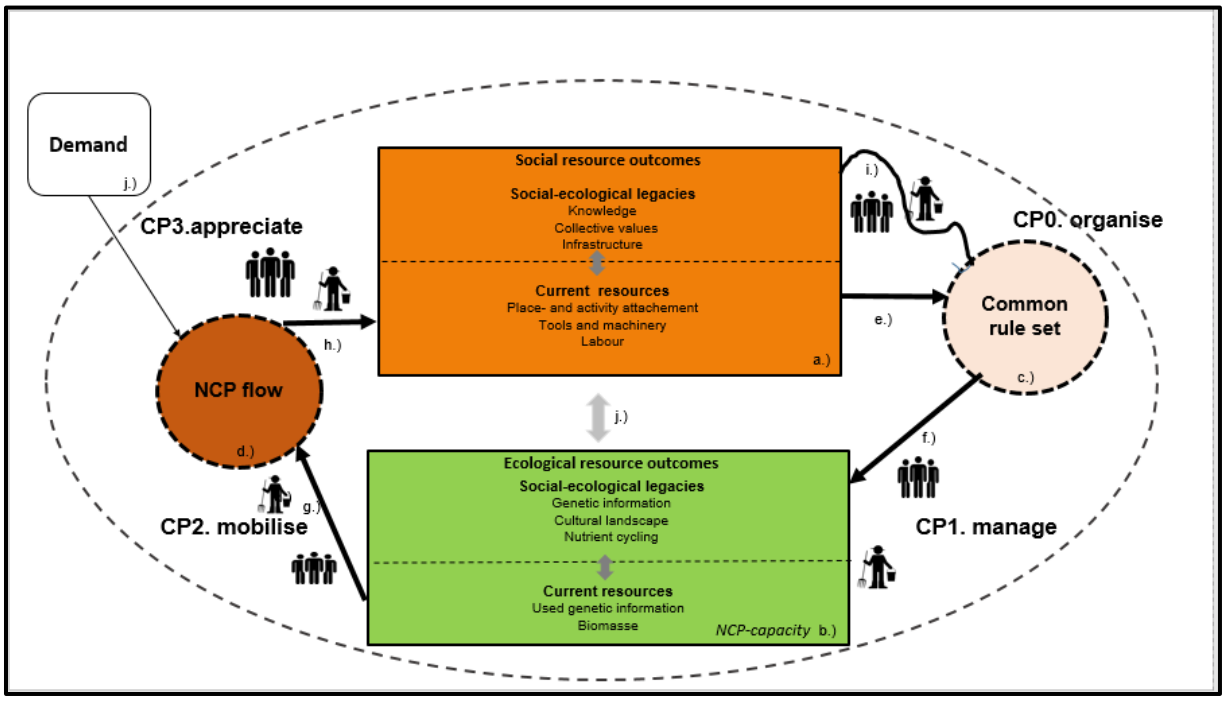


Fig. 1: The figure presents social (a, orange box) and ecological system (b, green box) as two subsystems along with their associated social-ecological legacies and current resources. The dashed lines within the two subsystems shows the porous boundaries between legacies and current resources. The terms NCP capacity (ecological system) and NCP flow refer to the cascade framework (Haines-Young and Potschin 2010). The two circles (c, d) describe the intermediate steps of NCP co-production. The different positions of the common rule set(c) and NCP flow (j) indicate that the steps of co-production can happen at different points of time. External demand (i, white box) affects NCP flow. The four straight arrows (e, f, and g, h) mark the social activities that link the successive steps of NCP co-production. We illustrate the organisation of the resource system with the crooked arrow (i), to underline the negotiation process between diverging interests. The text in the boxes is illustrative. The grey arrows (j) between the social and the ecological subsystems emphasizes there can be unnoticed flows between them.

We used an economic delineation of the boundaries based on material NCP, which are frequently agricultural or forestry products. This permits the identification of social activities and their actors. It allows for the possible modifications of social activities for future adaptation. More broadly, agricultural activities frequently present an "umbrella" for other non-monetarized NCP (such as pest control, pollination) (Lescourret et al. 2015). However, economic boundaries are more diffuse than biophysical boundaries and not spatially explicit.

Our top-down approach is in contrast to other (bottom-up) NCP studies based on biophysical boundaries that subsequently identify NCP in a given spatial area (Reyers et al. 2013). Economic boundaries are non-spatial, and actors involved in different NCP may share the same resources (Eakin et al. 2017). In the context of an Alpine region, for example, tourism shares the same pastureland as the agricultural system, but each of these socioeconomic activities represents different, yet linked, types of NCP co-production. In order to accentuate social activities interacting with their surrounding ecosystem, we limit this framework to the regional scale. To consider demand (see Fig. 1, white box), we integrate monetary flows (such as subsidies, tourist spending, etc.) that can influence the resource use in NCP co-production (Carrasco et al. 2017). For example, increased profits may lead to increased technology use (e.g. investments in new time saving machinery that leads to increases in farm size). Non-monetary, exogenous factors such as climate change (e.g. droughts), water pollution, higher-scale governance decisions or the externalised production of energy intensive products highlight the porosity of these human boundary constructs (Martín-López et al. 2017). Lastly, we assume there are unidentified flows (Fig.1, grey arrows) between the social and the ecological system that cannot be analysed with our conceptual framework.

2.1. Social-ecological legacies and current resources

Disentangling social-ecological legacies (landscape, livestock breeds, farm infrastructure, etc.) into social and ecological components is complex and often not straightforward (Remme et al. 2014; Jones et al. 2016). Based on Remme et al. (2014), we assign social-ecological legacies to the ecological or the social subsystem by identifying those for which ecological processes play a significant role. This allocation also acknowledges that current ecological processes cannot be substituted by technological or social innovations (Edens and Hein 2013). We incorporated this consideration into our framework. For example, we consider farm infrastructure as a social-ecological legacy in the social subsystem, which contains ecological resources (timber) previously mobilised by human intervention. Biomass is an ecological resource and if not extracted will become a social-ecological legacy (potentially leading to an increase in soil carbon) in the ecological subsystem. We easily identify these boundaries for common material resources (milk, biomass, etc.) utilized for later NCP co-production processes. In contrast, these distinctions are less evident for ongoing livestock husbandry. We regard mobilised resources of livestock husbandry (e.g. wool, milk, meat) as leaving the ecological subsystem, while grazing livestock (and its manure) remain in the ecological subsystem. When livestock is sold (and serves than as an NCP for various aspects of appreciation), we consider it as leaving the

ecological subsystem. However, the non-material dimension, such as genetic diversity remains in the subsystem. The knowledge and values to maintain this breed is a social-ecological legacy in the social subsystem and exhibits its own processes. While the notion of social-ecological legacy strongly emphasizes the intimate interlinkages between the social and the ecological system, we opted for didactic purposes for an analytical (and accordingly graphical) presentation of two separate spheres. In doing so, we also align with Riechers et al. (2020) reasoning that most resource types (e.g. infrastructure, genetic diversity, etc.) are best measured in social, respective ecological indicators.

Legacies and current resources can influence each other and are linked. For example, current practices such as irrigation and fertilisation along with the legacies of former land use and social values affect the amount of the current resource of biomass (Quétier et al. 2007). In addition, society can agree on maintaining extensive, labour intensive management practices based on previous experience coupled with current resources. For example, Alpine agricultural systems maintain traditional haymaking for winter livestock feed, but they have considerably reduced manual labour by increasing mechanization. Aspects of appreciation from NCP co-production can thus feedback into the social subsystem and influence how and which social-ecological legacies and current resources are used. In Table 1, we present an illustrative overview about possible variables for the analysis for co-production of a regional agricultural NCP (more information on indicators is provided in SM1).

Resource categories	Definition	Social subsystem	Examples of variables	Data for study area*	Main CP	Ecosystem	Example of variables	Data for study area**	Main CP
Social-ecological legacies	Experiences from past society-ecosystem.	**Common Values*** Views and preferences that influence how ecological resources are governed over time (van Riper et al. 2018; Chan et al. 2012).	Regional breeds of total livestock % local fodder of total fodder Mean farm size	100% 75% 31 ha	**CP0**	**Genetic information** Persisting impact of human activities (e.g. agriculture) on the abiotic or biotic characteristics of ecosystems (Cuddington 2011).	Taxon richness of grassland (in nr.)	432 Vanpeene-Bruhier, Moyne, and Bru(Vanpeene-Bruhier, Moyne, and Brun 1998)	**CP1**
		Traditional ecological knowledge* The evolving body of local knowledge, practice and belief, handed down through generations by cultural transmission (Berkes, Colding, and Folke 2000).	Grazing or harvest dates and duration (days) adjusted to interannual climate variability	Annual changes	**CP0/ CP1**	**Agricultural landscape** Ancestral landscapes can be the foundation of current agricultural production (Koohafkan and Altieri 2011)	Grassland cover	26% (RGDSMB 2014)	**CP1**

	Biophysical or physical memory from the past	**Physical infrastructure** Geographical proximity to production facilities can play a relevant role for social dynamics in regional production chains (Madelrieux, Bergeret, and Fillion 2018; Pachoud et al. 2020).	Travel time to transformation facility	30 min	**CP2**	**Amount of carbon stored in above and below ground biomass** Agricultural practices (e.g. grazing) can be, beneficial or detrimental for soil organic carbon (Smith 2014)(Garcia-Pausas et al. 2017).	Carbon stock	70 – 120 Mg/ha (Poulenard 2020, in prep.)	**CP1**
Current resources	The results of current society-ecosystem interactions influenced by external drivers	**Activity attachment** Motivation of individuals to pursue an activity despite purely economic objectives (Hinojosa et al. 2016; Madelrieux, Bergeret, and Fillion 2018).	Change in producer between 2012 and 2019	-3%	**CP3**	**Ecosystem productivity** Biophysical and social factors influence the net amount of carbon (Haberl et al. 2007)	Biomass production in grassland areas	Mean average for European Alps: 9.8 (+/- 3.8) (Jäger et al. 2020)	**CP2**

		Place attachment The feeling of relatedness to a place is a relevant factor in mountain farmin**g** (Hinojosa et al. 2016)	Change in utilised agricultural area between 1988-2010	-15%**	**CP3**	**Biomass production**	Fodder harvest	0.6 -9 t DM/ha	**CP1**
		Labour Labour is an input for agricultural production (Lescourret et al. 2015; Erb et al. 2013)**.**	Labour force unit/holding	2.06 Labour force Units/ha	**CP1**	**Livestock density**	Livestock Unit (LSU)/ ha	0.39 LSU/ha)	**CP1**
		Technology Factor of production for agricultural products (Erb et al. 2013).	Irrigated surface of total agricultural surface	4%	**CP1**				

*Table 1: Illustrative overview of indicators and respective sources for the conceptual framework application to Maurienne Beaufort cheese production (MBP). * Sources if not otherwise indicated (Clavel 2014; Schoch 2014, 2013; INAO 2015) **Sources for entire Maurienne valley*

2.2. Activities along the NCP co-production chain

Social activities make use of social-ecological legacies and current resources along the different steps of co-production. They define and affect the types of co-production (Spangenberg et al. 2014; Plieninger et al. 2015). Following the ecosystem service cascade framework (Potschin-Young et al. 2018) and its refinement for accounting explicitly for human agency in the delivery of benefits from ecosystems to people (Fedele, Locatelli, and Djoudi 2017; Bruley, Locatelli, and Lavorel 2021), we structured NCP co-production as a four step process (illustrated by the four arrows in Fig. 1). This disaggregation enables the more precise identification of the various actors (e.g. individual or collective) and eventually assessing their role along the entire NCP co-production process.

We define co-production step zero (CP0; organising) as a precursor which describes how different actors, either collectively or individual agree on a rule set over the types and modes of co-production. This step is in biophysical and spatial terms separate from the local ecological subsystem. In democratic structures this organisation of resources requires collective agreement on common values and knowledge (Ostrom 2000). It depends on the social-ecological context, hereby the social-ecological legacies, current resources and the involved actors. The crooked arrow indicates these rule sets are the consolidated result of often long negotiations among local stakeholders and government or regulatory authorities. Empirical research analyses these formalised relationships to capture the non-material collective values of a given social subsystem (Ostrom 1990). However, we advance that these formalised collective values only can only present a compromise between the different actors and they do not capture the totality of collective values.

Co-production at step one (CP1) is the stage of biophysical ecosystem management, such as fertilisation of agricultural fields. For example, actors apply different management practices based on the agreed rule set, their current resources (available labour, technology etc.) and their personal considerations on the management of the cultural landscape as shaped by social-ecological legacies. Thus, the combination of CP0 and individual perceptions of the involved actor underpin the management of the social-ecological legacy landscape.

Co-production at step two (CP2) is where activities of extraction of current resources (e.g. biomass) from the social-ecological legacies (livestock breed, landscape) occur, such as milking or haymaking. Mobilisation does not necessarily depend on the current management at CP1, but on the social-ecological legacies such as the amount of pastureland or infrastructure. Picking berries in a forest does not require targeted management for the production of these fruits, but

does require access (e.g. a path). However, current resources can modify type and quality of current ecological resources (e.g. fertilisation increases biomass yields). CP2 usually requires some social resources, such as permanent infrastructure, e.g. a form of physical access to mobilise ecological outputs (Bruley, Locatelli, and Lavorel 2021).

Co-production at step three (CP3) relates to the translation to a final NCP benefit, e.g. the sale or transformation of milk and other aspects of appreciation (happiness to be in nature, place of belonging, etc.) that co-producing actors consider as relevant. It requires multiple, frequently subtle cognitive factors e.g. feeling of attachment (Fedele, Locatelli, and Djoudi 2017). These appreciations feedback into the social subsystem as current resources.

3. The Maurienne Beaufort cheese production system

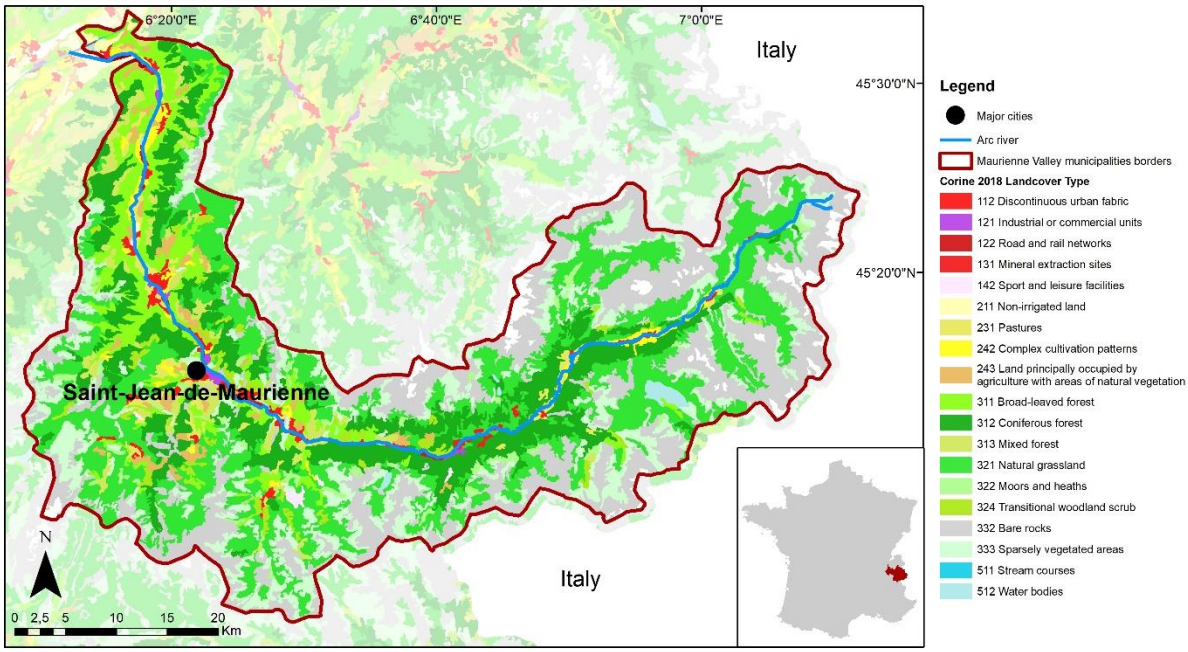


Fig. 2: Location of the study area

Beaufort cheese production takes place in three adjacent valleys (Beaufortain, Tarentaise and Maurienne) of the Northern French Alps. Since 1968, the EU-label "Protected designation of origin" (PDO) entails binding product specifications. This commonly agreed rule set guarantees the characteristics of the final product and the maintenance of associated management and production techniques (INAO 2015; Lynch and Harvois 2016). In the following, we exclusively discuss the Beaufort production system in the Maurienne valley; however, the rule set applies to the whole production area. The Maurienne valley with its three cooperatives representing about 80 producers (900 t of cheese / yr), has been an integral part of the Beaufort PDO since its inception in 1968. All 14 cooperatives in the three valleys are associated to a consortium. The consortium offers and regulates legal and technical assistance and control of the product

specifications. The Maurienne valley shaped by the Arc River spans almost 120 km and is the longest Alpine valley in France. Its 40,000 inhabitants live in predominantly rural settings with only three of the 56 municipalities exceeding 2,000 inhabitants (SPM 2020). The climate ranges from a humid pre-alpine climate in the west to a continental alpine climate in the east. Representing one third of the whole area, grasslands are a characteristic feature of landscape (Fig. 2). Today, the local economy largely reflects the general picture of European mountainous areas with a large part of the work force (25%) linked to the service sector, 19% to the industrial sector and 2% to the primary sector (EC 2009; SPM 2020).

To apply our framework to the Maurienne Beaufort production system, we conducted 20 semi-structured interviews with actors associated to the system. We first identified 100 actors directly economically affiliated with Beaufort production and selected interviewees based on internet searches and subsequent purposive snowballing (Bryman 2016). Seventeen of them were active in the Maurienne Beaufort production system during the research period, among which four actors in managing positions of the three cooperatives, one of the consortium and twelve Beaufort producers. In addition, we included three actors as "time witnesses" who were actively involved in the establishment of the Beaufort production system from the 1960s onwards. The interviews were conducted between February to September 2019 (see SM2). The interviews focused on the role and background of respective actors and their views on and relations to the Beaufort production system (Interview guide is provided in SM3).

Using qualitative manual coding with NVivo, we identified the main activities and associated resources used along NCP co-production by a predefined typology (Clarke and Braun 2014; QSR International 2020). This typology built on previous studies of agricultural NCP co-production and was iteratively improved during coding (Palomo et al. 2016; Vallet et al. 2019; Bruley, Locatelli, and Lavorel 2021). We drew the economic system boundaries as encompassing all resources, e.g. livestock, biomass or carbon storage and actors associated with the Beaufort production system in the valley.

3.1. Organising resources (CP0)

In our framework, we defined CP0, the organisation of a regional collective rule set, depending on social-ecological legacies and current resources of the social subsystem with its actors. The Beaufort consortium oversees the rule set of product specifications for the entire production area. It regularly consults its board composed of representatives of the cooperatives and producers (Lynch and Harvois 2016; INAO 2015). This rule set has not been externally

imposed, but actors have negotiated it over the years. An actor casually remarked: *"It's the history, which governs the conduct of the people."*

In the interviews, actors repeatedly referred to three main rules that shape the type of agriculture and the associated resource use along the NCP co-production steps (INAO 2015). The first rule links production quantity to the social-ecological legacy landscape (grassland covers 26% of total area) by requiring that 75% of fodder be regionally sourced. The second rule limits production through absolute milk quota at both the livestock unit, farm and cooperative level. This keeps farm size at a moderate level (average: 32 ha). The third rule requires that low yielding, regional cattle breeds ('Abondance' and 'Tarine') constitute 100% of livestock. These rules couple production to the landscape's social-ecological legacies. This collectively agreed rule set over social-ecological legacies of both the social and ecological subsystems maintains small-scale agriculture with extensive management embedded in a regional social-ecological context.

We consider this rule set as the consolidated result of negotiations between differing interests over common values and knowledge and current resource use (activity attachment, technology, etc.) that has been evolving over time. The limited choice of cattle breeds is the result of a long negotiation process in the 1980s, where some farmers favoured high yielding cattle breeds over the local low yielding types in order to increase production quantity (Lynch and Harvois 2016). More recently, a debate focussed on the easing of the 75% local fodder requirement. While some actors prefer low production quantities, others would prefer more flexible fodder requirements to allow for higher production. Some actors question the third rule, which limits farm size. A fraction of farmers proposes stricter rules, such as a shift to organic labelling. Thus, the modification of these social social-ecological legacies could affect the NCP co-production steps and the ecological subsystem (landscape, genetic diversity). However, any modification prompts lengthy administrative processes at consortium level followed by a public enquiry and national approval by regulatory authorities. The results of the public enquiry are not binding, but as a leading actor on this level stated: *"In any case, for modifications to be accepted in the field there must be maximum consensus and a majority of producers who ask for them."*

3.2. Producing fodder (CP1)

In the Beaufort production system, CP1 consists of the sum of available resources at farm level as limited by the commonly agreed rule set. Individual farmers manage the ecological subsystem by livestock grazing across different altitudes and by the management of meadows for haymaking in valley bottoms. These actors are represented in the management board of the

consortium and can voice their opinion in an annual general assembly. The consortium controls the compliance to the rule set. Actors apply the currently formulated rule set (CP0) and use their current resources, labour and technology to manage (and maintain) the social-ecological legacies of the ecological subsystem. Individual perceptions of exogenous factors (recurrent droughts, urban spread) and financial flows (subsidy schemes) have led some actors to change how they use the resources available to them. They have increased technological input through irrigation since 2015. Still, the used amount of labour (2.06 LFU/h), irrigation (4% of agricultural surface) and livestock unit density (0.39 LSU/ha) of the Beaufort cooperative system are extensive management practices in a biophysically limited spatial area. But, even within a common rule set that regulates social-ecological legacies, management strategies are evolving, due to changing current resource use and possible individual preferences. Overall, farmers considered their agriculture as extensive and adjusted to the local conditions: "*The PDO Beaufort and our practices are reasonable. It's important to stay coherent in what you're doing.*"

3.3. Mobilising ecological resources (CP2)

In our framework, mobilising ecological resources (CP2) is defined as a function of current resources and social-ecological legacies from the social and the ecological subsystems. In Maurienne, individual farmers mobilise the current resources of the ecological subsystem by milking cows. They must comply with high quality and hygienic standards. Cooperatives collect the milk once a day from individual farms. The nearby transformation facilities enable the mobilisation and subsequently easy access to markets. The relevance of physical infrastructure in farms proximity for mobilisation has been shown to be important in other Alpine regions (Bruley, Locatelli, Vendel, et al. 2021). Actors were aware of the relevance of mobilisation: "*Here, no big player would come and get my milk. It just wouldn't pay off for him.*"

3.4. Appreciating NCP (CP3)

In the Beaufort production system CP3 (appreciating NCP) can be considered as the multiple outcomes of the entire production chain. These appreciations feedback as current resources into the social subsystem. Cooperatives transform the milk and sell the Beaufort cheese through whole or direct sale. Individual farmers use the remuneration for different aspects they consider as meaningful. The sale of the product supports households' socioeconomic livelihood and implies by its specific local production a certain lifestyle. Actors use (and reproduce) current social resources such as activity attachment and place attachment to appreciate the outcomes.

The activity attachment of the Beaufort cooperative system appears to be only slightly declining; there was a reduction of -3% of Beaufort producers over the past 7 years (2012-2019). However, 15% of the Maurienne's grassland area was retired from agriculture from 1988 to 2010. In interviews, farmers expressed satisfaction with their socioeconomic livelihood (Grosinger et al., in review). The different steps of co-production interact. For example, the outcomes of CP3 such as place attachment and of the CP0 rule set reflect and shape each other. Place attachment affects how actors organise their rule set. For example, the compliance to the 75% local fodder requirement can be explained by the willingness of farmers to maintain certain landscape features (such as summer high pastures). Conversely, discussions about more flexible management rules may reflect the declining activity and place attachment of some farmers. Farmers might be less eager to pursue labour intensive, time-consuming activities in parcels difficult to access. In addition, a high appreciation of exclusive monetary benefits could motivate the desire for more flexible rule sets that favour greater production. The interdependency between place and activity attachment and rule sets is in particular evident when looking at the history of Beaufort. Actors with a strong activity and place attachment formalised and institutionalised their agricultural practices by the Beaufort cooperative in order to combat rural emigration and the decline of Alpine agriculture in the 1960s (Dubeuf 1996). It is yet unclear though how and if the Beaufort cooperative will be as effective to respond to ongoing and future challenges such as evolving life style expectations.

In analytical terms, the multiple individual cognitive dimensions of appreciations can render homogeneous, systemic quantification difficult. These deeply personal motivations might be difficult to upscale without losing the specific nature of such dimensions that contribute to a good quality of life. For example, an actor described her current activity as a realised desire from her childhood: *"Since I've been a child, I always wanted to have a farm. Me, the pasture land, I only see myself there."*

4. Discussion

We conceptualised NCP co-production within the context of a coupled SES. This allowed us to analyse the intentional society-ecosystem interactions within the SES and to elucidate the importance of social-ecological legacies and social activities for NCP production. Below, we first discuss possible applications and empirical limits of this framework. We then explore the complexities of integrating social-ecological legacies into NCP research. We conclude by highlighting the interplay between social-ecological legacies and social dynamics.

4.1. General applications of the framework

We believe this conceptual framework may most easily be applied in systems where social and ecological boundaries are delineated by formal institutions, such as areas falling within geographical indications (Santini et al. 2015; Belletti et al. 2017). This enables detailed analysis of linkages between collective rule sets and landscape features. Nevertheless, the framework could also be applied in less strongly structured systems like cultural landscapes. Their boundaries are delineated by informal rule sets and only subsequently regularized by formal institutions such as official labelling bodies (e.g. high nature value landscapes) (Oppermann et al. 2012; Beaufoy and HNV Link Partners 2017; Benedetti 2017). In addition, the framework might not be able to adequately assess structures with a high inflow of external resources, such as industrialized agricultural systems with possible less social-ecologically evolved patterns. We suggest that the framework is best applicable where society is intrinsically linked to local ecosystems by physical and cultural interlinkages that are expressed by common norms and practices.

From an academic perspective, the framework can facilitate collaboration between different fields. First, it can raise awareness of natural scientists about the relevance of social-ecological legacies and social activities for NCP-co-production at a regional scale (Hysing and Lidskog 2021). Secondly, the framework can accommodate a variety of interdisciplinary research questions, including the relations between collective values, ecosystems and regional governance rules (Ostrom 1990; Bodin 2017). From an analytical perspective, it integrates the economic dimensions of NCP co-production and associated actors with their surrounding ecosystem. In particular, the disaggregation of the steps of NCP co-production can highlight the multitude of actors and their social characteristics (and associated power in decision making) who are intimately linked by the resources used throughout co-production. Thus, it can facilitate a further integration of social sciences into assessments of society-ecosystem interactions (Stenseke and Larigauderie 2018).

Interdisciplinary approaches face the challenge of finding appropriate terms and underlying concepts that are intuitive and logical for multiple disciplines. For example social sciences frequently use the term “capital” when referring to what we named social-ecological legacies (Guerry et al. 2015). On the other hand, natural sciences consider social-ecological legacies as memories from the past and not as a potential resource for NCP co-production (Essl et al. 2015). We believe that our framework can support meaningful exchanges for reconciling these

diverging conceptualisations of available resources. We expect this will help further advancing research on value generation and associated modes of production in SES.

The framework deliberately emphasizes the complementarity of resources from the social and ecological subsystems to co-produce different dimensions of appreciation. Thereby, it embodies the vision of strong sustainability (Daly 1997). The aim of analysing NCP co-production is not to quantify the relative share of co-production between the two subsystems (e.g. 1 ton of maize is co-produced by 60% social and 40% ecological input.). The continuation of this thought would inevitably imply substitutability of ecological by social resources (Stiglitz 1997). Further, substitutability does neglect the impact of social-ecological legacies in NCP co-production processes. Nevertheless, we support suggestions from other research to investigate the effects of increasing levels of social resources in co-production on ecological degradation more thoroughly (Palomo et al. 2016; Outeiro et al. 2017). From a methodological perspective, the integration of social-ecological legacies like infrastructure might enable bridging the gap between research on NCP and other methods to analyse human-nature interactions, such as Material Flow Analysis or Life Cycle Analysis. The framework is relatively flexible. It does not assume to what extent NCP co-production is driven by social-ecological legacies or social activities. Some research suggests that NCP co-production is not based on natural resource endowments but on human agency (Ballet et al. 2011; Spangenberg et al. 2014; Schröter et al. 2020). On the other hand, long term studies on legacies suggest that biophysical drivers might have more explanatory power than socioeconomic variables for current land use patterns (Price et al. 2017). The application of our framework can incorporate both approaches.

Empirical application of the framework might encounter several challenges to account for external factors. Our case study describes a system whose boundaries were defined from the perspective of regional economic dynamics. The framework cannot capture the larger social structures that influence the regional SES. This is in particular evident for the different aspects of appreciation in the Beaufort production system in the Maurienne. The declining activity and place attachment reflect the general trend of decreasing farms in Europe. For that it cannot entirely be explained by the variables in our framework (EC 2009; Flury et al. 2013). In addition, the Beaufort production system depends on larger institutional structures, such as the European PDO label, that ensures an above market prize and the persistence of the this regional production system (Quiñones Ruiz et al. 2018). Also changing consumer patterns, such as favouring high quality can support this low yielding extensive agricultural system (Lamarque and Lambin 2015). The framework incorporates these diverse drivers as one black box factor

(demand). Thus, we suggest linking this framework with recent telecoupling approaches that consider such indirect external factors more explicitly (Hull and Liu 2018). We acknowledge that distinguishing social-ecological legacies in the social and ecological subsystems remains complex and requires further quantification and systematisation. This is in particular evident when comparing the framework with comparable conceptualisations that frequently consider livestock as anthropogenic assets and not, as in the reasoning of this framework, as a social-ecological resource within the ecological subsystem (Díaz et al. 2015; Lescourret et al. 2015).

The framework is in line with the IPBES-framework that underlines the pervasiveness of non-material, cognitive elements in all components of NCP (Díaz et al. 2018). However, a structured assessment of these cognitive factors, such as values and aspects of appreciations usually requires some level of simplification. For that, the framework might not be able to capture the various aspects of appreciation by different actors (Schröter et al. 2020). For example, the indicators we used for place and activity attachment measure its effects, but not its intrinsic underlying mechanisms. This weakness is shared across NCP research overall (Schulz and Martin-Ortega 2018), though recent developments help addressing multiple values of nature and their incorporation into analyses of SES (Schröter et al. 2020; Pascual et al. 2021 Mar 25). While we support the use of a simple range of qualitative and quantitative key indicators (e.g. Schröter et al. 2020), we believe that applying the framework starts with qualitative research.

4.2. Integrating social-ecological l legacies for understanding NCP co-production

The regional rule set of a given landscape emerges as a complex integration of interacting norms and behaviours over a period of time. The illustrative example of Beaufort NCP co-production in the Maurienne valley indicates that the way in which social-ecological legacies are organised by a common agreement (such as a collective rule set) among actors can affect the entire production system. For example, compliance to regional livestock breeds and fodder sourcing influence farm size and presumably different aspects of appreciation. The organisation of resources by a rule set can only be understood by integrating social-ecological legacies such as common values as a key resource. In case of the Beaufort production system, the organisation of collective values allowed an otherwise not competitive product to ensure the maintenance of mountain agriculture (Lynch and Harvois 2016). This suggests that the (re)organisation of non-material social-ecological legacies can facilitate possible adaptation strategies to other challenges (e.g. climate change) for regional SES (Berkes et al. 2000; Oteros-Rozas et al. 2013; Lavorel et al. 2020). To advance agroecological transitions, collective institutions may

(re)formulate or adjust collective rule sets in accordance with the anticipated aspects of appreciation (Lamine et al. 2019). Thus, collective rule sets can be relevant for the preservation of landscapes with a specific biodiversity and cultural values, such as High Nature Value (HNV) landscapes. Recent research explicitly studying these linkages in Slovenia has highlighted the relevance of collective rule sets and associated collective value sets for these landscapes (Rac et al. 2020). Some research suggests that collective rule sets can promote biodiversity conservation, but more numerous and standardized, or at least comparable, studies exploring these interlinkages are needed (Chappell et al. 2016). However, as can be seen in the case study actors currently rather favour easing restrictions (e.g. 75% local fodder requirement) and only a fraction support stricter environmental measures. Social-ecological legacies can impede the introduction of new practices, for example the proposition of organic labelling for the Beaufort production is considered as controversial. This is in line with a recent meta-analysis on the modifications of PDO-labels which suggests that ecological considerations only play a minor role in the amendment processes of the products (Marescotti et al. 2020). Thus, collective rule sets can either facilitate or hamper (e.g. by institutional inertia, path dependency or "stickiness") the continuation or change of NCP co-production (Waylen et al. 2015; Colloff et al. 2020; Lavorel et al. 2020).

4.3. Evolving current resources and types of appreciation

We showed that actors need to comply with a certain rule set, but are then relatively free to set their current resource use in their management activities. Changes in energy and material regimes, embodied as current resources can profoundly impact current and future NCP co-production and subsequently modify these social-ecological legacies (Plutzar et al. 2016; Le Noë et al. 2020). In line with previous studies on natural resource management, our analysis of the Beaufort production system showed that the rule set could influence the use of current resources in management practices (Ostrom 1990). Social-ecological legacies coupled with evolving current resources and aspects of appreciation can lead to new management practices like increasing irrigation (Waylen et al. 2015). In our case study, new irrigation technology can lead to undesirable effects on the social-ecological legacies of the ecosystem (e.g. modifying soil carbon) (Mudge et al. 2021). Therefore, the rigidity of collective rule sets combined with changing current resources can lead to social-ecological traps, with the unintentional degradation of ecosystems (Boonstra and de Boer 2014). On the other hand, social-ecological legacies and evolving types of appreciations have also led to new forms of non-material NCP, such as landscape appreciation. In the case of the Beaufort production system, the cooperatives

acknowledge this aspect and offer regular tourist visits to their transformation facilities or to grazing cattle on nearby pastures. On a larger scale, some European national or supranational subsidy schemes prioritise this non-material dimension of NCP co-production indirectly. The subsidies favour landscape management over production quantity to maintain a desired aesthetic appearance (von Glasenapp and Thornton 2011; Flury et al. 2013; Daugstad 2019). More research investigating the links between current resources, social-ecological legacies, individual management practices and types of appreciation are needed to better understand the role of social-ecological legacies in NCP co-production.

5. Conclusion

Our conceptual framework showed how regional societies make use of available resources for aspects they consider as relevant. We integrated social-ecological legacies and social activities to thoroughly analyse biophysical constraints and modifiable conditions SES are embedded in. The framework highlights the relevance of consensus among actors on the management of regional landscapes. We argued that a balanced recognition of social-ecological legacies of the social and the ecological subsystem is essential for describing agricultural systems. Further, the relations of outcomes with collective rule sets facilitate the understanding of actors' choices in their resource use. While the framework is conceptually complex and requires knowledge from multiple disciplines, we argue it will advance analyses of agricultural development, social-ecological legacies and regional governance systems because it decidedly focusses on the contextual specifics of these systems. Additionally it allows rapidly identifying relevant key stakeholders. We believe that the explicit linking of society and ecosystems through social-ecological legacies provides a common ground for natural and social sciences in a regional context. This can nurture the discourse on value pluralism and foster research of non-material aspects that people consider as meaningful to their life.

Acknowledgements

This work was supported by the Université Grenoble Alpes Cross-Disciplinary Project Trajectories funded by the French National Research Agency "Investissements d'avenir" program (ANR-15-IDEX-02). This work was carried out within the eLSTER site Zone Atelier Alpes.

References

Alessa L, Kliskey A, Altaweel M. 2009. Toward a typology for social-ecological systems. Sustain Sci Pract Policy. 5(1):31–41. doi:10.1080/15487733.2009.11908026.

Anderies JM, Janssen MA, Ostrom E. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. Ecol Soc. 9(1). doi:10.5751/ES-00610-090118. [accessed 2021 Feb 12]. http://www.ecologyandsociety.org/vol9/iss1/art18/.

Ballet J, Bazin D, Dubois J-L, Mahieu F-R. 2011. A note on sustainability economics and the capability approach. Ecol Econ. 70(11):1831–1834. doi:10.1016/j.ecolecon.2011.05.009.

Barnaud C, Corbera E, Muradian R, Salliou N, Sirami C, Vialatte A, Choisis J-P, Dendoncker N, Mathevet R, Moreau C. 2018. Ecosystem services, social interdependencies, and collective action. Ecol Soc. 23(1).

Beaufoy G, HNV Link Partners. 2017. THE HNV LINK COMPENDIUM Comparative collection of High Nature Value innovations, experiences, needs and lessons from 10 European "Learning Areas" A thematic network on High Nature Value farming Learning, Innovation & Knowledge T.

Belletti G, Marescotti A, Touzard J-M. 2017. Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies. World Dev. 98:45–57. doi:10.1016/j.worlddev.2015.05.004.

Benedetti Y. 2017. Trends in High Nature Value farmland studies: a systematic review. Eur J Ecol. 3(2):19–32. doi:10.1515/eje-2017-0012.

Bennett EM, Cramer W, Begossi A, Cundill G, Díaz S, Egoh BN, Geijzendorffer IR, Krug CB, Lavorel S, Lazos E, et al. 2015. Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr Opin Environ Sustain. 14:76–85. doi:10.1016/j.cosust.2015.03.007.

Bergeret A, Lavorel S. in press. Stakeholder visions for trajectories of adaptation to climate change in the Drôme catchment (French Alps). Reg Environ Change.

Berkes F, Colding J, Folke C. 2000. Rediscovery of Traditional Ecological Knowledge as adaptive management. Ecol Appl. 10(5):1251. doi:10.2307/2641280.

Bodin Ö. 2017. Collaborative environmental governance: achieving collective action in social-ecological systems. Science. 357(6352):eaan1114. doi:10.1126/science.aan1114.

Boonstra WJ, de Boer FW. 2014. The historical dynamics of social–ecological traps. AMBIO. 43(3):260–274. doi:10.1007/s13280-013-0419-1.

Bruley E, Locatelli B, Lavorel S. 2021. Nature's contributions to people: coproducing quality of life from multifunctional landscapes. Ecol Soc. 26(1). doi:10.5751/ES-12031-260112. [accessed 2021 Apr 26]. https://www.ecologyandsociety.org/vol26/iss1/art12/.

Bruley E, Locatelli B, Vendel F, Bergeret A, Elleaume N, Grosinger J, Lavorel S. 2021. Historical reconfigurations of a social–ecological system adapting to economic, policy and climate changes in the French Alps. Reg Environ Change. 21(2). doi:10.1007/s10113-021-01760-8. [accessed 2021 Apr 26]. http://link.springer.com/10.1007/s10113-021-01760-8.

Carrasco LR, Chan J, McGrath FL, Nghiem LTP. 2017. Biodiversity conservation in a telecoupled world. Ecol Soc. 22(3). doi:10.5751/ES-09448-220324. [accessed 2021 Mar 1]. https://www.ecologyandsociety.org/vol22/iss3/art24/.

Chaigneau T, Brown K, Coulthard S, Daw TM, Szaboova L. 2019. Money, use and experience: identifying the mechanisms through which ecosystem services contribute to wellbeing in coastal Kenya and Mozambique. Ecosyst Serv. 38:100957. doi:10.1016/j.ecoser.2019.100957.

Chan KMA, Guerry AD, Balvanera P, Klain S, Satterfield T, Basurto X, Bostrom A, Chuenpagdee R, Gould R, Halpern BS, et al. 2012. Where are cultural and social in ecosystem services? A framework for constructive engagement. BioScience. 62(8):744–756. doi:10.1525/bio.2012.62.8.7.

Chappell MJ, Moore JR, Heckelman AA. 2016. Participation in a city food security program may be linked to higher ant alpha- and beta-diversity: an exploratory case from Belo Horizonte, Brazil. Agroecol Sustain Food Syst. 40(8):804–829. doi:10.1080/21683565.2016.1160020.

Clarke V, Braun V. 2014. Thematic analysis. In: Teo T, editor. Encyclopedia of Critical Psychology. New York, NY: Springer New York. p. 1947–1952. [accessed 2021 Apr 4]. http://link.springer.com/10.1007/978-1-4614-5583-7_311.

Clavel C. 2014. Etude prospective coopérative de La Haute Maurienne- Etat des lieux.

Colding J, Barthel S. 2019. Exploring the social-ecological systems discourse 20 years later. Ecol Soc. 24(1). doi:10.5751/ES-10598-240102. [accessed 2021 Feb 26]. https://www.ecologyandsociety.org/vol24/iss1/art2/.

Colloff MJ, Wise RM, Palomo I, Lavorel S, Pascual U. 2020. Nature's contribution to adaptation: insights from examples of the transformation of social-ecological systems. Ecosyst People. 16(1):137–150. doi:10.1080/26395916.2020.1754919.

Cook EM, Hall SJ, Larson KL. 2012. Residential landscapes as social-ecological systems: a synthesis of multi-scalar interactions between people and their home environment. Urban Ecosyst. 15(1):19–52. doi:10.1007/s11252-011-0197-0.

Cuddington K. 2011. Legacy effects: the persistent impact of ecological interactions. Biol Theory. 6(3):203–210. doi:10.1007/s13752-012-0027-5.

Daugstad K. 2019. Resilience in mountain farming in Norway. Sustainability. 11(12):3476. doi:10.3390/su11123476.

Dearing JA, Wang R, Zhang K, Dyke JG, Haberl H, Hossain MS, Langdon PG, Lenton TM, Raworth K, Brown S, et al. 2014. Safe and just operating spaces for regional social-ecological systems. Glob Environ Change. 28:227–238. doi:10.1016/j.gloenvcha.2014.06.012.

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, et al. 2015. The IPBES conceptual framework — connecting nature and people. Curr Opin Environ Sustain. 14:1–16. doi:10.1016/j.cosust.2014.11.002.

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, et al. 2018. Assessing nature's contributions to people. Science. 359(6373):270–272. doi:10.1126/science.aap8826.

Eakin H, Rueda X, Mahanti A. 2017. Transforming governance in telecoupled food systems. Ecol Soc. 22(4). doi:10.5751/ES-09831-220432. [accessed 2021 Mar 1]. https://www.ecologyandsociety.org/vol22/iss4/art32/.

EC (European Commission-DIRECTORATE-GENERAL FOR AGRICULTURE AND RURAL DEVELOPMENT). 2009. Peak performance - New insights into mountain farming in the European Union.

Edens B, Hein L. 2013. Towards a consistent approach for ecosystem accounting. Ecol Econ. 90:41–52. doi:10.1016/j.ecolecon.2013.03.003.

Egarter Vigl L, Schirpke U, Tasser E, Tappeiner U. 2016. Linking long-term landscape dynamics to the multiple interactions among ecosystem services in the European Alps. Landsc Ecol. 31(9):1903–1918. doi:10.1007/s10980-016-0389-3.

Erb K-H, Haberl H, Jepsen MR, Kuemmerle T, Lindner M, Müller D, Verburg PH, Reenberg A. 2013. A conceptual framework for analysing and measuring land-use intensity. Curr Opin Environ Sustain. 5(5):464–470. doi:10.1016/j.cosust.2013.07.010.

Ernstson H. 2013. The social production of ecosystem services: a framework for studying environmental justice and ecological complexity in urbanized landscapes. Landsc Urban Plan. 109(1):7–17. doi:10.1016/j.landurbplan.2012.10.005.

Essl F, Dullinger S, Rabitsch W, Hulme PE, Pyšek P, Wilson JRU, Richardson DM. 2015. Historical legacies accumulate to shape future biodiversity in an era of rapid global change. Kueffer C, editor. Divers Distrib. 21(5):534–547. doi:10.1111/ddi.12312.

Europarc F. 2018. European protected areas & sustainable agriculture working in partnership for biodiversity and rural development. [accessed 2021 Apr 7]. https://www.europarc.org/news/2018/03/position-paper-sustainable-agriculture/.

Fedele G, Locatelli B, Djoudi H. 2017. Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst Serv. 28:43–54. doi:10.1016/j.ecoser.2017.09.011.

Feranec J, Soukup T, Feranec G, Jaffrain G, editors. 2016. European landscape dynamics: CORINE land cover data. 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742: CRC Press. [accessed 2021 Apr 7]. http://www.crcnetbase.com/doi/book/10.1201/9781315372860.

Fischer A, Eastwood A. 2016. Coproduction of ecosystem services as human–nature interactions—An analytical framework. Land Use Policy. 52:41–50. doi:10.1016/j.landusepol.2015.12.004.

Flury C, Huber R, Tasser E. 2013. Future of mountain agriculture in the Alps. In: Mann S, editor. The Future of Mountain Agriculture. Berlin, Heidelberg: Springer Berlin Heidelberg. p. 105–126. [accessed 2020 Oct 8]. http://link.springer.com/10.1007/978-3-642-33584-6_8.

Folke C. 2006. Resilience: the emergence of a perspective for social–ecological systems analyses. Glob Environ Change. 16(3):253–267. doi:10.1016/j.gloenvcha.2006.04.002.

Foster D, Swanson F, Aber J, Burke I, Brokaw N, Tilman D, Knapp A. 2003. The importance of land-use legacies to ecology and conservation. BioScience. 53(1):77. doi:10.1641/0006-3568(2003)053[0077:TIOLUL]2.0.CO;2.

Garcia-Pausas J, Romanyà J, Montané F, Rios AI, Taull M, Rovira P, Casals P. 2017. Are soil carbon stocks in mountain grasslands compromised by land-use changes? In: Catalan J, Ninot

JM, Aniz MM, editors. High Mountain Conservation in a Changing World. Vol. 62. Cham: Springer International Publishing. p. 207–230. [accessed 2020 Nov 4]. http://link.springer.com/10.1007/978-3-319-55982-7_9.

von Glasenapp M, Thornton TF. 2011. Traditional ecological knowledge of Swiss Alpine farmers and their resilience to socioecological Change. Hum Ecol. 39(6):769–781. doi:10.1007/s10745-011-9427-6.

Guerry AD, Polasky S, Lubchenco J, Chaplin-Kramer R, Daily GC, Griffin R, Ruckelshaus M, Bateman IJ, Duraiappah A, Elmqvist T, et al. 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proc Natl Acad Sci. 112(24):7348–7355. doi:10.1073/pnas.1503751112.

Haberl H, Erb KH, Krausmann F, Gaube V, Bondeau A, Plutzar C, Gingrich S, Lucht W, Fischer-Kowalski M. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proc Natl Acad Sci. 104(31):12942–12947. doi:10.1073/pnas.0704243104.

Haines-Young R, Potschin M. 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli DG, Frid CLJ, editors. Ecosystem Ecology. Cambridge: Cambridge University Press. p. 110–139. [accessed 2021 Jan 18]. https://www.cambridge.org/core/product/identifier/CBO9780511750458A013/type/book_part.

Hanspach J, Loos J, Dorresteijn I, Abson DJ, Fischer J. 2016. Characterizing social-ecological units to inform biodiversity conservation in cultural landscapes. Di Minin E, editor. Divers Distrib. 22(8):853–864. doi:10.1111/ddi.12449.

Hernández-Morcillo M, Hoberg J, Oteros-Rozas E, Plieninger T, Gómez-Baggethun E, Reyes-García V. 2014. Traditional ecological knowledge in Europe: status quo and insights for the environmental policy agenda. Environ Sci Policy Sustain Dev. 56(1):3–17. doi:10.1080/00139157.2014.861673.

Herrero-Jáuregui C, Arnaiz-Schmitz C, Reyes M, Telesnicki M, Agramonte I, Easdale M, Schmitz M, Aguiar M, Gómez-Sal A, Montes C. 2018. What do we talk about when we talk about social-ecological systems? A literature review. Sustainability. 10(8):2950. doi:10.3390/su10082950.

Hinojosa L, Lambin EF, Mzoughi N, Napoléone C. 2016. Place attachment as a factor of mountain farming permanence: a survey in the French Southern Alps. Ecol Econ. 130:308–315. doi:10.1016/j.ecolecon.2016.08.004.

Hull V, Liu J. 2018. Telecoupling: a new frontier for global sustainability. Ecol Soc. 23(4). doi:10.5751/ES-10494-230441. [accessed 2021 Mar 1]. https://www.ecologyandsociety.org/vol23/iss4/art41/.

Hysing E, Lidskog R. 2021. Do conceptual innovations facilitate transformative change? The case of biodiversity governance. Front Ecol Evol. 8. doi:10.3389/fevo.2020.612211. [accessed 2021 Apr 18]. https://www.frontiersin.org/articles/10.3389/fevo.2020.612211/full.

INAO (Institut national de l'origine et de la qualité). 2015. Cahier des charges de l'appellation d'origine « Beaufort ».

Jäger H, Peratoner G, Tappeiner U, Tasser E. 2020. Grassland biomass balance in the European Alps: current and future ecosystem service perspectives. Ecosyst Serv. 45:101163. doi:10.1016/j.ecoser.2020.101163.

Jones L, Norton L, Austin Z, Browne AL, Donovan D, Emmett BA, Grabowski Z., Howard DC, Jones JPG, Kenter J., et al. 2016. Stocks and flows of natural and human-derived capital in ecosystem services. Land Use Policy. 52:151–162. doi:10.1016/j.landusepol.2015.12.014.

Kim G, Vaswani RT, Lee D. 2017. Social-ecological memory in an autobiographical novel: ecoliteracy, place attachment, and identity related to the Korean traditional village landscape. Ecol Soc. 22(2). doi:10.5751/ES-09284-220227. [accessed 2021 Mar 24]. https://www.ecologyandsociety.org/vol22/iss2/art27/.

Kofinas GP, Chapin FS. 2009. Sustaining livelihoods and human well-being during social-ecological change. In: Folke C, Kofinas GP, Chapin FS, editors. Principles of Ecosystem Stewardship. New York, NY: Springer New York. p. 55–75. [accessed 2021 Mar 23]. http://link.springer.com/10.1007/978-0-387-73033-2_3.

Koohafkan P, Altieri MA. 2011. Globally important agricultural heritage systems: a legacy for the future. Food and Agriculture Organization of the United Nations Rome.

Lamarque P, Lambin EF. 2015. The effectiveness of marked-based instruments to foster the conservation of extensive land use: The case of Geographical Indications in the French Alps. Land Use Policy. 42:706–717. doi:10.1016/j.landusepol.2014.10.009.

Lamine C, Magda D, Amiot M-J. 2019. Crossing sociological, ecological, and nutritional perspectives on agrifood systems transitions: towards a transdisciplinary territorial approach. Sustainability. 11(5):1284. doi:10.3390/su11051284.

Lavorel S, Locatelli B, Colloff MJ, Bruley E. 2020. Co-producing ecosystem services for adapting to climate change. Philos Trans R Soc B Biol Sci. 375(1794):20190119. doi:10.1098/rstb.2019.0119.

Le Noë J, Roux N, Billen G, Gingrich S, Erb K-H, Krausmann F, Thieu V, Silvestre M, Garnier J. 2020. The phosphorus legacy offers opportunities for agro-ecological transition (France 1850–2075). Environ Res Lett. 15(6):064022. doi:10.1088/1748-9326/ab82cc.

Lescourret F, Magda D, Richard G, Adam-Blondon A-F, Bardy M, Baudry J, Doussan I, Dumont B, Lefèvre F, Litrico I, et al. 2015. A social–ecological approach to managing multiple agro-ecosystem services. Curr Opin Environ Sustain. 14:68–75. doi:10.1016/j.cosust.2015.04.001.

Lynch E, Harvois F. 2016. Le Beaufort: réinventer le fruit commun. Lyon: Libel.

Madelrieux S, Bergeret A, Fillion L. 2018. Forms of territorial embeddedness in dairy value chains- Case of the Chartreuse massif (French Alps): geographical and historical perspectives. Open Agric. 3(1):618–631. doi:10.1515/opag-2018-0065.

Marescotti A, Quiñones-Ruiz XF, Edelmann H, Belletti G, Broscha K, Altenbuchner C, Penker M, Scaramuzzi S. 2020. Are protected geographical indications evolving due to environmentally related justifications? An analysis of amendments in the fruit and vegetable sector in the European Union. Sustainability. 12(9):3571. doi:10.3390/su12093571.

Martín-López B, Palomo I, García-Llorente M, Iniesta-Arandia I, Castro AJ, García Del Amo D, Gómez-Baggethun E, Montes C. 2017. Delineating boundaries of social-ecological systems for landscape planning: a comprehensive spatial approach. Land Use Policy. 66:90–104. doi:10.1016/j.landusepol.2017.04.040.

Mastrángelo ME, Pérez-Harguindeguy N, Enrico L, Bennett E, Lavorel S, Cumming GS, Abeygunawardane D, Amarilla LD, Burkhard B, Egoh BN, et al. 2019. Key knowledge gaps to achieve global sustainability goals. Nat Sustain. 2(12):1115–1121. doi:10.1038/s41893-019-0412-1.

McGinnis MD. 2011. An introduction to IAD and the language of the Ostrom workshop: A simple guide to a complex framework. Policy Stud J. 39(1):169–183. doi:10.1111/j.1541-0072.2010.00401.x.

McGinnis MD, Ostrom E. 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol Soc. 19(2). doi:10.5751/ES-06387-190230. [accessed 2020 Oct 23]. http://www.ecologyandsociety.org/vol19/iss2/art30/.

MEA MEA (Porgram). 2005. Ecosystems and human well-being. Washington, D.C: Island Press.

Meyfroidt P, Roy Chowdhury R, de Bremond A, Ellis EC, Erb K-H, Filatova T, Garrett RD, Grove JM, Heinimann A, Kuemmerle T, et al. 2018. Middle-range theories of land system change. Glob Environ Change. 53:52–67. doi:10.1016/j.gloenvcha.2018.08.006.

Mudge PL, Millar J, Pronger J, Roulston A, Penny V, Fraser S, Eger A, Caspari T, Robertson B, Mason NWH, et al. 2021. Impacts of irrigation on soil C and N stocks in grazed grasslands depends on aridity and irrigation duration. Geoderma. 399:115109. doi:10.1016/j.geoderma.2021.115109.

Muhar A, Raymond CM, van den Born RJG, Bauer N, Böck K, Braito M, Buijs A, Flint C, de Groot WT, Ives CD, et al. 2018. A model integrating social-cultural concepts of nature into frameworks of interaction between social and natural systems. J Environ Plan Manag. 61(5–6):756–777. doi:10.1080/09640568.2017.1327424.

Oppermann R, Beaufoy G, Jones G. 2012. High nature value farming in Europe. Ubstadt-Weiher: verlag regionalkultur.

Ostrom E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge ; New York: Cambridge University Press (The Political economy of institutions and decisions).

Ostrom E. 2000. Collective action and the evolution of social norms. J Econ Perspect Vol 14 No 3.:37–158.

Ostrom E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science. 325(5939):419–422. doi:10.1126/science.1172133.

Oteros-Rozas E, Ontillera-Sánchez R, Sanosa P, Gómez-Baggethun E, Reyes-García V, González JA. 2013. Traditional ecological knowledge among transhumant pastoralists in Mediterranean Spain. Ecol Soc. 18(3). doi:10.5751/ES-05597-180333. [accessed 2020 Nov 23]. http://www.ecologyandsociety.org/vol18/iss3/art33/.

Outeiro L, Ojea E, Garcia Rodrigues J, Himes-Cornell A, Belgrano A, Liu Y, Cabecinha E, Pita C, Macho G, Villasante S. 2017. The role of non-natural capital in the co-production of marine ecosystem services. Int J Biodivers Sci Ecosyst Serv Manag. 13(3):35–50. doi:10.1080/21513732.2017.1415973.

Pachoud C. 2019. Identity, feeling of belonging and collective action in localized agrifood systems. Example of the Serrano cheese in the Campos de Cima da Serra, Brazil. Cah Agric. 28:28. doi:10.1051/cagri/2019028.

Pachoud C, Delay E, Da Re R, Ramanzin M, Sturaro E. 2020. A relational approach to studying collective action in dairy cooperatives producing mountain cheeses in the Alps: the case of the Primiero cooperative in the Eastern Italians Alps. Sustainability. 12(11):4596. doi:10.3390/su12114596.

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U. 2016. Disentangling the pathways and effects of ecosystem service co-production. In: Advances in Ecological Research. Vol. 54. Elsevier. p. 245–283. [accessed 2020 Aug 25]. https://linkinghub.elsevier.com/retrieve/pii/S0065250415000276.

Pascual U, Adams WM, Díaz S, Lele S, Mace GM, Turnhout E. 2021 Mar 25. Biodiversity and the challenge of pluralism. Nat Sustain. doi:10.1038/s41893-021-00694-7. [accessed 2021 Apr 21]. http://www.nature.com/articles/s41893-021-00694-7.

Plieninger T, Kizos T, Bieling C, Le Dû-Blayo L, Budniok M-A, Bürgi M, Crumley CL, Girod G, Howard P, Kolen J, et al. 2015. Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. Ecol Soc. 20(2). doi:10.5751/ES-07443-200205. [accessed 2020 Oct 16]. http://www.ecologyandsociety.org/vol20/iss2/art5/.

Plutzar C, Kroisleitner C, Haberl H, Fetzel T, Bulgheroni C, Beringer T, Hostert P, Kastner T, Kuemmerle T, Lauk C, et al. 2016. Changes in the spatial patterns of human appropriation of net primary production (HANPP) in Europe 1990–2006. Reg Environ Change. 16(5):1225–1238. doi:10.1007/s10113-015-0820-3.

Potschin-Young M, Haines-Young R, Görg C, Heink U, Jax K, Schleyer C. 2018. Understanding the role of conceptual frameworks: reading the ecosystem service cascade. Ecosyst Serv. 29:428–440. doi:10.1016/j.ecoser.2017.05.015.

Price B, Kaim D, Szwagrzyk M, Ostapowicz K, Kolecka N, Schmatz DR, Wypych A, Kozak J. 2017. Legacies, socio-economic and biophysical processes and drivers: the case of future forest cover expansion in the Polish Carpathians and Swiss Alps. Reg Environ Change. 17(8):2279–2291. doi:10.1007/s10113-016-1079-z.

QSR International. 2020. NVIVO (released in March 2020). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home.

Quétier F, Rivoal F, Marty P, de Chazal J, Thuiller W, Lavorel S. 2010. Social representations of an Alpine grassland landscape and socio-political discourses on rural development. Reg Environ Change. 10(2):119–130. doi:10.1007/s10113-009-0099-3.

Quétier F, Thébault A, Lavorel S. 2007. Plant traits in a state and transition framework as markers of ecosystem response to land-use change. Ecol Monogr. 77(1):33–52. doi:10.1890/06-0054.

Quiñones Ruiz XF, Forster H, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Broscha K, Braito M, Altenbuchner C. 2018. How are food Geographical Indications evolving? – An analysis of EU GI amendments. Br Food J. 120(8):1876–1887. doi:10.1108/BFJ-02-2018-0087.

Rac I, Juvančič L, Erjavec E. 2020. Stimulating collective action to preserve high nature value farming in post-transitional settings. A comparative analysis of three Slovenian social-ecological systems. Nat Conserv. 39:87–111. doi:10.3897/natureconservation.39.51216.

Remme RP, Schröter M, Hein L. 2014. Developing spatial biophysical accounting for multiple ecosystem services. Ecosyst Serv. 10:6–18. doi:10.1016/j.ecoser.2014.07.006.

Renard D, Rhemtulla JM, Bennett EM. 2015. Historical dynamics in ecosystem service bundles. Proc Natl Acad Sci. 112(43):13411–13416. doi:10.1073/pnas.1502565112.

Reyers B, Biggs R, Cumming GS, Elmqvist T, Hejnowicz AP, Polasky S. 2013. Getting the measure of ecosystem services: a social–ecological approach. Front Ecol Environ. 11(5):268–273. doi:10.1890/120144.

RGDSMB R de G des données SMB. 2014. Mise à jour des données d'occupation réelle des sols sur les départements de Savoie et Haute Savoie. https://www.rgd.fr.

Riechers M, Balázsi Á, Betz L, Jiren TS, Fischer J. 2020. The erosion of relational values resulting from landscape simplification. Landsc Ecol. 35(11):2601–2612. doi:10.1007/s10980-020-01012-w.

van Riper CJ, Thiel A, Penker M, Braito M, Landon AC, Thomsen JM, Tucker CM. 2018. Incorporating multilevel values into the social-ecological systems framework. Ecol Soc. 23(3). doi:10.5751/ES-10047-230325. [accessed 2020 Oct 12]. https://www.ecologyandsociety.org/vol23/iss3/art25/.

Santini F, Guri F, Aubard A, Gomez y Paloma S. 2015. Geographical indications and territories with specific geographical features in the eu: the cases of mountain and island areas. Pap Prep 145th EAAE Semin "Intellectual Prop Rights Geogr Indic What Stake TTIP."

Schoch M. 2013. Etude prospective coopérative de la Chambre- Etat des lieux.

Schoch M. 2014. Etude prospective coopérative de la Vallée des Arves- Etat des lieux.

Schröter M, Başak E, Christie M, Church A, Keune H, Osipova E, Oteros-Rozas E, Sievers-Glotzbach S, van Oudenhoven APE, Balvanera P, et al. 2020. Indicators for relational values of nature's contributions to good quality of life: the IPBES approach for Europe and Central Asia. Ecosyst People. 16(1):50–69. doi:10.1080/26395916.2019.1703039.

Schulz C, Martin-Ortega J. 2018. Quantifying relational values — Why not? Curr Opin Environ Sustain. 35:15–21. doi:10.1016/j.cosust.2018.10.015.

Spangenberg JH, Görg C, Truong DT, Tekken V, Bustamante JV, Settele J. 2014. Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manag. 10(1):40–53. doi:10.1080/21513732.2014.884166.

Spiegelberger T, Hegg O, Matthies D, Hedlund K, Schaffner U. 2006. Long-term effects of short-term perturbation in a subalpine grassland. Ecology. 87(8):1939–1944. doi:10.1890/0012-9658(2006)87[1939:LEOSPI]2.0.CO;2.

SPM (Syndicat du pays de Maurienne). 2020. Schéma de cohèrence territoriale.

Tengberg A, Fredholm S, Eliasson I, Knez I, Saltzman K, Wetterberg O. 2012. Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. Ecosyst Serv. 2:14–26. doi:10.1016/j.ecoser.2012.07.006.

Upton C. 2008. Social capital, collective action and group formation: developmental trajectories in post-socialist Mongolia. Hum Ecol. 36(2):175–188. doi:10.1007/s10745-007-9158-x.

Vallet A, Locatelli B, Levrel H, Dendoncker N, Barnaud C, Quispe Conde Y. 2019. Linking equity, power, and stakeholders’ roles in relation to ecosystem services. Ecol Soc. 24(2). doi:10.5751/ES-10904-240214. [accessed 2020 Aug 25]. https://www.ecologyandsociety.org/vol24/iss2/art14/.

Vanpeene-Bruhier S, Moyne M-L, Brun J-J. 1998. La richesse spécifique : un outil pour la prise en compte de la biodiversité dans la gestion de l'espace - Application en Haute Maurienne (Aussois, Savoie). :47–59.

Vilá B, Arzamendia Y. 2020 Oct 26. South American camelids: their values and contributions to people. Sustain Sci. doi:10.1007/s11625-020-00874-y. [accessed 2021 Apr 6]. http://link.springer.com/10.1007/s11625-020-00874-y.

Walker B, Carpenter SR, Anderies JM, Abel N, Cumming G, Janssen MA, Lebel L, Norberg J, Peterson GD, Pritchard R. 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conserv Ecol. 6(1). doi:10.5751/ES-00356-060114. [accessed 2021 Feb 11]. http://www.ecologyandsociety.org/vol6/iss1/art14/.

Walker B, Gunderson L, Kinzig A, Folke C, Carpenter S, Schultz L. 2006. A handful of heuristics and some propositions for understanding resilience in social-ecological systems. Ecol Soc. 11(1). doi:10.5751/ES-01530-110113. [accessed 2021 Feb 10]. http://www.ecologyandsociety.org/vol11/iss1/art13/.

Waylen KA, Blackstock KL, Holstead KL. 2015. How does legacy create sticking points for environmental management? Insights from challenges to implementation of the ecosystem approach. Ecol Soc. 20(2). doi:10.5751/ES-07594-200221. [accessed 2020 Nov 9]. http://www.ecologyandsociety.org/vol20/iss2/art21/.

Winkler KJ, Dade MC, Rieb JT. 2021 Mar 16. Mismatches in the ecosystem services literature—a review of spatial, temporal, and functional-conceptual mismatches. Curr Landsc Ecol Rep. doi:10.1007/s40823-021-00063-2. [accessed 2021 Mar 25]. http://link.springer.com/10.1007/s40823-021-00063-2.

Winner L. 1980. Do artifacts have politics? In: Marchant GE, Wallach W, editors. Emerging Technologies: Ethics, Law and Governance. 1st ed. Routledge. p. 15–30. [accessed 2021 Mar 23]. https://www.taylorfrancis.com/books/9781000108927/chapters/10.4324/9781003074960-3.

Wu X, Wei Y, Fu B, Wang S, Zhao Y, Moran EF. 2020. Evolution and effects of the social-ecological system over a millennium in China's Loess plateau. Sci Adv. 6(41):eabc0276. doi:10.1126/sciadv.abc0276.

Annexes

- Supplementary materials 1 Overview and reasoning of indictors
- Supplementary materials 2 Conducted interviews

Supplementary materials 1 Indicators

Resource categories	Social subsystem	Examples of variables	Reasoning *	Ecosystem	Example of variables	Reasoning
Social-ecological legacies	**Common Values*** .	% of regional breeds of total livestock	The maintenance of regional breeds can indicate the willingness to maintain traditional farming structures. Research also suggests that regional breeds are more prevalent in small-scale agricultural holdings such as mountain farming systems (Hiemstra et al. 2010; Battaglini et al. 2014).	**Genetic information**	Taxon richness of grassland (in nr.)	Species richness in European mountain areas can serve as a rough approximate average value for biodiversity (Väre et al. 2003). We used a case study that measured plant diversity in pastures with varying management intensity between 1300-2000 m altitude (Vanpeene-Bruhier, Moyne, and Brun 1998).
		% local fodder of total fodder	This farm management practice can reflect common perceptions and readiness to maintain traditional farming practices (EC 2017; van den Pol-van Dasselaar, Hennessy, and Isselstein 2020).			

		Mean farm size	We suggest that smaller farm size can reflect the maintenance of farming traditions.			
	Traditional ecological knowledge* .	Grazing or harvest dates and duration (days) adjusted to interannual climate variability	This indicator underlines that traditional ecological knowledge is constantly evolving and shaped by ecological and social circumstances. For example grazing duration can favour higher quantity of biomass or different grass composition (von Glasenapp and Thornton 2011)	**Agricultural landscape**	Grassland cover	The extent of grassland cover can reflect a social-ecological legacy in cultural landscape such as mountain areas (Foster et al. 2003)
	Physical infrastructure .	Travel time to transformation facility	Local proximity to transformation saves time for farmers, can foster social relations and it can facilitate the maintenance of agricultural production system (Madelrieux, Bergeret, and Fillion 2018; Pachoud et al. 2020) .	**Amount of carbon stored in above and below ground biomass** .	Carbon stock	We used carbon stocks as a widely available proxy (2b) (Teillard et al. 2016). Soils hold material legacies of the ecological system that are particularly important to livestock production. Pastoral management practices are important drivers of the amount of nutrients in the soil of mountain pastures (Pittarello et al. 2020).
Current resources	**Activity attachment** .	Change in producer between 2012 and 2019	We suggest that quantitative changes of farmers can indicate changing activity attachments of farmers on a regional level.	**Ecosystem productivity**	Biomass production in grassland areas	Biomass production in mountain areas is mainly governed by the ecological subsystem (growing season length, elevation,location of climate zone) and social factors (Jäger et al. 2020; Haberl et al. 2007)

	Place attachment	Change in utilised agricultural area between 1988-2010	This indicator can show agricultural decline and associated impacts on the cultural landscape (e.g. changes in biodiversity) (Teillard et al. 2016).	**Biomass production**	Fodder harvest	Fodder harvest can indicate potential mismatches between biomass productivity and fodder demand. However, a detailed analysis was beyond the scope of this illustrative case study. Information on fodder harvest for the Maurienne was based on a feasibility study about irrigation from the local department of the Agricultural chamber (Clavel 2013). These results are in line with comparable case studies in French mountains (Graux et al. 2020; Grigulis and Lavorel 2020).
	Labour	Labour force unit (LFU)/holding	This is a common indicator to measure labour force in agricultural production in agronomic studies at various scales (van Ittersum et al. 2008; Erb et al. 2013).	**Livestock density**	Livestock Unit (LSU)/ha	This indicator can reflect agricultural practices (Lebacq, Baret, and Stilmant 2013). In the context of mountain farming, this indicator can vary considerable due to biophysical constraints.
	Technology Production factor for agricultural products	Irrigated surface of total agricultural surface	Irrigation serves here as a proxy-indicator for technology. Biophysical constraints can limit some other intensification strategies (e.g. mechanization) in mountain farming(Flury, Huber, and Tasser 2013).			

Table 1: Overview about the different indicators along the NCP co-production chain

Supplementary Materials 2 Conducted Interviews

Table 1: Overview of conducted interviews with the corresponding actors' characteristics

Socio demo	Age group	Type	Gender
Int. 1	>62	Farmer	M
Int. 2	36- 45	Employee	M
Int. 3	18-35	Employee	F
Int. 4	46-55	Employee	F
Int. 5	36- 45	Farmer	F
Int. 6	18-35	Farmer	F
Int. 7	56-62	Farmer	M
Int. 8	56-62	Farmer	F
Int. 9	36- 45	Farmer	M
Int. 10	46-55	Farmer	M
Int. 11	36- 45	Farmer	M
Int. 12	18-35	Farmer	M
Int. 13	36- 45	Employee	M
Int. 14	56-62	Farmer	M
Int. 15	36- 45	Farmer	M
Int. 16	>62	Farmer	M
Int. 17	56-62	Employee	F
Int. 18	>62	Time witness	M
Int. 19	>62	Time witness	M
Int. 20	>62	Time witness	M

Supplementary Materials 3: Interview guide

First part: Interviewee/institution presentation

1. Could you present yourself, your profession and your background?

2. Could you present your institution and the history of your institution?

1. What is the main activity of your institution in relation to the agricultural sector in the Maurienne?

2. How many people are working in your institution?

3. How many members are affiliated to/controlled by your institution?

Second part: interactions with other actors

4. Who are the other actors you are working with?

5. Do you have relations to …. (name of different institutions)

6. Who is in your mind the most powerful (in terms of decision-making) actor in the agricultural sector of the Maurienne?

7. Who is in your mind the most competent (knowledge) actor in the agricultural sector in the Maurienne?

8. With whom would you like to work more together?

Third part: Describing the agricultural sector in the Maurienne valley

9. How do you describe the agricultural sector in the Maurienne?

10. What are the challenges of the agricultural sector in the Maurienne?

11. How do you see agriculture in the Maurienne in 2050?

12. Do you think that climate change will have an impact on the agricultural sector?

Fourth part: Co-production activities

13. How to you intervene in the management of pasture land?

14. Can you describe the milking process in summer and in winter? How long does it take you?

15. How many hours are you working per week?

16. What is your motivations?

17. What would you improve if you could?

18. What do you think about the specification requirements of Beaufort cheese?

References for Supplementary Materials

Battaglini, L., Bovolenta, S., Gusmeroli, F., Salvador, S., and Sturaro, E. (2014). Environmental sustainability of Alpine livestock farms. Ital. J. Anim. Sci. 13, 3155.

Clavel, C. (2013). L'irrigation aujourd'hui (Aussois).

EC, E.C.-D.-G. for H. and F.S. (2017). Welfare of cattle on dairy farms: overview report.

Erb, K.-H., Haberl, H., Jepsen, M.R., Kuemmerle, T., Lindner, M., Müller, D., Verburg, P.H., and Reenberg, A. (2013). A conceptual framework for analysing and measuring land-use intensity. Curr. Opin. Environ. Sustain. 5, 464–470.

Flury, C., Huber, R., and Tasser, E. (2013). Future of mountain agriculture in the Alps. In The Future of Mountain Agriculture, S. Mann, ed. (Berlin, Heidelberg: Springer Berlin Heidelberg), pp. 105–126.

Foster, D., Swanson, F., Aber, J., Burke, I., Brokaw, N., Tilman, D., and Knapp, A. (2003). The importance of land-use legacies to ecology and conservation. BioScience 53, 77.

von Glasenapp, M., and Thornton, T.F. (2011). Traditional ecological knowledge of Swiss Alpine farmers and their resilience to socioecological Change. Hum. Ecol. 39, 769–781.

Graux, A.-I., Resmond, R., Casellas, E., Delaby, L., Faverdin, P., Le Bas, C., Ripoche, D., Ruget, F., Thérond, O., Vertès, F., et al. (2020). High-resolution assessment of French grassland dry matter and nitrogen yields. Eur. J. Agron. 112, 125952.

Grigulis, K., and Lavorel, S. (2020). Simple field-based surveys reveal climate-related anomalies in mountain grassland production. Ecol. Indic. 116, 106519.

Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., and Fischer-Kowalski, M. (2007). Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proc. Natl. Acad. Sci. 104, 12942–12947.

Hiemstra, S.; de Hass, Y., Maeki-Tanila, A., Gandini, G. (2010). Local cattle breeds in Europe: development of policies and strategies for self-sustaining breeds (The Netherlands: Wageningen Academic Publishers).

van Ittersum, M.K., Ewert, F., Heckelei, T., Wery, J., Alkan Olsson, J., Andersen, E., Bezlepkina, I., Brouwer, F., Donatelli, M., Flichman, G., et al. (2008). Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS). Agric. Syst. 96, 150–165.

Jäger, H., Peratoner, G., Tappeiner, U., and Tasser, E. (2020). Grassland biomass balance in the European Alps: current and future ecosystem service perspectives. Ecosyst. Serv. 45, 101163.

Lebacq, T., Baret, P.V., and Stilmant, D. (2013). Sustainability indicators for livestock farming. A review. Agron. Sustain. Dev. 33, 311–327.

Madelrieux, S., Bergeret, A., and Fillion, L. (2018). Forms of territorial embeddedness in dairy value chains- Case of the Chartreuse massif (French Alps): geographical and historical perspectives. Open Agric. 3, 618–631.

Pachoud, C., Delay, E., Da Re, R., Ramanzin, M., and Sturaro, E. (2020). A relational approach to studying collective action in dairy cooperatives producing mountain cheeses in the Alps: the case of the Primiero cooperative in the Eastern Italians Alps. Sustainability 12, 4596.

Pittarello, M., Lonati, M., Ravetto Enri, S., and Lombardi, G. (2020). Environmental factors and management intensity affect in different ways plant diversity and pastoral value of Alpine pastures. Ecol. Indic. 115, 106429.

van den Pol-van Dasselaar, A., Hennessy, D., and Isselstein, J. (2020). Grazing of dairy cows in Europe—An in-depth analysis based on the perception of grassland experts. Sustainability 12, 1098.

Teillard, F., Assumpcio, A., Dumont, B., Finn, J.A., Henry, B.., de Souza, D.M., Manzano, P., Mila i Canals, L., Phelps, C., Said, M., et al. (2016). A review of indicators and methods to assess biodiversity: application to livestock production at global scale- Livestock Environmental Assessment and Performance (LEAP) Partnership.

Vanpeene-Bruhier, S., Moyne, M.-L., and Brun, J.-J. (1998). La richesse spécifique : un outil pour la prise en compte de la biodiversité dans la gestion de l’espace - Application en Haute Maurienne (Aussois, Savoie). 47–59.

Väre, H., Lampinen, R., Humphries, C., and Williams, P. (2003). Taxonomic diversity of vascular plants in the European Alpine areas. In Alpine Biodiversity in Europe, L. Nagy, G. Grabherr, C. Körner, and D.B.A. Thompson, eds. (Berlin, Heidelberg: Springer Berlin Heidelberg), pp. 133–148.

Chapter IV- Applying collective capabilities to understand the co-production of nature's contributions to people

Most of the Beaufort production takes place within collective structures (credits: l'Atelier S.Madelon/SDB)

Based on the conceptual framework (see Chapter III), we focused in this chapter on social dynamics, which we identified as a major component for the functioning of social-ecological systems at territorial scale. Based on the main scientific objective of this chapter: "What is the role of collective capabilities in NCP co-production?" we specifically questioned:

- Who are the actors of involved in the Alpine agricultural system?
- Which and how co-production activities generate collective capabilities?
- How do collective capabilities contribute to local identities

We found that a number of actors within and outside of the Beaufort production systems generate collective capabilities by different types of social capital along the NCP co-production chain. Our approach underlined the importance of relational values emphasized by dimensions of local identities that are generated along these co-production activities. This allows an otherwise non-competitive agricultural system to maintain its production and the associated options for actors to freely choose a life they have reason to value. We found that the integration of collective capabilities in NCP co-production can uncover the subtle relational values of people in social-ecological interactions at territorial scale.

Grosinger, J.; Vallet, A.; Palomo, I., Buclet, N.; Lavorel S. Collective capabilities shape the co-production of nature´s contributions to people in the Alpine agricultural system of the Maurienne valley, France. Regional Environmental Change (accepted)

How collective capabilities shape local identities and the co-production of nature´s contributions to people in an Alpine agricultural system: the Maurienne valley, France

Grosinger Julia[1,2], Vallet Améline[3,4], Palomo Ignacio[2], Buclet Nicolas[1], Lavorel Sandra[2,5]

Submitted to *Regional Environmental Change*: in review

[1]Université Grenoble Alpes, CNRS, Sciences Po Grenoble, PACTE, 38000 Grenoble, France
[2] Laboratoire d'Ecologie Alpine, CNRS – Université Grenoble Alpes – Université Savoie Mont-Blanc, 38000 Grenoble, France
[3] Ecologie Systématique Evolution, AgroParisTech, CNRS, Université Paris-Sud, Université Paris-Saclay, Orsay, France
[4] CIRED, AgroParisTech, Cirad, CNRS, EHESS, Ecole Des Ponts ParisTech, Université Paris-Saclay, Nogent-Sur-Marne, France
[5] Manaaki Whenua Landcare Research, Lincoln, New Zealand

Abstract

Nature' Contributions to People (NCP) do not flow automatically from ecosystems to society, but they result from a co-production process of interactions between social and ecological systems. In this study we focussed on the social dimensions of NCP co-production by using the collective capabilities approach. These are the benefits collective structures retrieve from social-ecological interactions that individuals could not have achieved on their own and which frequently exceed pure instrumental values. Collective structures mobilise different types of social capitals in order to generate these collective capabilities. Here, we specifically investigated linkages between collective capabilities and their contributions to common perceptions and local identities. We conducted 44 semi-structured interviews with two distinct different actors' groups in a French Alpine agricultural system surrounding the production of the quality labelled Beaufort cow cheese. We analysed the interviews qualitatively, and conducted quantitative analyses as well as content and sentiment analysis to identify the different levels and types of collective investment mobilized by actors to generate collective capabilities. We found that collective capabilities via NCP co-production contributed to common perceptions and to specific dimensions of local identities by relational values construction. Further, the analysis suggests that collective capability relies on dense social interactions between actors that contribute to a good quality of life in itself. This study advances previous attempts to further investigate the role of intra-social relations for NCP co-production.

Key words: Nature's contributions to People (NCP), collective capabilities, local identities, common perceptions, co-production

1. Introduction

Ecosystems contribute to the multiple facets of people's good quality of life (Russell et al. 2013; Bratman et al. 2019). Nature's contributions to people (NCP) are subjective, and highly context-dependent, and the understanding of their intricate material and non-material dimensions stands out as an enduring knowledge gap in social-ecological science (Díaz et al. 2018; Mastrángelo et al. 2019). The various dimensions of a good quality of life supported by nature relate to the satisfaction of human needs, including material NCP like food and shelter, and often highly subjective non-material NCP like belonging or identity (Max-Neef et al. 1989; Sen 2000). Therefore, a good quality of life is not exclusively quantified by material outcomes but also "on one's ability to choose the life one has reason to value" (Sen 2000), including in relation to others, as sense of place, belonging, identity are intrinsically collective. This is crucial to understand the complex choices people make, like trade-offs between dimensions of a good quality of life to align with their values (e.g. lower salary vs. more leisure time).

Recent conceptual frameworks representing social-ecological interactions highlight that NCP often require society's inputs, referred to as NCP co-production (Spangenberg et al. 2014; Díaz et al. 2015; Lescourret et al. 2015; Palomo et al. 2016). For example water quality can be improved by ecosystems along with human infrastructure to benefit society (e.g. treatment plants, pipeline networks) (Palomo et al. 2016). Co-production processes and society's underpinning material (e.g. labour) and non-material (e.g. social capital) inputs need to be considered along the several steps from ecosystems to benefits to people (Fedele et al. 2017; Vallet et al. 2019a; Bruley et al. 2020). Co-production activities are tightly linked to actors' capabilities and their use and access to different capitals, also called resources (labour, technology, infrastructure,…) (Leach et al. 1999; Fischer and Eastwood 2016; Bruley, Locatelli, and Lavorel 2021).

NCP co-production depends on individual actions or resources, and on interactions among actors, along with collective capabilities. The concept of collective capabilities are the benefits people retrieve from social-ecological interactions, that individuals could not have achieved on their own (Comim and Carey 2001; Ibrahim 2006). Social capital broadly describes social relations and interactions between people (Ibrahim 2006). In practice, collective capabilities can be achieved by collective investments to mobilise different forms of social capital. These underlying social structures and resources (e.g. social relations, social behaviour, collective structures, norms...) support activities (Ostrom 1999; Lehtonen 2004). For example, agricultural cooperatives are collective structures using social capital to bundle and provide services to

farmers like marketing, sharing machines or equipment (e.g. irrigation systems), transformation facilities or procuring inputs. They allow farmers to specialize in some production activities to save transaction costs and can facilitate the local maintenance of agricultural activities (Ostrom 1990; Filippi and Torre 2003). Thus, collective structures can be identified as important engines to mobilize collective investments of social capital for collective capabilities in rural and marginalized landscapes including mountains (Ibrahim 2006; Pachoud et al. 2020).

Collective capabilities rely on common perceptions, shared interests, and associated (less evident) identity related dimensions like a sense of belonging to a place or group (Evans 2002; Pelenc et al. 2015). Common perceptions are the way in which people observe, understand, interpret and evaluate social-ecological systems and processes (Bennett 2016; Partelow et al. 2021). In southern Brazil, the involvement in producers' associations or cooperatives was found to be tightly related to common perceptions and farmers' local identities. Farmers were more likely to represent themselves through the typicality of their Serrano cheese, and the belonging to Serrano and Rio Grande do Sul landscapes (Pachoud 2019).

Therefore, collective capabilities, common perceptions and local identities are dynamically interlinked. There are several published examples showing how common perceptions about natural resource management can encourage the implementation of more sustainable practices and policies (Frey and Berkes 2014; Forster et al. 2017; Dendoncker et al. 2018; Partelow et al. 2021). Indeed, NCP co-production exemplifies how collective capabilities, common perceptions and local identities drive (collective) action (Kramer and Tyler 1996; Rudd 2000). How these emerge from social-ecological interactions, actors' organisation, cooperation, or legacies are avenues for research in ecological economics and social ecology (Bennett 2016; Ballet et al. 2018). More precisely, there is a need to understand which kind and level of collective capabilities are useful for NCP co-production, and conversely how co-production contributes to local identities, and hence to a good quality of life (Cook et al. 2012; Lessmann and Rauschmayer 2013; Forsyth 2015).

Mountain social-ecological systems are exemplary to address these questions. First, mountain traditional farming systems can co-produce a diversity of NCP, while maintaining iconic biodiversity and cultural landscapes (Martín-López et al. 2019; Vallet et al. 2019b). For instance, Alpine extensive livestock farming supports co-production of fodder for cheese or meat, along with aesthetic enjoyment, experiences of nature and hazard regulation (Grosinger et al. in review; Bruley, Locatelli, Vendel, et al. 2021). Secondly, farmers in mountain areas are often organised collectively to be competitive, for instance through cooperative systems specialized in local products (Ricard 2015; Pachoud et al. 2020). Actors in mountain landscapes generate and

establish collective capabilities, especially in the cheese production sector (Dissart 2012; Pachoud et al. 2020). The cheese cooperative system is therefore highly relevant to analyse how common perceptions and collective capabilities relate to NCP co-production. As existing studies focus on the economic benefits of such collective institutions, this study aimed to bring new insights into sense of place, belonging and other identity-related non-material dimensions meaningful to Alpine traditional farming systems (Koohafkan and Altieri 2011; Buclet and Donsimoni 2018; Fagerholm et al. 2020; Petway et al. 2020).

In this study, we focused on co-production of the NCP of the cattle milk cheese "Beaufort" in the Maurienne valley (Savoy, France). The objectives of this paper are to: (1) unravel co-production activities implemented by actors; (2) identify collective capabilities and associated collective investments of social capital mobilized by actors for different co-production activities; (3) analyse whether actors with specific perceptions and feelings about collective capabilities also have specific local identities. We conducted 44 semi-structured interviews with local actors that we analysed using text and sentiment analysis.

Materials and methods

Study area

Figure 1: Map of the Maurienne valley in the French Alps. Source:(IGN-F 2006; Copernicus Land Monitoring Service 2018; IGN-F 2019).

The Maurienne valley is located in Savoy, a French region known for its traditional mountain agricultural systems. The 40,000 inhabitants live in predominantly rural settings; only three of the 62 municipalities exceed 2,000 inhabitants (SPM 2020). Population density is well below the average in the Alps (22 vs. 75 inhabitants/km²) (Elmi 2018). The climate ranges from a humid pre-alpine climate in the west to a continental alpine climate in the east. Covering one third of the valley, grasslands are a characteristic land cover (Figure 1). Consistent with other Alpine regions, a quarter of the work force is linked to winter tourism, with 24 skiing resorts. At the bottom of the valley, the industrial sector provides income for 19% of the working population. Livestock farming is the prevalent farming activity and represents with around 350 farms 2% of the total workforce (SPM 2020).

The Maurienne valley falls within the boundaries of the Protected Designation of Origin (PDO) label for the Beaufort cow cheese (INAO 2015). This EU-wide regulatory framework promotes specific agricultural products, their distinctive regional features and associated modes of production (Quiñones Ruiz et al. 2018). A consortium of fourteen cooperatives manages the

production of the PDO cheese Beaufort (annual production: 5,000 t/yr) in three adjacent valleys of Savoy. The Maurienne's three cooperatives with about 80 producers (900 t/yr) are an integral part of this system since the registration of Beaufort in 1968. Each cooperative organises milk collection, transformation and sale. Milk production for Beaufort cheese within this cooperative system constitutes the major structuring agricultural activity in Maurienne, and concerns 38% of farms. Beef and small livestock (sheep, goat) are much less institutionalized (SPM 2020). The history of Beaufort as a high quality consumer brand dates back to the 1960s when local actors looked for an effective response to combat rural emigration and the associated decline of Alpine agriculture (Dubeuf 1996). Similar to other PDO cheese production systems, the cooperatives are currently associated within a consortium, which regulates and facilitates modes of production and market relations. The mandatory compliance to specification requirements protects the uniqueness of the product (INAO 2015; Lynch and Harvois 2016). These collectively agreed regulations are to various extents historical (limiting livestock to two regional breeds: "Tarine" and "Abondance"); economic (restricted milk quantity at cooperative and farm level) or technical (75% of the forage originates from the valley). These various restrictions guarantee the uniqueness and homogeneity of the product (INAO 2015; Lynch and Harvois 2016).

2. Materials and Methods

2.1. Study area

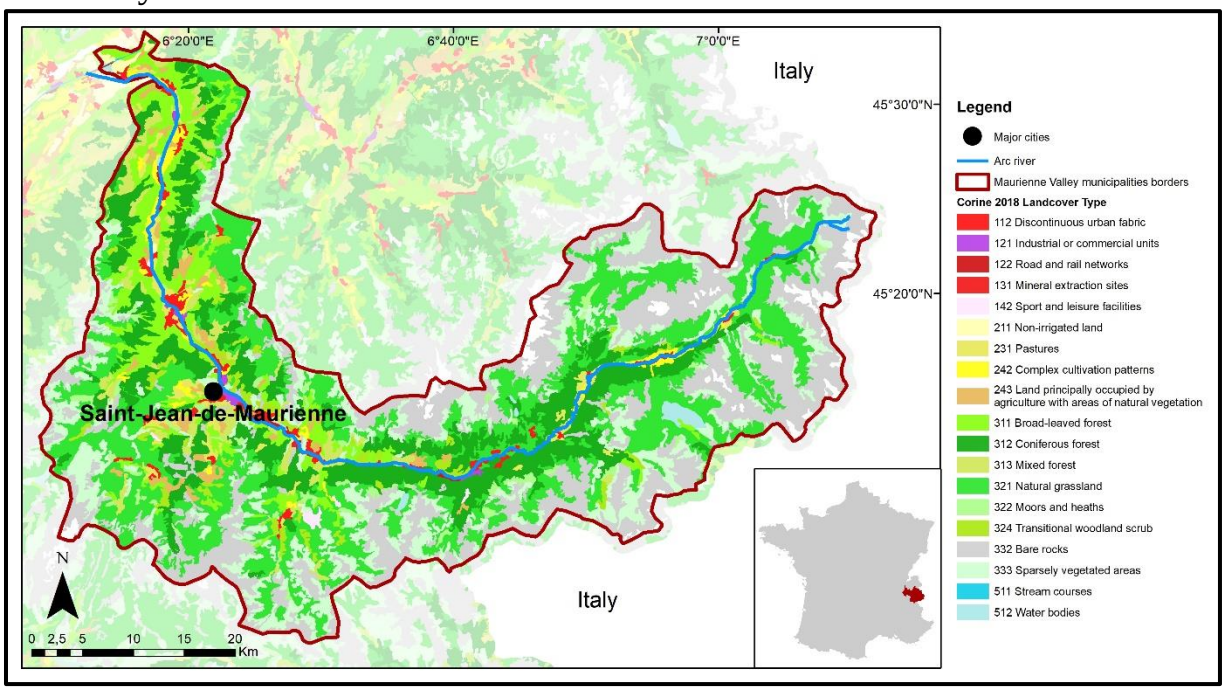


Figure 1: Map of the Maurienne valley in the French Alps. Source:(IGN-F 2019, 2006; Copernicus Land Monitoring Service 2018).

The Maurienne valley is located in Savoy, a French region known for its traditional mountain agricultural systems. The 40,000 inhabitants live in predominantly rural settings; only three of the 62 municipalities exceed 2,000 inhabitants (SPM 2020). Population density is well below the average in the Alps (22 vs. 75 inhabitants/km²) (Elmi 2018). The climate ranges from a humid pre-alpine climate in the west to a continental alpine climate in the east. Covering one third of the valley, grasslands are a characteristic land cover (Figure 1). Consistent with other Alpine regions, a quarter of the work force is linked to winter tourism, with 24 skiing resorts. At the bottom of the valley, the industrial sector provides income for 19% of the working population. Livestock farming is the prevalent farming activity and represents with around 350 farms 2% of the total workforce (SPM 2020).

The Maurienne valley falls within the boundaries of the Protected Designation of Origin (PDO) label for the Beaufort cow cheese (INAO 2015). This EU-wide regulatory framework promotes specific agricultural products, their distinctive regional features and associated modes of production (Quiñones Ruiz et al. 2018). A consortium of fourteen cooperatives manages the production of the PDO cheese Beaufort (annual production: 5,000 t/yr) in three adjacent valleys of Savoy. The Maurienne's three cooperatives with about 80 producers (900 t/yr) are an integral part of this system since the registration of Beaufort in 1968. Each cooperative organises milk collection, transformation and sale. Milk production for Beaufort cheese within this cooperative system constitutes the major structuring agricultural activity in Maurienne, and concerns 38% of farms. Beef and small livestock (sheep, goat) are much less institutionalized (SPM 2020). The history of Beaufort as a high quality consumer brand dates back to the 1960s when local actors looked for an effective response to combat rural emigration and the associated decline of Alpine agriculture (Dubeuf 1996). Similar to other PDO cheese production systems, the cooperatives are currently associated within a consortium, which regulates and facilitates modes of production and market relations. The mandatory compliance to specification requirements protects the uniqueness of the product (INAO 2015; Lynch and Harvois 2016). These collectively agreed regulations are to various extents historical (limiting livestock to two regional breeds: "Tarine" and "Abondance"); economic (restricted milk quantity at cooperative and farm level) or technical (75% of the forage originates from the valley). These various restrictions guarantee the uniqueness and homogeneity of the product (INAO 2015; Lynch and Harvois 2016).

2.2. Overview of the approach

We used a three-step methodology to analyse the collective capabilities mobilized along NCP co-production of Beaufort cheese and understand if well-perceived co-production activities also contribute to local identities (Figure 2): (1) stakeholder analysis; (2) Beaufort co-production activities analysis; (3) description of the local identities surrounding the Beaufort production system in Maurienne. In order to highlight potential differences in perceptions, all analyses were replicated for two groups of actors, defined on whether they directly participate in the Beaufort production chain.

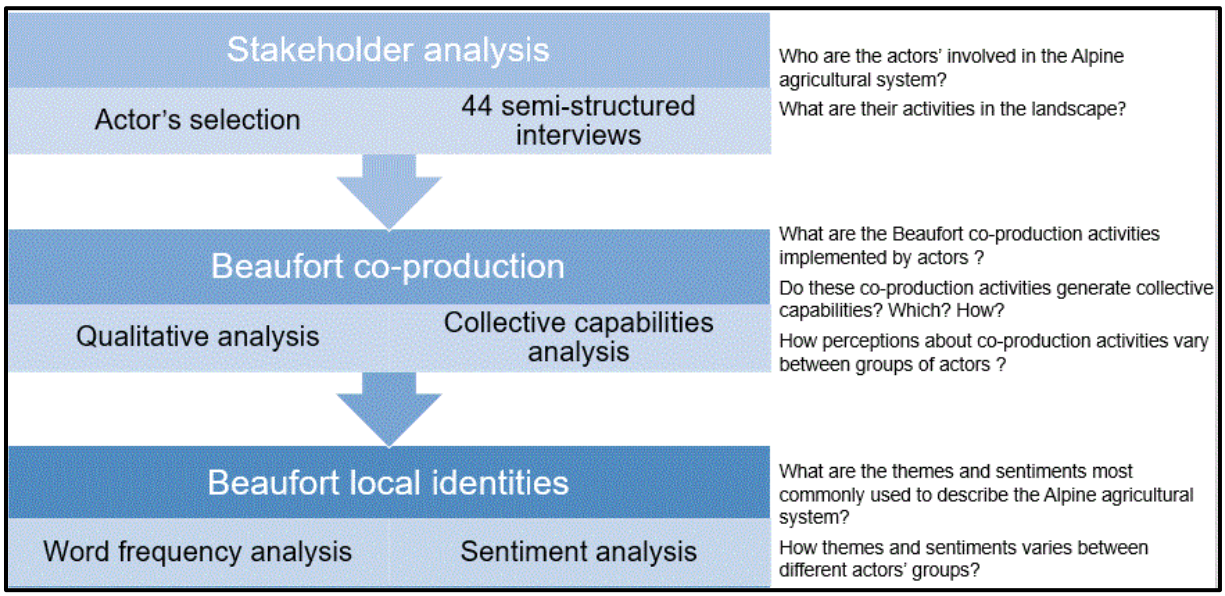


Figure 2: The three step-methodology to determine common perceptions about the Maurienne Alpine agricultural system

2.3. Actor selection

Stakeholder analysis supports the identification of actors and the analysis of their behaviour, concerns and roles (Reed et al. 2009). We defined relevant actors as the user groups who influence or benefit from Beaufort production in Maurienne (Reed et al. 2009; Herzog and Ingold 2019). This encompasses actors from the wider agricultural sector like regulatory authorities and agricultural associations; and actors from the tourism and industrial sectors who indirectly derive benefits from Beaufort production. Ultimately, we identified around 400 actors relevant to Maurienne's Beaufort production system, among which three cooperatives, 10 agricultural associations, 62 municipalities, 355 farm holdings (of which 80 are cooperative members), 22 pastoral land associations, one major industrial actor, 24 tourism actors and 5 services of the regional authority. We restricted our analysis to 43 actors from this list (Supplementary Materials 1), in line with our resources. The 43 selected actors were identified based on a preliminary internet search of academic and grey literature and a brainstorming process with

four academic experts of the region representing different disciplines. We then iteratively updated this list over the course of field research by purposive snowballing (Bryman 2016). The composition and distribution of the selected actors reflect to a certain extent the composition of the agricultural sector in Maurienne, so we consider the interview data set as a representative sample of the 400 actors relevant to its Beaufort production system (SPM 2020).

We classified actors into two groups, to determine whether specific cooperative structures built around Beaufort production foster different perceptions of NCP co-production activities and the associated collective capabilities than actors not directly linked economically to the Beaufort production system. The first group, hereafter referred as "within Beaufort production" group (WB, n=17) included actors directly involved in the Beaufort production chain. It included eleven full-time farmers, eight of which with different roles in Beaufort production. The six remaining actors were full-time employees in cooperatives. Actors representing the interest of Beaufort farmers, like in agricultural associations or trading unions were also included in this first group. In contrast, the second group hereafter referred to "outside Beaufort production" (OB, n=27) represented actors who either benefit indirectly (e.g. by non-material aspects like landscape appearance, tourism) or who contribute or manage indirectly Beaufort production (e.g managing pasture land, road infrastructure, knowledge sharing). For example, agricultural associations provide guidance, technical or administrative assistance to individual farmers, but do not interfere directly in the production chain. Actors of the OB group act in a social-ecological landscape shaped by Beaufort production that they influence indirectly through their action on land use (e.g. protection of biodiversity or cultural heritage, land consolidation). This group was composed of local and regional state institutions, agricultural associations, one industrial company and included two farmers outside of the Beaufort production system (beef and small livestock). It is worth noting that almost all farmers producing Beaufort cheese in the study area are affiliated to one of the three cooperatives: in 2019 there were only two farmers who produced Beaufort independently all-year-round, and ten seasonally.

2.4. Data collection

We conducted 44 semi-structured interviews, representing the 43 selected actors. We selected interviewees based on their involvement in their institutions. They included farmers, officials (e.g. agricultural chamber), collective institutions (e.g. associations for agricultural development, pastoral land associations) or skiing resorts (Supplementary Materials 1). For collective actors or regional authorities, we selected interviewees in either leading or managing

positions, or actively involved in Beaufort production. For instance, we conducted interviews with chairs of six pastoral associations. Thirteen interviewees were full time farmers. Consistent with other Alpine agricultural systems, most of them had representative, managing, leading or technical roles (often voluntary) in collective institutions (e.g. cooperatives, pastoral land associations), in addition to managing their farm (Schermer et al. 2010).

To elicit interviewees' perceptions of agriculture, semi-structured interviews focused on the role and background of respective institutions, on their professional position, their perceptions and relations to the Maurienne agricultural landscape, including the agricultural sector and Beaufort production (Interview guide in Supplementary Materials 2). With institutional representatives, we specifically asked interviewees to explain the role of their organisation. Interviews took place from February to September 2019 in the actors' working environment, with an average duration of 60-90 minutes. We transcribed and uploaded the dataset of 350 pages in the original language (French) into the qualitative data analysis software NVivo, release 1.2 (QSR International 2020).

3. Data analysis

3.1. Unravelling collective capabilities at different steps of Beaufort co-production

We considered that NCP co-production follows three steps along the NCP cascade from ecosystems to society and good quality of life (Bruley et al. 2020). Co-production step 1 (CP1) refers to ecosystem biophysical management, like fertilisation. Co-production step 2 (CP2) refers to activities of extraction of material or non-material outputs from the social-ecological system, like milking or haymaking. Co-production step 3 (CP3) relates to translation to a final NCP benefit, e.g. milk, a transformed dairy product or to nature's appreciation and other non-material NCP.

Our analysis focused on deliberate co-production activities mentioned by actors from the two groups. First, we coded all co-production activities in NVivo, using a predefined typology. This typology was built using existing studies on co-production of agricultural NCP (Palomo et al. 2016; Vallet et al. 2019a; Bruley, Locatelli, and Lavorel 2021). The typology was then iteratively improved while coding the interviews; the final version is provided in Supplementary Materials 3.

Then, for each co-production activity, we qualitatively determined what types and levels of collective investment were mobilized for collective capabilities using interview materials (see Table 1 and Supplementary Materials 3). For types of collective investment, we followed Ostrom's typology for social capital, distinguishing: actors' networks (formal and informal interactions), shared norms (e.g. trust, reciprocity), social beliefs and knowledge (held values), conventions (replicating prior individual decisions), collective rule systems (institutionalized rule sets) and family structure (e.g. family lineage and composition) (Ostrom 1999). We note that a clear differentiation between types remains difficult and might be contextual.

The levels of collective investment for collective capabilities refer to the existence of coordination and frequent interactions between actors, about goals, management practices and rules associated to the Beaufort production system. The sharing of common pool resources (communal pastures, irrigation network...) requires more social coordination of individual objectives and practices between involved actors than the choice of agricultural practices implemented on individual farms (fertilization levels, crop rotation...) (Ostrom 1990). Therefore, we distinguished between three levels of collective investment: low, medium and high. Although actors, for instance farmers, are embedded in a collaborative system ruled by a set of norms, they can autonomously set their own goals and decide their agricultural practices (e.g. decreasing herd size in winter due to limiting infrastructure). Those activities can be implemented with low levels of collective investment. Actors do not necessarily share the same goals, nor implement identical activities: duration of grazing period, herd size, accessibility, grass harvesting or time resources can differ across farms. These individual farmer decisions only marginally affect the Beaufort production system. In contrast, some activities require actors to coordinate and agree on the management and the associated rules for the social-ecological system, for instance deciding the use of common lands. These medium-levels of collective investment corresponds to situations where actors collectively agree on rules over the use or management, but with possible different goals, that do not affect the logic of the Beaufort production chain. For instance, farmers can be involved in the same collective irrigation systems, while pursuing different objectives (e.g. supplementary hay for winter fodder vs. increase total livestock). Finally, high levels of collective investment correspond to activities where actors share the same goals and agree on the activities and rules to implement. If actors would modify this co-production activity (e.g. change the type of cattle allowed in Beaufort production), then entire Beaufort production chain would be impacted.

3.2. Analysing perceptions and associated sentiments about Beaufort co-production

In a second step, we analysed the associated sentiments expressed by actors about different co-production activities. Sentiment analysis is widely used for marketing or communication purposes (Twitter, customer related review sites), but less commonly for qualitative interview data (Liu and Zhang 2012; Lee et al. 2020). In social-ecological research, it has been applied to measure place-based perceptions of non-material NCP (Jones et al. 2020). We used sentiment analysis to test whether actors share similar positive or negative sentiments about Beaufort co-production activities. We used a four-level Likert-scale (very positive, moderately positive, moderately negative, very negative) to code and systemize interviewees' overall feeling associated to each of the identified activities. Sentiments were coded manually using the NVivo node system, considering the whole sentence and the general context of the discussion with the interviewee (Neuendorf and Skalski 2009; Liu and Zhang 2012). Very positive sentiments corresponded to sentences where interviewees used highly sentiment-loaded words like "admire" and "love", and very negative sentiments to sentences with overall negative words like "struggle" or "difficult". Moderately positive and moderately negative categories corresponded to less obvious negative or positive meaning. Sentiments were not coded for each specific co-production activity, but for broad sets at each step (CP1, CP2 and CP3) of co-production (twelve in total). They encompass for example categories like technology, transport and work-life balance, (see Table 1 and refer to Supplementary Materials 3 for the detailed list).

Finally, we analysed the links between collective capabilities and sentiments to identify if activities associated with high levels of collective investment are perceived differently in the two actors' groups.

3.3. Content analysis for detecting local identities

Content analysis is a research technique to identify and systemize intentions, themes, trends in texts like online media, journals or transcribed interviews (Gheyle and Jacobs 2017). Content analysis has been used extensively to reveal collective notions like understanding, perceptions, identity in diverse contexts especially in the field of political science (Neuendorf and Skalski 2009). In social-ecological research, content analysis has been widely applied to analyse the evolution of the discipline (Stojanovic et al. 2016), social and environmental disclosures of organisations in social and environmental reporting (Vourvachis and Woodward 2015) and visual and textual representation of ecosystem services in social media (Weber et al. 2017; Oteros-Rozas

et al. 2018). Further, content analysis has been applied to understand perceptions of NCP in relation to agricultural practices at regional scale (Bernués et al. 2016).

To implement content analysis, first, we used NVivo built-in tool for word frequency analysis to identify the most frequently mentioned nouns (called 'terms' in the following) across all interviews, and separately within each group of actors (Jones et al. 2020). We hence identified the most frequent terms separately for each group, and checked common terms. We first treated plural and singular forms separate as synonyms and totalled them in a second step for the most frequent terms. We limited our selection to the 16 most frequent terms in each group as the following less frequent terms were overall synonymous or related to the top 16 (Supplementary Materials 4); this kept the number of selected terms tractable for the next step of the analysis (manual sentiment analysis). We grouped these terms into three categories: institutions, place and resources. These are fundamental components on studies on collaborative structures in natural resource management (Ostrom 1990) and were used in other studies on collaborative structures (Pelenc and Ballet 2015). Terms not falling in these categories were grouped in an "other" category.

Secondly, for each term we conducted a sentiment analysis, following the same approach as for the sentiment analysis described in the previous section (i.e. we used the same four-levels Likert-scale, and the same detection criteria for coding sentiment levels).

Finally, we identified the underlying themes related to the most frequent terms, one for each of the three categories (place, institution, resources). These corresponded to the major topics of interviews, which interviewees repeatedly mentioned and therefore constituted a relevant part of their perceptions of the Beaufort production system.

3.4. Comparing content and sentiment between actors' groups

We analysed whether term frequencies and sentiment levels varied between the two groups of actors (WB group vs. OB group) using Student t-tests and standardized residual analysis (Agresti 2007). More precisely, we tested: (1) the effect of actors' group on each word frequency and sentiment levels (Student t-test); (2) the effect of actors' group on the sentiment levels expressed for each term (residual analysis).

Standardized residuals describe the difference between expected (if there was no pattern of association between actors' group, terms, and associated sentiment levels) and observed frequencies in contingency tables. As they follow a standard normal distribution (mean = 0, standard deviation = 1), residuals with an absolute value that exceeds 2 or 3 mean that there is

a significant statistical association between the variables (i.e. residuals are greater than we would expect if the variables were truly independent). In contrast, residuals with values close to zero mean that there is no association. The sign of the residuals describes the nature of the association (positive or negative) (Agresti 2007). Standardized residuals were represented as mosaic graphs (Meyer et al. 2006). The mosaic plot was drawn with the *vcd* package and R version 4.0.2 (Meyer et al. 2006; Zeileis et al. 2007; R Core Team 2020; Meyer et al. 2020). All graphs were created with R, and the tidyverse (Wickham et al. 2019), ggpubr (Kassambara 2020a), rstatix (Kassambara 2020b) and viridis (Garnier 2018) packages.

4. Results

4.1. Beaufort co-production activities

A total of twelve co-production activities were identified along the Beaufort production chain in the interviews, for a total of 974 quotes (Table 1 and SM 3). In the first step (CP1), representing fodder production, actors mentioned four types of activities: modifying the share of regional fodder (to comply with the 75% specification), improving the technological equipment (irrigation, machinery…), increasing land extension (exchanges, purchases...), and managing the crop calendar and the main agricultural practices on the farm (harvest date, herd size...). CP2 considers the mobilisation of ecological resources, e.g. only milk from the two regional cattle breeds (which we consider as an ecological resource) is legitimate for the production of Beaufort cheese. In CP2, actors cited as activities: regional cattle breeds (Tarine and Abondance), increasing milk quantity, improving milk quality (protein and fat levels, hygiene indicators) and transporting the milk to the cooperative. In CP3 (product sale), actors listed socioeconomic livelihood, landscape appearance, personal satisfaction and work-life balance as main elements.

Co-production activities related to personal satisfaction (CP3) received the highest number of quotes, then followed by land expansion (CP1) (Table 1). The number of quotes each activity received during the interviews varied across actors' groups: actors involved directly in the Beaufort chain (WB group) mentioned much more activities related to the translation of agricultural activities to a final NCP benefit CP3) than other actors (Table 1). This highlights the importance of Beaufort production for their good quality of life.

4.2. Collective capabilities surrounding Beaufort co-production

Co-production activities required different types of collective social capital, listed in Table 1, and that we further classified into three levels of collective investment (low, medium and high),

depending on the social coordination of individual objectives and practices between involved actors for Beaufort co-production.

The types and levels of collective investment of social capital mobilized for the NCP co-production varied along the co-production cascade (Table 1). For CP1, crop calendar management was an individual decision, reflecting each farmer's preferences and possibilities and less interactions with other actors (low levels of collective investment): this involved only social beliefs and knowledge and household structure. Improving the technological equipment and increasing land extension received the highest number of quotes in both groups. This activity required the actors to coordinate at some point, across or within the two groups, using conventions and actors' networks (medium levels of collective investment), as illustrated by this quote:

> *"[About land exchange] They don't necessarily like each other, everyone does things differently, but still they work together on that". (Int. 1, Farmer, 07/2019)*

The easing or tightening of the 75% regional fodder requirement required high levels of collective investment. This rule is part of a set of PDO specifications (i.e. a collective rule set) that shapes the entire production system. Actors from the OB group are less involved in this activity and quoted them accordingly less. However, it was subject to many discussions for actors from the WB group:

> *"We need to evaluate the restrictions for Beaufort for all farms. But, for sure we must not change them, it's on us to adapt." (Int. 36, Farmer, WB, 08/2019)*

Activities in CP2 were mainly cited by the WB group and less by the OB group, suggesting the latter are less involved at this step of co-production (Table 1) Activities related to increasing milk quantity, improving quality (both mobilized collective rules) and transporting milk from farm to cooperative level (norms, networks) required medium-levels of collective investment. They corresponded to each farmer's individual objectives and strategies to have a viable business while complying with PDO specifications, national regulations (hygiene, milk storage) and the individual cooperatives' habits for transport. The restriction to local cow breeds (also based on collective rules) relies on high levels of collective investment as the restriction to low yielding cattle implies extensive farming, a strong symbol for the Beaufort cheese. Any modification would entail fundamental changes in the current production, as expressed in this quote:

"If you want another cattle breed that produces more, it's because of its genes, but then the hay is not sufficient, it needs more grains. And then you lose the link with the region" (Int. 02, Employee, WB, 07/2019)

At CP3, activities were more frequently mentioned by actors from the WB group (Table 1 and SM 3/Table 2). As personal satisfaction and work-life balance can be considered as individual choices which depend on individual appreciation, most of the social capital mobilized (i.e. social beliefs and family structure) corresponded to low collective investment, except landscape appearance (medium levels of collective investment) and socioeconomic livelihood (high levels of collective investment) which rather mobilized networks and collective rules. Overall, the PDO specifications (controlling livestock breed, milk quantity at CP2 and forage origin at CP1) effectively limit the farm size and set as a rule small-scale traditional farming systems. The specifications also provide a financial security as farmers can sell their milk to Beaufort cooperatives at almost double the market price. This is illustrated by the following quote:

"Thanks to the cooperative I have money on my bank account." (Int. 23, Farmer, WB, 08/2019)

NCP co-production activities		Description	# of quotes	Types of social capital involved	Levels of collective investment	Example citations
CP1- fodder production	Modifying the share of regional fodder	Current Beaufort PDO requires a minimum of 75% of regional fodder. Some actors suggested to maintain, soften, or increase this value.	WB: 8 OB: 10	Collective rule system (PDO certification)	High	*"We made some temporary exceptions regarding the share of regional fodder a few years ago. But, at the moment, we don't ask ourselves to ease that requirement, there is too much behind it." (Int. 11, Employee, WP, 07/2019)*
	Land expansion	Actors' different strategies to fight land fragmentation. It includes land acquisition, land exchange and the collaborative management of pastures through land pastoral associations.	WB: 87 OB: 84	Family structure, networks, convention (land contracts, regulations and land consolidation)	Medium	*"Is it better to make housing for 50 people in the village or better to keep the farmer? That's often the question." (Int. 22, State official, OB, 07/2019)*
	Improving technological equipment	Irrigation systems, additional seeding or machinery.	WB: 50 OB: 40	Networks, Convention (agreeing over land, timing and type of irrigation system across actors' groups)	Medium	*"Irrigation is important for the Beaufort zone. There is a real economy behind these hectares." (Int. 7, State official, OB, 7/2019)*
	Managing the crop calendar	Agricultural practices implemented on farm: harvest dates, grazing duration, permanent or temporary herd size.	WB: 50 OB: 18	Family structure, social beliefs and knowledge (habits, traditions and exchange over experience and knowledge)	Low	*"I stay less time in the mountains, I return end of September and cows graze on the bottom of the valley. If they stay up there, they give less milk. "(Int. 23, Farmer, WB, 08/2019)*
CP2- milk transfer from farm to cooperative level	Local cattle breeds	Beaufort PDO currently allows only two breeds (Tarine and Abondance) for milk production.	WB: 40 OB: 6	Collective rule system (PDO certification)	High	*"But what is behind the colour of a cow is a real fight over a production system" (Int. 11, Employee, WB, 07/2019).*
	Improving milk quality	Milk quality is frequently controlled by cooperatives. Beaufort PDO and national. regulations define quality rules.	WB: 55 OB: 1	Collective rule system (PDO specifications)	Medium	*"After changing all the farm system, last year the cooperative told me that I'm the cleanest producer regarding the milk proteins. How was I proud!" (Int. 14, Farmer, WB, 02/2019)*

	Increasing milk quantity	Milk quantity produced on-farm is restricted by a quota system, often contested by actors. The variability of milk production during the year is difficult for cooperatives to manage (milk shortages).	WB: 67 OB: 2	Family structure, social beliefs and knowledge, collective rule system (maintenance of small to medium holding size)	Medium	*"There is a real risk of losing quantity; we have producers where nobody knows if somebody will take the farm after them." (Int. 39, Employee, WB, 08/2019)*
	Transporting milk from farm- to cooperative	Cooperatives collect milk daily from the individual farms.	WB: 13 OB: 20	Norms, networks (government institutions provide road infrastructure)	Medium	*"It's important for the farmers that we open up the mountain passes in spring so that they can access their pasture land. (Int.40, State official, OB, 08/2019)*
CP3-product sale	Socioeconomic livelihood	Economic benefits and quality of life generated by Beaufort production.	WB: 74 OB: 37	Social beliefs and knowledge, family structure (attitudes towards farming profession)	High	*"Here, if there wouldn't be the Beaufort, there would be no agriculture here" (Int. 1, Farmer, WB, 07/2019)*
	Landscape appearance	The Beaufort production maintains by extensive grazing activities the cultural landscape.	WB: 16 OB: 27	Networks, social beliefs, and norms (consensus over landscape appearance)	Medium	*That's an important aspect. The maintenance of space. Because if agriculture stops tomorrow, the vegetation, the landscape will deteriorate. For that agriculture needs to stay." (Int. 25, Employee, OB, 03/2019)*
	Personal satisfaction	Actors' subjective feelings about Beaufort production and Alpine agricultural systems.	WB: 125 OB: 47	Social beliefs and knowledge, family structure (recognition from other actors)	Low	*"It's more a passion and less a work". (Int. 26, WB, Farmer, 08/2019)*
	Work-life balance	The ratio between leisure and working time.	WB: 66 OB: 11	Social beliefs and knowledge, family structure	Low	*"I also want to see my daughter. Sometimes she asks me when I will sell the cows."(Int. 14, WB, Farmer, 02/2019)*

Table 1: Description of co-production activities observed for Beaufort production. Three levels of collective investment are distinguished: low collective investment (i.e. each actor can independently decide of their goals and activities without any coordination with other actors), medium collective investment (i.e. actors pursue different goals, but need to coordinate on the activities they implement to reach them) and high collective investment (i.e. actors pursue the same goals and therefore coordinate to reach them together).

4.3. Sentiments about Beaufort co-production activities

In general, co-production activities were described with positive sentiments by the two groups (very or moderately positive levels represented more than 65% in both groups), except milk quantity, land extension and work-life balance which received higher levels of negative sentiments (Figure 3).

In the WB group, activities receiving the highest share of positive sentiments were local breeds (CP2) and landscape appearance (CP3). In the OB group, the best perceived activities were milk quality and transport, and landscape appearance (Figure 3). These activities are tightly related to the Beaufort PDO, and require high cooperation and interactions between actors (medium to high levels of collective investment). This suggests that the Beaufort PDO is not seen as a constraint, but as an opportunity that contributes to sustain local agriculture. The milk quotas (milk quantity) imposed by the PDO received mixed sentiments: some actors said it prevented them from increasing production, which might become a problem in the future if milk production does not keep up with the demand for Beaufort cheese. But others also indicated that the quota system keeps milk production aligned with available land, environmental constraints, infrastructure and workforce, which was positively perceived.

'For doing agriculture in the mountains, first you need to love mountains, second you need to love agriculture, this means you need to love constraints." (Int. 36, Farmer,WB, 08/2019)

We did not detect any significant association between the type of social capital mobilized by different levels of collective investment co-producing NCP and the associated sentiments. This suggests that perceptions about co-production depend more on the nature of the activity and its contributions to good quality of life than on the specific social capitals mobilized.

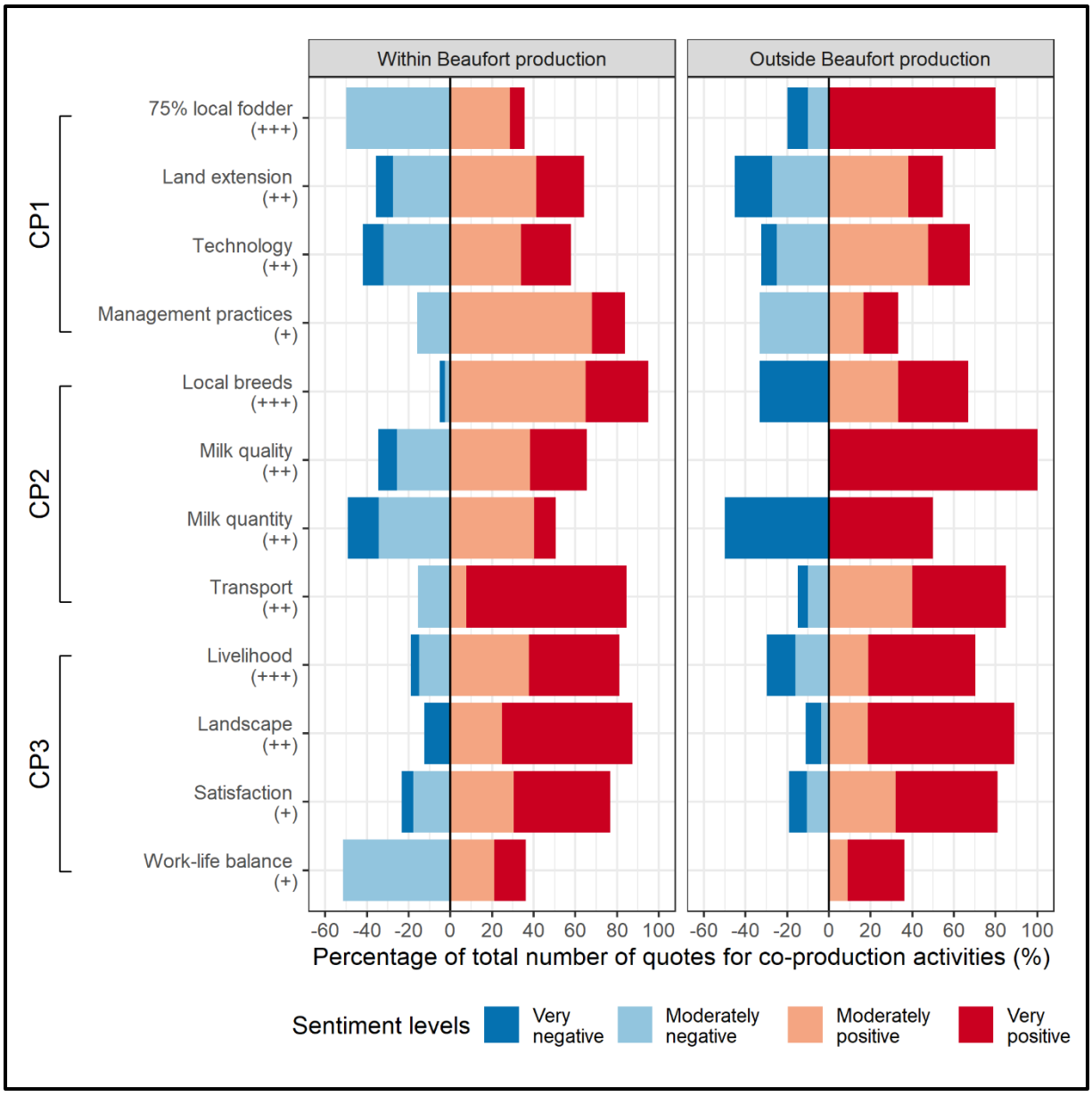


Figure 2: Sentiment analysis for activities at the three steps of NCP co-production. Each NCP co-production activity is associated with a level of collective investment (+=low, ++=medium, +++=high).

4.4. Highlighting local identities with terms frequency analysis

Among the 16 most frequent terms analysed in each group, twelve were common to both (Figure 4B and 4C), suggesting a common understanding and perception of local identities associated to Maurienne agricultural landscapes. These terms were "land", "Maurienne", "mountain" and "summer pasture" in the place category; "cow" and "time" in the resources category; and "Beaufort" (this word is often used to describe the organisational structure, rarely the cheese product), "council of municipalities", "municipality", and "pastoral land association" in the institutions category. The terms "project" and "people" were too general to specifically belong to any of these categories, and were merged as "other". Few terms were

specific to each group; they were mainly related to cattle farming in WB and to tourism in OB (Figure 4B and 4C). A list of total quotes of terms for each sentiment level is provided in Supplementary Materials 4, Figure 1, a qualitative description of the 16 most frequent terms of both groups in Supplementary Materials 5 and significance tests in Supplementary Material 6.

We identified 4134 quotes including at least one of the 20 frequent terms mentioned in the two groups. Terms referring to institutions were the most frequent (32% total quotes), followed by place (29%) and resources (22%) (Figure 4A). Interestingly, resources terms represented 29% of WB quotes, while it concerned only 16% of OB group. This underlines the relevance of the key resources cattle and time for agricultural activities. Both groups similarly referred to place terms, indicating agreement on the importance of the mountain environment for the Beaufort agricultural system and the construction of local identities.

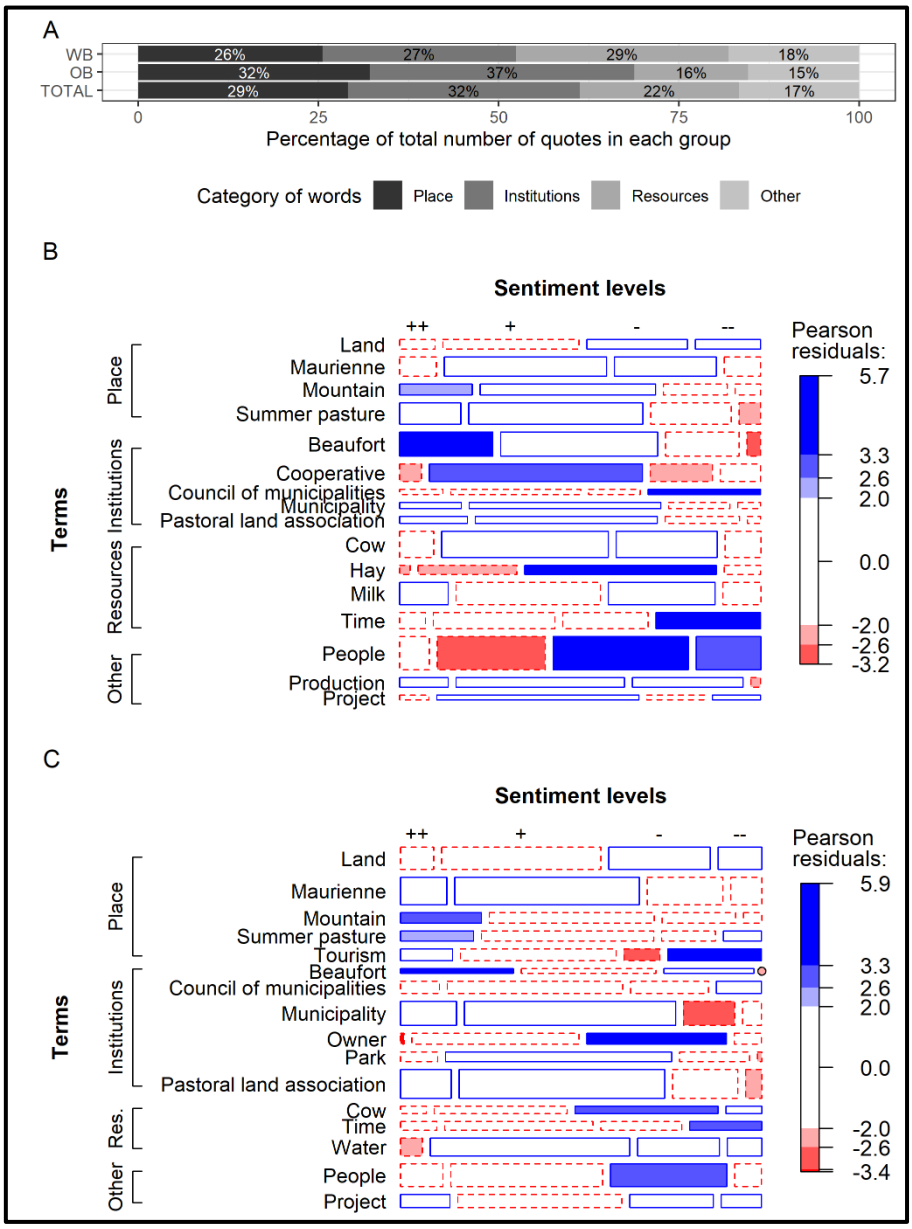


Figure 4: 4A: Figure shows the relative distribution of quotes in each group and total. 4B and 4C: Mosaic plot of the frequency of the sentiment analysis of the 16 most frequent terms for the two different groups of actors (Panel B : WB group, Panel C : OB). Each box is associated with a term in the left list and a Likert-scale level on the top (++=very positive, +=moderately positive, -=moderately negative, --=very negative). The height of a box is proportional to the word counts. The width of a box is proportional to the number of counts at each level of the Likert-scale, for the two groups of actor separately. Box colour highlights cells which are individually significant at approximately α= 0.05, α= 0.01 and α= 0.001 levels, respectively. Blue boxes indicate positive residuals (i.e. it is more likely that an actor of a group mentions a term with a given sentiment level than expected if the variables were independent), and red

boxes indicate negative residuals. For sake of simplicity, boxes with absolute residuals below the critical value of 95% are white.

.

4.5. Sentiments differences between groups

WB actors quoted resource terms “cow” and “time” significantly more than OB actors (Figure 4B and 4C). Notably, WB actors used the term “time” with significantly more negative sentiments. This is because time was often referred to as limiting production, but also life quality. It echoes the previous observation from the analysis of co-production activities, where we observed that work-life balance was more often mentioned with negative sentiments. As an actor exclaimed:

> *“Today the farmer works every day. He doesn’t have the time to go to any festivities. And that’s also really important.” (Int. 01, Farmer, WB, 07/2019)*

WB actors also used “summer pasture” and “Beaufort” with significantly more positive sentiments. OB actors quoted “Beaufort” less frequently, but with more positive sentiments. This highlights the importance of the mountain environment and Beaufort PDO in the sense of place and local identities of the Maurienne valley, as illustrated by the following citations:

> *“Without Beaufort, without that decision, without this choice, agriculture in the mountains would have disappeared.” (Int. 1, Farmer, WB, 07/2019)*

> *"Beaufort has really saved the agriculture here. Without Beaufort there would be no agriculture here” (Int. 22, State official, OB, 07/2019)*

WB actors referred significantly less than expected to institution terms “pastoral land association” and “municipality”, while OB actors used them more frequently, with positive sentiments only (Figure 4B, 4C, SM 6). This suggests actors might have diverging views and opinions on the institutions facilitating agricultural activities in Maurienne, with WB actors praising the cooperative systems, while OB actors favoured public institutions. This is not surprising given our prior definition of the groups.

WB actors used the term “land” with significantly less positive sentiments, and OB actors with significantly more negative sentiments (Figure 4), which reflects strong land competition, including with tourism:

> *“What kind of mountains do we want? A protected mountain, one for sport, one for only agriculture, an empty one? We have to talk about this” (Int. 7, State official, OB, 07/2019)*

5. Discussion

5.1. Collective capabilities contributions to NCP co-production

Our results highlight the importance of several collective capabilities supporting Beaufort production. We found that most activities, which structure, organise and maintain Beaufort production, including the 75% local fodder requirement and the restriction to local cattle breeds rely on high levels of collective investment. The positive sentiments of both actors' groups regarding these activities highlight the importance of shared views across heterogeneous actors in regional production systems. This indicates that actors inside and outside these systems are aware of the collective capabilities, thus the benefits they retrieve from this type of social-ecological interaction. It highlights that these benefits surpass pure economic considerations that benefit a wide range of actors. In addition, the Beaufort system depends on activities that require low and medium levels of collective investment. Interestingly we did not find any congruent pattern between the levels of collective investment and the types of mobilised social capital. This suggests that collective capabilities depend on current formal or informal institutions and less on pre-existing social capital. For future research we suggest to extend research on social capital by integrating social network analysis (Pachaud et al., 2020). This could evaluate the relevance of the qualitative and quantitative strength of relations between individual actors on collective capabilities. Other studies similarly observed that collective structures are essential for the co-production of NCP and the maintenance of small-scale mountain farming systems, in the French Alps (Lamarque and Lambin 2015), the Italian Alps (Pachoud et al. 2020) or Austria and Norway (Schermer et al. 2016). Some results of our interviews also suggest that actors' individual agency and resources were crucial in the production and the functioning of relevant collective capabilities. For instance, some individuals played a crucial role in mobilising social capital (e.g. by meeting actors across scales and professions) during the creation of the Beaufort cooperative system in the 1960s (Dubeuf 1996; Faure 1999; Lynch and Harvois 2016). This supports the idea that collective capabilities result from social interactions coupled with individual agency (Ballet et al. 2007). To better address these interlinkages between collective capabilities and agency, future research needs to investigate enabling conditions at individual level and regarding actors' organisation within society enabling the emergence and maintenance of collective capabilities (Sen 2000; Ibrahim 2006). Quantitative methods like social network analysis could support this research (Vallet et al. 2019b; Pachoud et al. 2020).

5.2. How does NCP co-production via collective capabilities contribute to local identities?

Our analyses identified the Beaufort PDO as an important collective institution generating collective capabilities that contribute to local identities. This is consistent with previous conclusions that local identity is an incontestable part of the Beaufort production (Dubeuf 1996; Faure 1999; Lynch and Harvois 2016). The regional fodder requirement establishes strong links between livestock numbers and available land, thus effectively preventing large increases of herd sizes. The requirement of regional cattle breeds maintains the cultural heritage. Indeed, small-scale milk production for Beaufort cheese appeared central to local identities in Maurienne, as supported by interviewees' frequent mentions of: "summer pasture", "cattle" and "Beaufort". Additionally, the differences between the two actors' groups match previous findings on differing perceptions regarding agriculture's contributions to good quality of life depending on their activities and actions in agricultural production (Poppenborg and Koellner 2013). Nevertheless, actors recognised a trade-off between this valued production system and its time intensiveness, which aligns with recurring perceptions in agricultural systems (Lunner Kolstrup et al. 2013; Naik 2017; Annibal et al. 2019).

The overall positive sentiments highlight the positive social representation of the Beaufort cheese. This intrinsic link between Beaufort production and local identities already identified 25 years ago (Dubeuf 1996) appears to have persisted. Cheese production can be a defining element of local identities (Bérard et al. 2008; Dos Santos 2017). Mountain cheese production is linked to the surrounding landscape and traditional farming practices and can thus become a symbol of local identities (Delfosse 2006). European quality schemes like PDO labels, and since 2012 the "mountain products" label, acknowledge the strong cultural identity and tradition of mountain regions (Santini et al. 2013; EC 2020). Similar identity dimensions of quality labels were observed for the Jura region in the French Alps Comté cheese (Dos Santos 2017). The contributions of collective capabilities to local identities has been observed for products with comparable geographical indications labels, like Serrano cheese in Southern Bazil (Pachoud 2019), olive oil in Spanish Andalusia (Sanz Cañada and Macías Vázquez 2005) or coffee in the mountains of Bali (Fournier 2008). These products can maintain regional identities by sustaining rural economies (Cei et al. 2018) and contribute to local ecosystem protection (Belletti et al. 2015; Lamarque and Lambin 2015; Dos Santos 2017).

5.3. Local identities, relational values and contributions to good quality of life

NCP co-production contributes in multiple ways to a good quality of life (Díaz et al. 2015). The Beaufort production system insures socioeconomic livelihood (CP3). In addition, actors considered other co-production aspects beyond instrumental/economic benefits. We grouped these non-material aspects of personal satisfaction, landscape appearance and work-life balance (CP3) under the notion of relational values (Pascual et al. 2017; Schröter et al. 2020). Actors quoted different dimensions of personal satisfaction, such as being satisfied with their professions, their working environment or their animal husbandry. In addition, actors appreciated the appearance of their surrounding ecosystem. Relational values can explain the number of quotes for personal satisfaction (172 quotes) against the lower number of quotes and low level of positive sentiments for work-life balance (77 quotes). The importance of relational values can explain the absence of revenue related terms (e.g. money, capital, income) in the discourses. This is consistent with evidence that economic considerations are accompanied by questions of lifestyle when choosing mountain farming as a profession (Hinojosa et al. 2016; Schermer et al. 2016).These observations also align the capability approach highlighting that people engage in activities not only for the pure maximization of joy and happiness, but because the process itself aligns with higher goals and contributes to their interpretation of a meaningful life (Alkire 2008; Ballet et al. 2018). In addition, collective capabilities theories argue that social interactions with people who share one's interests contribute to a good quality of life and are central to the development of identities (Evans 2002). Given this multidimensionality of relational values, individuals can appreciate the involvement in collaborative structures for diverse reasons (Rauschmayer et al. 2018). Summed up, our analyses showed how in the Maurienne's Beaufort production system collective capabilities contribute in socioeconomic terms, subjective feelings, and social interactions to a good quality of life and facilitate in a wider framing the maintenance of local identities.

5.4. Methodological considerations: Unravelling the links between NCP co-production, collective capabilities and local identities with sentiment analysis

We evaluated the role of collective capabilities in the different steps of Beaufort cheese co-production in the French Alps from interviews of 43 actors of the Maurienne agricultural system, depending on whether actors were directly involved Beaufort cheese production chain or not. Our mixed method enabled integrating qualitative and quantitative information. Word frequency, commonly used to analyse general themes in interviews or large corpus data sets (Droste, D'Amato, and Goddard 2018), enabled a precise and exhaustive identification of key terms.

Post-interpreting sentiment from in-text context rather than explicitly asking interviewees to express their sentiment about terms and activities is common practice (Lee et al. 2020). Such qualitative information is crucial in sentiment analyses as automated algorithms (e.g. NVivo) attributing predetermined sentiment scores to "sentimentally loaded words" (Jones et al. 2020) do not always correctly reveal people's preferences and value-systems. Although manual coding was in some cases a difficult and time consuming task, as subtle, less pronounced emotions can be difficult to detect in written data sets, we believe it was more efficient for determining sentiment scores depending on context. This way, some terms received both positive and negative scores, like milk whose production is crucial for Beaufort cheese (and justifies positive sentiments), but whose quota restrictions and the associated work load are often seen as constraints by farmers (negative sentiments). However, manual coding limits the transferability of our method to other contexts, as a profound familiarisation with the dataset precedes manual coding. Data mining tools offer promising avenues for future, more sensitive coding of themes for sentiment analysis (Liu and Zhang 2012; Hale et al. 2019; Mascareño et al. 2020).

6. Conclusion

Our empirical analysis of the Maurienne's Beaufort cheese production system advanced prior research on linkages between collective capabilities, identities and their contribution to a good quality of life. We shifted the unit of analysis from collective resource management to the entire production chain and focused on the social dimensions of NCP co-production. The emphasis on the social dimensions of NCP co-production allowed us to unravel the role of social interactions, thus going beyond analyses of flows between society and ecosystems. The collective capability approach appeared particularly useful in conceptualising multidimensional and cross-sectoral benefits of collective action to different dimensions of a good quality of life because it renders the different levels and types of interactions between actors visible. However, aspects of a good quality of life appeared to be more linked to the type of activity than the form of social interaction. Nevertheless, we suggest investigating possible linkages between types of social coordination and their contributing role in social-ecological interactions more thoroughly. Considering the impacts of evolving lifestyles and consumption patterns on regional extensive farming systems, such new approaches are required to understand how people relate to their surrounding environment. This will help developing pathways to maintain these local production systems. Lastly, our approach offers the opportunity to further investigate

and operationalise the role of collective structures in social ecological interactions from a social science perspective.

Acknowledgements

This work was supported by the Université Grenoble Alpes Cross-Disciplinary Project Trajectories funded by the French National Research Agency "Investissements d'avenir" program (ANR-15-IDEX-02). This work was carried out within the eLSTER site Zone Atelier Alpes.

References

Agresti A. 2007. An introduction to categorical data analysis. 2nd ed. Hoboken, NJ: Wiley-Interscience (Wiley series in probability and mathematical statistics).

Alkire S. 2008. The capability approach to the quality of Life.

Annibal I, Prize L, Sellick J. 2019. Health and Wellbeing Report. [accessed 2020 Sep 25]. http://eprints.lincoln.ac.uk/id/eprint/41180/.

Ballet J, Dubois J, Mahieu F. 2007. Responsibility for Each Other's Freedom: Agency as the Source of Collective Capability. J Hum Dev. 8(2):185–201. doi:10.1080/14649880701371000.

Ballet J, Marchand L, Pelenc J, Vos R. 2018. Capabilities, identity, aspirations and ecosystem services: an integrated framework. Ecol Econ. 147:21–28. doi:10.1016/j.ecolecon.2017.12.027.

Belletti G, Marescotti A, Sanz-Cañada J, Vakoufaris H. 2015. Linking protection of geographical indications to the environment: Evidence from the European Union olive-oil sector. Land Use Policy. 48:94–106. doi:10.1016/j.landusepol.2015.05.003.

Bennett NJ. 2016. Using perceptions as evidence to improve conservation and environmental management: perceptions and conservation. Conserv Biol. 30(3):582–592. doi:10.1111/cobi.12681.

Bérard L, Marchenay P, Voinson J. 2008. From Localized Products to Geographical Indications- Awareness and Action. Bourg-en-Bresse: CNRS, Ressources des terroirs-Cultures, usages, sociétés.

Bernués A, Tello-García E, Rodríguez-Ortega T, Ripoll-Bosch R, Casasús I. 2016. Agricultural practices, ecosystem services and sustainability in High Nature Value farmland: unraveling the perceptions of farmers and nonfarmers. Land Use Policy. 59:130–142. doi:10.1016/j.landusepol.2016.08.033.

Bratman GN, Anderson CB, Berman MG, Cochran B, de Vries S, Flanders J, Folke C, Frumkin H, Gross JJ, Hartig T, et al. 2019. Nature and mental health: An ecosystem service perspective. Sci Adv. 5(7):eaax0903. doi:10.1126/sciadv.aax0903.

Bruley E, Locatelli B, Lavorel S. 2020. Nature's contributions to people: Co-producing quality of life from multifunctional landscapes. Ecol Soc Revis.

Bruley E, Locatelli B, Lavorel S. 2021. Nature's contributions to people: coproducing quality of life from multifunctional landscapes. Ecol Soc. 26(1). doi:10.5751/ES-12031-260112. [accessed 2021 Apr 26]. https://www.ecologyandsociety.org/vol26/iss1/art12/.

Bruley E, Locatelli B, Vendel F, Bergeret A, Elleaume N, Grosinger J, Lavorel S. 2021. Historical reconfigurations of a social–ecological system adapting to economic, policy and climate changes in the French Alps. Reg Environ Change. 21(2). doi:10.1007/s10113-021-01760-8. [accessed 2021 Apr 26]. http://link.springer.com/10.1007/s10113-021-01760-8.

Bryman A. 2016. Social research methods. Fifth Edition. Oxford ; New York: Oxford University Press.

Buclet N, Donsimoni M. 2018. L'écologie territoriale ou comment resituer l'économie au-delà de la sphère monétaire. In: Renouveler la géographie économique,. Magali Talandier, Benard Pecqueur. (Economica).

Cei L, Defrancesco E, Stefani G. 2018. From geographical indications to rural development: a review of the economic effects of European Union policy. Sustainability. 10(10):3745. doi:10.3390/su10103745.

Comim F, Carey F. 2001. Social capital and the capability approach : are Putnam and Sen incompatible bedfellows ? Work Pap St Edmund's Coll.

Cook EM, Hall SJ, Larson KL. 2012. Residential landscapes as social-ecological systems: a synthesis of multi-scalar interactions between people and their home environment. Urban Ecosyst. 15(1):19–52. doi:10.1007/s11252-011-0197-0.

Copernicus Land Monitoring Service. 2018. Corine Land Cover (CLC) Version 2020_20u1. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=metadata.

Delfosse C. 2006. La localisation de la production fromagère : évolutions des approches géographiques. Géocarrefour. 81(4):311–318. doi:10.4000/geocarrefour.1674.

Dendoncker N, Boeraeve F, Crouzat E, Dufrêne M, König A, Barnaud C. 2018. How can integrated valuation of ecosystem services help understanding and steering agroecological transitions? Ecol Soc. 23(1). doi:10.5751/ES-09843-230112. [accessed 2020 Sep 30]. https://www.ecologyandsociety.org/vol23/iss1/art12/.

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, et al. 2015. The IPBES conceptual framework — connecting nature and people. Curr Opin Environ Sustain. 14:1–16. doi:10.1016/j.cosust.2014.11.002.

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, et al. 2018. Assessing nature's contributions to people. Science. 359(6373):270–272. doi:10.1126/science.aap8826.

Dissart J-C. 2012. Co-construction des capacités et des ressources territoriales dans les territoires touristiques de montagne: Étude de cas sur l'Oisans. Rev Géographie Alp.(100–2). doi:10.4000/rga.1781. [accessed 2021 Apr 28]. http://journals.openedition.org/rga/1781.

Dos Santos A. 2017. Labelling mountain food products in Europe- Beyond the simple quality distinction, an opportunity to join forces and build resilient food systems. [Netherlands]:

Wageningen University. [accessed 2020 Sep 24]. https://www.euromontana.org/en/our-approche/euromontanas-publications/.

Dubeuf B. 1996. La construction d'un produit de terroir haut de gamme : le Beaufort. Économie Rurale. 232(1):54–61. doi:10.3406/ecoru.1996.4784.

EC EC. 2020. Quality schemes explained. [accessed 2020 Sep 23]. https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/quality-schemes-explained_en#otherschemes.

Elmi M. 2018. The Alps in 25 maps. Bolzano; = Bozen: Permanent Secretariat of the Alpine Convention.

Evans P. 2002. Collective capabilities, culture, and Amartya Sen's development as freedom. Stud Comp Int Dev. 37(2):54–60. doi:10.1007/BF02686261.

Fagerholm N, Martín-López B, Torralba M, Oteros-Rozas E, Lechner AM, Bieling C, Stahl Olafsson A, Albert C, Raymond CM, Garcia-Martin M, et al. 2020. Perceived contributions of multifunctional landscapes to human well-being: evidence from 13 European sites. Lovell R, editor. People Nat. 2(1):217–234. doi:10.1002/pan3.10067.

Faure M. 1999. Un produit agricole « affiné » en objet culturel: Le fromage Beaufort dans les Alpes du Nord. Terrain.(33):81–92. doi:10.4000/terrain.2703.

Fedele G, Locatelli B, Djoudi H. 2017. Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst Serv. 28:43–54. doi:10.1016/j.ecoser.2017.09.011.

Filippi M, Torre A. 2003. L'organisation en réseau: de l'instauration de règles locales aux actions collectives. In: Entreprises et territoires ; les nouveaux enjeux de la proximité. La Documentation française. Dupuy Claude, Burmeister Antje.

Fischer A, Eastwood A. 2016. Coproduction of ecosystem services as human–nature interactions—An analytical framework. Land Use Policy. 52:41–50. doi:10.1016/j.landusepol.2015.12.004.

Forster J, Turner RA, Fitzsimmons C, Peterson AM, Mahon R, Stead SM. 2017. Evidence of a common understanding of proximate and distal drivers of reef health. Mar Policy. 84:263–272. doi:10.1016/j.marpol.2017.07.017.

Forsyth T. 2015. Ecological functions and functionings: towards a Senian analysis of ecosystem services: Dev Change. 46(2):225–246. doi:10.1111/dech.12154.

Fournier S. 2008. Les Indications géographiques : une voie de pérennisation des processus d'action collective au sein des Systèmes agroalimentair. Cah Agric. 17(6):547–551. doi:10.1684/agr.2008.0250.

Frey JB, Berkes F. 2014. Can partnerships and community-based conservation reverse the decline of coral reef social-ecological systems? Int J Commons. 8(1):26. doi:10.18352/ijc.408.

Garnier S. 2018. viridis: Default Color Maps from "matplotlib". R package version 0.5.1. https://CRAN.R-project.org/package=viridis. https://CRAN.R-project.org/package=viridis.

Gheyle N, Jacobs T. 2017. Content analysis: a short overview. Intern Res Note.

Grosinger J, Potts MD, Buclet N, Lavorel S. in review. Memory over matter? – A conceptual framework to integrate social-ecological legacies in agricultural NCP co-production. Sustain Sci.

Hale RL, Cook EM, Beltrán BJ. 2019. Cultural ecosystem services provided by rivers across diverse social-ecological landscapes: A social media analysis. Ecol Indic. 107:105580. doi:10.1016/j.ecolind.2019.105580.

Herzog LM, Ingold K. 2019. Threats to common-pool resources and the importance of forums: on the emergence of cooperation in CPR problem settings. Policy Stud J. 47(1):77–113. doi:10.1111/psj.12308.

Hinojosa L, Napoléone C, Moulery M, Lambin EF. 2016. The "mountain effect" in the abandonment of grasslands: insights from the French Southern Alps. Agric Ecosyst Environ. 221:115–124. doi:10.1016/j.agee.2016.01.032.

Ibrahim SS. 2006. From individual to collective capabilities: the capability approach as a conceptual framework for self-help. J Hum Dev. 7(3):397–416. doi:10.1080/14649880600815982.

IGN-F I national de l'information géographique et forestière. 2006. BD Carthage Version 3.0. http://www.sandre.eaufrance.fr/sites/default/files/IMG/pdf/1-DC_BDCARTHAGE_3_0.pdf.

IGN-F I national de l'information géographique et forestière. 2019. BD TOPO® -Base de Données Topographiques. https://geoservices.ign.fr/ressources_documentaires/Espace_documentaire/BASES_VECTORIELLES/BDTOPO/IGNF_BDTOPOr_3-0.html.

INAO (Institut national de l'origine et de la qualité). 2015. Cahier des charges de l'appellation d'origine « Beaufort ».

Jones L, Holland RA, Ball J, Sykes T, Taylor G, Ingwall-King L, Snaddon JL, S.-H. Peh K. 2020. A place-based participatory mapping approach for assessing cultural ecosystem services in urban green space. Ladle R, editor. People Nat. 2(1):123–137. doi:10.1002/pan3.10057.

Kassambara A. 2020a. ggpubr: "ggplot2" Based Publication Ready Plots. R package version 0.4.0. https://CRAN.R-project.org/package=ggpubr.

Kassambara A. 2020b. rstatix: Pipe-Friendly Framework for Basic Statistical Tests. R package version 0.6.0. https://CRAN.R-project.org/package=rstatix.

Koohafkan P, Altieri MA. 2011. Globally important agricultural heritage systems: a legacy for the future. Food and Agriculture Organisation of the United Nations Rome.

Kramer R, Tyler T. 1996. Trust in Organisations: Frontiers of Theory and Research. SAGE Publications, Inc. [accessed 2021 Apr 28]. http://sk.sagepub.com/books/trust-in-organisations.

Lamarque P, Lambin EF. 2015. The effectiveness of marked-based instruments to foster the conservation of extensive land use: The case of Geographical Indications in the French Alps. Land Use Policy. 42:706–717. doi:10.1016/j.landusepol.2014.10.009.

Leach M, Mearns R, Scoones I. 1999. Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management. :225–247.

Lee J, Park H, Kim I, Kwon H. 2020. Analysis of cultural ecosystem services using text mining of residents' opinions. Ecol Indic. 115:106368. doi:10.1016/j.ecolind.2020.106368.

Lehtonen M. 2004. The environmental–social interface of sustainable development: capabilities, social capital, institutions. Ecol Econ. 49(2):199–214. doi:10.1016/j.ecolecon.2004.03.019.

Lescourret F, Magda D, Richard G, Adam-Blondon A-F, Bardy M, Baudry J, Doussan I, Dumont B, Lefèvre F, Litrico I, et al. 2015. A social–ecological approach to managing multiple agro-ecosystem services. Curr Opin Environ Sustain. 14:68–75. doi:10.1016/j.cosust.2015.04.001.

Lessmann O, Rauschmayer F. 2013. Re-conceptualizing sustainable development on the basis of the capability approach: a model and Its difficulties. J Hum Dev Capab. 14(1):95–114. doi:10.1080/19452829.2012.747487.

Liu B, Zhang L. 2012. A Survey of opinion mining and sentiment Analysis. In: Aggarwal CC, Zhai C, editors. Mining Text Data. Boston, MA: Springer US. p. 415–463. [accessed 2020 Aug 26]. http://link.springer.com/10.1007/978-1-4614-3223-4_13.

Lunner Kolstrup C, Kallioniemi M, Lundqvist P, Kymäläinen H-R, Stallones L, Brumby S. 2013. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. J Agromedicine. 18(3):244–255. doi:10.1080/1059924X.2013.796903.

Lynch E, Harvois F. 2016. Le Beaufort: réinventer le fruit commun. Lyon: Libel.

Martín-López B, Leister I, Lorenzo Cruz P, Palomo I, Grêt-Regamey A, Harrison PA, Lavorel S, Locatelli B, Luque S, Walz A. 2019. Nature's contributions to people in mountains: a review. Saunders ME, editor. PLOS ONE. 14(6):e0217847. doi:10.1371/journal.pone.0217847.

Mascareño A, Henríquez PA, Billi M, Ruz GA. 2020. A Twitter-Lived Red Tide Crisis on Chiloé Island, Chile: What Can Be Obtained for Social-Ecological Research through Social Media Analysis? Sustainability. 12(20):8506. doi:10.3390/su12208506.

Mastrángelo ME, Pérez-Harguindeguy N, Enrico L, Bennett E, Lavorel S, Cumming GS, Abeygunawardane D, Amarilla LD, Burkhard B, Egoh BN, et al. 2019. Key knowledge gaps to achieve global sustainability goals. Nat Sustain. 2(12):1115–1121. doi:10.1038/s41893-019-0412-1.

Max-Neef M, Elizalde A, Hopenhayn M. 1989. Human scale development: an option for the future. Dev Dialogue.:1–136.

Meyer D, Zeileis A, Hornik K. 2006. The Strucplot Framework: Visualizing Multi-way Contingency Tables with vcd. J Stat Softw. 17(1):1–48. doi:10.18637/jss.v017.i03.

Meyer D, Zeileis A, Hornik K. 2020. vcd Visualizing Categorical Data. R package version 1.4-7.

Naik A. 2017. In search of farmer wellbeing. Int J Agric Manag 06 1. [accessed 2020 Sep 25]. https://ageconsearch.umn.edu/record/287265.

Neuendorf KA, Skalski PD. 2009. Quantitative content analysis and the measurement of collective Identity. In: Abdelal R, Herrera YM, Johnston AI, McDermott R, editors. Measuring Identity. Cambridge: Cambridge University Press. p. 203–236. [accessed 2020 Aug 26]. https://www.cambridge.org/core/product/identifier/CBO9780511810909A019/type/book_part.

Ostrom E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge ; New York: Cambridge University Press (The Political economy of institutions and decisions).

Ostrom E. 1999. Social capital : a fad or a fundamental concept? In: Social capital : a multifaceted perspective. World Bank. Washington, D.C: Dasgupta Partha, Serageldin Ismail. p. 172–214.

Oteros-Rozas E, Martín-López B, Fagerholm N, Bieling C, Plieninger T. 2018. Using social media photos to explore the relation between cultural ecosystem services and landscape features across five European sites. Ecol Indic. 94:74–86. doi:10.1016/j.ecolind.2017.02.009.

Pachoud C. 2019. Identity, feeling of belonging and collective action in localized agrifood systems. Example of the Serrano cheese in the Campos de Cima da Serra, Brazil. Cah Agric. 28:28. doi:10.1051/cagri/2019028.

Pachoud C, Delay E, Da Re R, Ramanzin M, Sturaro E. 2020. A relational approach to studying collective action in dairy cooperatives producing mountain cheeses in the Alps: the case of the Primiero cooperative in the Eastern Italians Alps. Sustainability. 12(11):4596. doi:10.3390/su12114596.

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U. 2016. Disentangling the pathways and effects of ecosystem service co-production. In: Advances in Ecological Research. Vol. 54. Elsevier. p. 245–283. [accessed 2020 Aug 25]. https://linkinghub.elsevier.com/retrieve/pii/S0065250415000276.

Partelow S, Jäger A, Schlüter A. 2021. Linking fisher perceptions to social-ecological context: mixed method application of the SES framework in Costa Rica. Hum Ecol. 49(2):187–203. doi:10.1007/s10745-021-00228-x.

Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Başak Dessane E, Islar M, Kelemen E, et al. 2017. Valuing nature's contributions to people: the IPBES approach. Curr Opin Environ Sustain. 26–27:7–16. doi:10.1016/j.cosust.2016.12.006.

Pelenc J, Ballet J. 2015. Strong sustainability, critical natural capital and the capability approach. Ecol Econ. 112:36–44. doi:10.1016/j.ecolecon.2015.02.006.

Pelenc J, Bazile D, Ceruti C. 2015. Collective capability and collective agency for sustainability: a case study. Ecol Econ. 118:226–239. doi:10.1016/j.ecolecon.2015.07.001.

Petway JR, Lin Y-P, Wunderlich RF. 2020. A place-based approach to agricultural nonmaterial intangible cultural ecosystem service values. Sustainability. 12(2):699. doi:10.3390/su12020699.

Poppenborg P, Koellner T. 2013. Do attitudes toward ecosystem services determine agricultural land use practices? An analysis of farmers' decision-making in a South Korean watershed. Land Use Policy. 31:422–429. doi:10.1016/j.landusepol.2012.08.007.

QSR International. 2020. NVIVO (released in March 2020). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home.

Quiñones Ruiz XF, Forster H, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Broscha K, Braito M, Altenbuchner C. 2018. How are food geographical indications evolving? – An analysis of EU GI amendments. Br Food J. 120(8):1876–1887. doi:10.1108/BFJ-02-2018-0087.

R Core Team. 2020. A language and environment for statistical computing. R foundation for statistical computing. Vienna,Austria. http://www.r-project.org.

Rauschmayer F, Polzin C, Mock M, Omann I. 2018. Examining collective action through the capability approach: the example of community currencies. J Hum Dev Capab. 19(3):345–364. doi:10.1080/19452829.2017.1415870.

Reed MS, Graves A, Dandy N, Posthumus H, Hubacek K, Morris J, Prell C, Quinn CH, Stringer LC. 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. J Environ Manage. 90(5):1933–1949. doi:10.1016/j.jenvman.2009.01.001.

Ricard D. 2015. Dairy Cooperatives in the French Mountains: Heritage, Diversity of Structures, Dynamics of Movement. Rev Géographie Alp.(103–1). doi:10.4000/rga.2751. [accessed 2021 Apr 28]. http://journals.openedition.org/rga/2751.

Rudd MA. 2000. Live long and prosper: collective action, social capital and social vision. Ecol Econ. 34(1):131–144. doi:10.1016/S0921-8009(00)00152-X.

Russell R, Guerry AD, Balvanera P, Gould RK, Basurto X, Chan KMA, Klain S, Levine J, Tam J. 2013. Humans and Nature: How Knowing and Experiencing Nature Affect Well-Being. Annu Rev Environ Resour. 38(1):473–502. doi:10.1146/annurev-environ-012312-110838.

Santini F, Guri F, Gomez y Paloma S, Institute for Prospective Technological Studies. 2013. Labelling of agricultural and food products of mountain farming. Luxembourg: Publications Office. [accessed 2020 Sep 24]. http://dx.publications.europa.eu/10.2791/67942.

Sanz Cañada J, Macías Vázquez A. 2005. Quality certification, institutions and innovation in local agro-food systems: Protected designations of origin of olive oil in Spain. J Rural Stud. 21(4):475–486. doi:10.1016/j.jrurstud.2005.10.001.

Schermer M, Darnhofer I, Daugstad K, Gabillet M, Lavorel S, Steinbacher M. 2016. Institutional impacts on the resilience of mountain grasslands: an analysis based on three European case studies. Land Use Policy. 52:382–391. doi:10.1016/j.landusepol.2015.12.009.

Schermer M, Renting H, Oostindie H. 2010. Collective farmers marketing inititatives, diversity, contextuality and dynamics. Int J Sociol Agric Food.:1–11.

Schröter M, Başak E, Christie M, Church A, Keune H, Osipova E, Oteros-Rozas E, Sievers-Glotzbach S, van Oudenhoven APE, Balvanera P, et al. 2020. Indicators for relational values of nature's contributions to good quality of life: the IPBES approach for Europe and Central Asia. Ecosyst People. 16(1):50–69. doi:10.1080/26395916.2019.1703039.

Sen A. 2000. Development as freedom. 1. Anchor Books ed. New York: Anchor Books.

Spangenberg JH, Görg C, Truong DT, Tekken V, Bustamante JV, Settele J. 2014. Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manag. 10(1):40–53. doi:10.1080/21513732.2014.884166.

SPM (Syndicat du pays de Maurienne). 2020. Schéma de cohèrence territoriale.

Stojanovic T, McNae HM, Tett P, Potts TW, Reis J, Smith HD, Dillingham I. 2016. The aspect of social-ecological systems: a critique of analytical frameworks and findings from a multisite study of coastal sustainability. Ecol Soc. 21(3). doi:10.5751/ES-08633-210315. [accessed 2020 Aug 31]. http://www.ecologyandsociety.org/vol21/iss3/art15/.

Vallet A, Locatelli B, Levrel H, Dendoncker N, Barnaud C, Quispe Conde Y. 2019a. Linking equity, power, and stakeholders’ roles in relation to ecosystem services. Ecol Soc. 24(2). doi:10.5751/ES-10904-240214. [accessed 2020 Aug 25]. https://www.ecologyandsociety.org/vol24/iss2/art14/.

Vallet A, Locatelli B, Levrel H, Dendoncker N, Barnaud C, Quispe Conde Y. 2019b. Linking equity, power, and stakeholders' roles in relation to ecosystem services. Ecol Soc. 24(2). doi:10.5751/ES-10904-240214. [accessed 2020 Aug 25]. https://www.ecologyandsociety.org/vol24/iss2/art14/.

Vourvachis P, Woodward T. 2015. Content analysis in social and environmental reporting research: trends and challenges. J Appl Account Res. 16(2):166–195. doi:10.1108/JAAR-04-2013-0027.

Weber MA, Caplan S, Ringold P, Blocksom K. 2017. Rivers and streams in the media: a content analysis of ecosystem services. Ecol Soc. 22(3). doi:10.5751/ES-09496-220315. [accessed 2020 Aug 26]. https://www.ecologyandsociety.org/vol22/iss3/art15/.

Wickham H, Averick M, Bryan J, Chang W, McGowan L, François R, Grolemund G, Hayes A, Henry L, Hester J, et al. 2019. Welcome to the Tidyverse. J Open Source Softw. 4(43):1686. doi:10.21105/joss.01686.

Zeileis A, Meyer D, Hornik K. 2007. Residual-based shadings for visualizing (Conditional) Independence. J Comput Graph Stat. 16(3):507–525. doi:10.1198/106186007X237856.

Annexes

- Supplementary materials 1: Conducted interviews
- Supplementary materials 2: Interview guide
- Supplementary materials 3: Co-production activities related to Beaufort production
- Supplementary materials 4: List of the 20 most frequent terms of the two actors' groups
- Supplementary materials 5: Qualitative description of the 12 most frequent terms
- Supplementary materials 6: Detailed chi-squared and fisher-exact tests

Interview	Actors' group	Actor	Type of actor	Position**	Professional activity
Int. 1	WB	Actor 1	Beaufort cooperative system	leading	Farmer
Int. 2	WB		Beaufort cooperative system	managing	Employee
Int. 3	OB	Actor 2	Skiing resort	managing	Employee
Int. 4	OB	Actor 3	Environmental non-government organisation	technical	Retired
Int. 5	OB	Actor 4	Environmental non-government organisation	leading	Retired
Int. 6	OB	Actor 5	Skiing resort	managing	Employee
Int. 7	OB	Actor 6	Regional authority	technical	State official
Int. 8	WB	Actor 7	Regional authority	technical	State official
Int. 9	OB	Actor 8	Agricultural association	leading	Farmer
Int. 10	OB	Actor 9	Skiing resort	managing	Employee
Int. 11	WB	Actor 10	Beaufort cooperative system	leading	Employee
Int. 12	OB	Actor 11	Industry	technical	Employee
Int. 13	OB	Actor 12	Agricultural association	technical	Employee
Int. 14	WB	Actor 13	Farmer	leading	Farmer
Int. 15	OB	Actor 14	Skiing resort	managing	Employee
Int. 16	OB	Actor 15	Pastoral land association	leading	Employee
Int. 17	OB	Actor 16	Pastoral land association	leading	Retired
Int. 18	WB	Actor 17	Slaughterhouse	leading	Farmer
Int. 19	WB	Actor 18	Agricultural association	leading	Farmer
Int. 20	WB	Actor 19	Agricultural association	leading	Farmer
Int. 21	OB	Actor 20	National forestry office	managing	State official
Int. 22	OB	Actor 21	Local authority	leading	State official
Int. 23	WB	Actor 22	Agricultural association	leading	Farmer
Int. 24	OB	Actor 23	Regional authority	technical	State official
Int. 25	OB	Actor 24	Skiing resort	managing	Employee
Int. 26	WB	Actor 25	Beaufort cooperative system	technical	Farmer
Int. 27	WB	Actor 26	Farmer	leading	Farmer
Int. 28	OB	Actor 27	Local authority	leading	State official
Int. 29	WB	Actor 28	Farmer	leading	Farmer
Int. 30	OB	Actor 29	Pastoral land association	leading	Retired
Int. 31	WB	Actor 30	Agricultural association	technical	State official
Int. 32	OB	Actor 31	Cultural association	technical	Employee
Int. 33	OB	Actor 32	Pastoral land association	leading	Retired
Int. 34	OB	Actor 33	Pastoral land association	leading	Retired
Int. 35	OB	Actor 34	Skiing resort	managing	Employee
Int. 36	WB	Actor 35	Agricultural association	leading	Farmer
Int. 37	WB	Actor 36	Beaufort cooperative system	leading	Farmer
Int. 38	WB	Actor 37	Agricultural association	technical	Employee
Int. 39	WB	Actor 38	Beaufort cooperative system	managing	Employee
Int. 40	OB	Actor 39	Regional authority	managing	State official
Int. 41	OB	Actor 40	Farmer	leading	Farmer
Int. 42	OB	Actor 41	National Park	technical	State official
Int. 43	OB	Actor 42	Skiing resort	managing	Employee
Int. 44	OB	Actor 43	Pastoral land association	leading	Retired

Table 1: Overview of conducted interviews with the corresponding actors characteristics (WP: Within Beaufort production, OB: Outside Beaufort production). Leading: encompasses mainly representative roles such as president and chairs. Formulating and defending the large principles of the association. Managing: controlling and directing these principles, Technical: executing these principles). Interview 1 and 2 represent one actor (the same cooperative)

Supplementary materials 2: Interview guide

First part: Interviewee/institution presentation

1. Could you present yourself, your profession and your background?

2. Could you present your institution and the history of your institution?

1. What is the main activity of your institution in relation to the agricultural sector in the Maurienne?

2. How many people are working in your institution?

3. How many members are affiliated/controlled by your institution?

Second part: interactions with other actors

4. Who are the other actors you are working with?

5. Do you have relations to …. (name of different institutions)

6. Who is in your mind the most powerful (in terms of decision-making) actor in the agricultural sector of the Maurienne?

7. Who is in your mind the most competent (knowledge) actor in the agricultural sector in the Maurienne?

8. With whom would you like to work more together?

Third part: Describing the agricultural sector in the Maurienne valley

9. How do you describe the agricultural sector in the Maurienne?

10. What are the challenges of the agricultural sector in the Maurienne?

11. How do you see agriculture in the Maurienne in 2050?

12. Do you think that climate change will have an impact on the agricultural sector?

Fourth part: Co-production activities

13. How to you intervene in the management of pasture land?

14. Can you describe the milking process in summer and in winter? How long does it take you?

15. How many hours are you working per week?

16. What is your motivations?

17. What would you improve if you could?

18. What do you think about the specification requirements of Beaufort cheese? [**Only for actors of the Beaufort cooperative system]**

Supplementary materials 3: Co-production activities related to Beaufort production

Table 2: Detailed description of the different co-production activities observed for Beaufort production.

NCP co-production activities		**Description**	**Detailed co-production activities**	**Citation**
CP1- fodder production	Modifying the share of regional fodder	Current Beaufort PDO requires a minimum share of 75% of regional fodder. Some actors suggested to maintain, soften, or increase this value.	Link the historical background with present co-production activities	*"The fight was hard between the ones who wanted more quantity and those who wanted more quality"(Int. 11, Employee,WB, 07/2019)*
			Maintain or modify the regional fodder specifications	*"We made some temporary exceptions regarding the share of regional fodder a few years ago. But, at the moment, we don't ask ourselves to ease that requirement, there is too much behind it." (Int. 11, Employee, WB, 07/2019)*
	Land extension	Actors' different strategies to fight against land fragmentation. It includes land acquisition, land exchange, and the collaborative management of pastures through land pastoral associations.	Consolidate fragmented land by land pastoral association	*"If the people are not interested in having a land pastoral association, I'm sorry for them, but it has to come from them, not from us."(Int. 38, State official, OB, 07/2019)*
			Exchange land with public and private land owners	*"If there is a farmer who don't want to exchange land he not only punishes himself, but also the others. But this land exchange demands a lot of reflections."(Int. 26, Farmer, WB, 08/2019)*
			Rent land with varying conditions	*"As soon as someone dies you call the family. You need to react immediately, if not someone else will get the land ."(Int. 14, Farmer, WB 02/2019)*
	Improving the technological equipment	Irrigation systems, additional seeding or machinery.	Maintain permanent existing irrigation	*"Last year I was self-reliant for the first time. With irrigation it's possible to make a second harvest on the same surface."(Int. 27, Farmer,WB, 02/2019)*
			Undertake planned irrigation projects	*"With climate change, irrigation is indispensable."(Int.1, Farmer,WB, 07/2019)*
			Access new machinery	*"Today, everybody has its own tractor, there is no sharing anymore."(Int. 1, Farmer, WB 07/2019)*
			Pursue additional seeding	*"If you irrigate, you also need to seed so you can make a second cut. "(Int. 27, Farmer,WB 02/2019)*
	Managing the crop calendar	Agricultural practices implemented on farm: harvest dates, grazing duration, permanent or temporary herd size.	Decide on harvest dates	*"Usually I hay the first time in May, the grass grows better afterward." "(Int. 20, Farmer, WB 10/2019)*
			Grazing duration	*"I stay less time in the mountains, I return end of September and cows graze on the bottom of the valley. If they stay up there, they give less milk. "(Int. 20, Farmer, WB, 10/2019)*
			Change of permanent or temporary herd size	*"In winter I bring the cows back to Chambery (town outside the Beaufort zone), so I have more time."(Int. 23, Farmer, WB, 08/2019)*
CP2- milk transfer from farm to cooperative level	Local cattle breeds	Beaufort PDO currently allows only two low-yielding (5.000 l/yr) regional breeds for milk production: Tarine and Abondance.	Type of cattle for agricultural production	*"But what is behind the colour of a cow is a real fight over a production system." "(Int. 11, Employee, WB, 07/2019)*
	Improving milk quality	Milk quality is frequently controlled by cooperatives.	Maintain product properties such as protein and fat content	*"You cannot do what you want. Everybody needs to deliver good milk quality." (Int. 37, Farmer,WB, 10/2019)*

		Beaufort PDO and national regulations define quality rules.	Maintain sanitary conditions and animal health	*"For me, the biggest problem is the renowned mammitis"(Int. 29, Farmer, WB, 02/2019)*
	Increasing milk quantity	Milk quantity produced on-farm is restrained by a quota system, often contested by actors. In addition, the variability of milk production during the year is difficult for cooperatives to manage (milk shortages).	Plan milk quantity on cooperative level	*"There is a real risk of losing quantity, we have producers where nobody knows if somebody will take the farm after them."(Int. 39, Employee, WB, 08/2019)*
			Plan milk quotas on farm level	*"I try to keep my quota, I try to increase my herd size in the next years. "(Int. 14, Farmer, WB, 02/2019)*
	Improving milk quality	Milk quality is frequently controlled by cooperatives. Beaufort PDO and national regulations define quality rules.	Maintain product properties such as protein and fat content	*"You cannot do what you want. Everybody needs to deliver good milk quality." (Int. 37, Farmer, WB, 10/2019)*
			Maintain sanitary conditions and animal health	*"For me, the biggest problem is the renowned mammitis."(Int. 29, Farmer, WB, 02/2019)*
	Transporting milk from farm to cooperative	Cooperatives collect milk daily from the individual farms.	Cooperatives collect milk	*"It's easy. The trucks leave at 6:30 and at 9:15 everybody is back." (Int.39, Employee, WB, 08/2019)*
			Quality of road infrastructure	*"We are really accessible, even the pasture land is well connected We have very good roads." (Int. 1, Farmer, WB, 07/2019)*
CP3-product sale	Socioeconomic livelihood	Economic benefits and quality of life generated by Beaufort production.	Financial security	*"Here, if there wouldn't be the Beaufort, there would be no agriculture here." (Int. 1, Farmer, WB, 07/2019)*
	Landscape appearance	Appreciation of landscape aesthetics	Feelings about landscape	*"We need to maintain this image ,this identity, the landscape needs to stay open. We need to preserve this."(Int. 24, State official, OB, 07/2019)*
	Personal satisfaction	Actors' subjective feelings about Beaufort production and Alpine agricultural systems.	Feel positive or negative about professional activity	*"It's more a passion and less a work."(Int. 26, Farmer, WB, 08/2019)*
	Balancing work life ratio	The ratio between leisure and working time.	Feelings about time resources	"*I also want to see my daughter. Sometimes she asks me when I will sell the cows."(Int. 14, Farmer, WB, 02/2019)*

Supplementary materials 4: List of the 20 most frequent terms for the two actors' groups

Most frequent terms were identified using NVIVO built-in tool for word frequency analysis across all interviews (QSR International 2020). For the detailed sentiment analysis, we selected the 16 most frequent terms. Word stems of the term "agriculture" (first line of Table 2) were not further analyzed, as this was the general focus of the interviews. For each of these 16 terms, we conducted a sentiment analysis. We used a four-level Likert-scale (very positive, moderately positive, moderately negative, very negative), to code and systemize interviewee's overall feeling associated to each of the 16 frequent terms. Sentiments were coded manually using NVIVO node system, considering the whole sentence (i.e. the 10 words preceding and following each of the 16 frequent terms) and the general context of the discussion with the interviewee (Liu and Zhang 2012; Neuendorf and Skalski 2009). For coding the sentiments, we used both singular and plural forms of each term, but not stemmed words. These terms corresponded only to noun words.

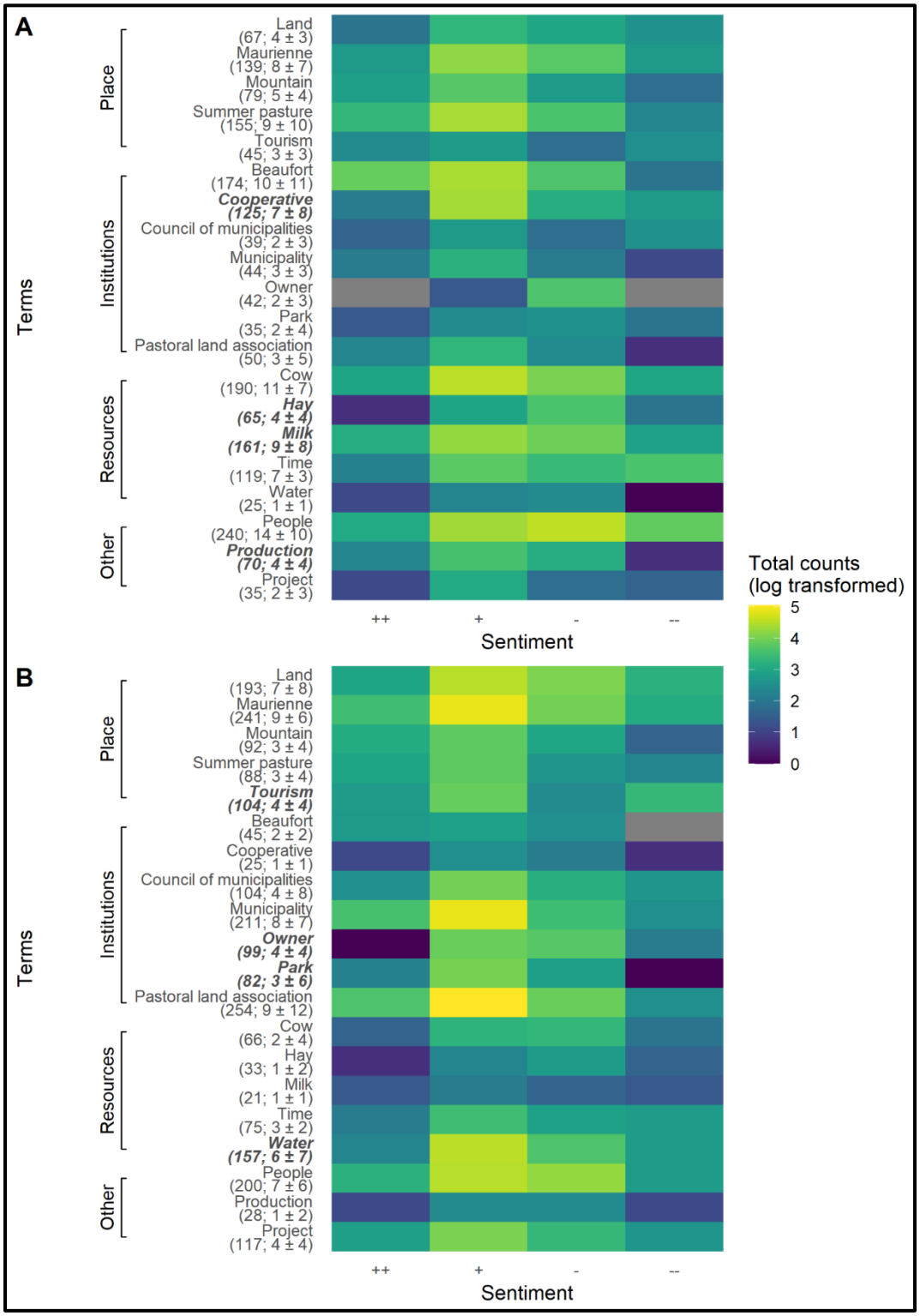
Very positive sentiments corresponded to sentences where interviewees used highly sentiment-loaded words such as "admire" and "love", and very negative sentiments to sentences with overall negative words such as "struggle" or "difficult". Moderately positive and moderately negative categories corresponded to less obvious negative or positive meaning. If a given term was used repeatedly several times in the same sentence, sentiment analysis was conducted for only one of the occurrences, not for each. Therefore, the total number of term occurrences does not always match with the number of coded occurrences, which is the variable used in the results (Table 3.

*Table 3 and Table 4: Overview of the 20 most frequent noun words with their French translation (original language) of WB group (Table 3) and OB group (Table 4). We only analysed the 16 most frequent terms for each group.*indicates the terms specific to the group*

	Terms of the WB group	**Terms in French (original language)**	Number of occurences	Number of coded occurences	Weighted Percentage (%)
1	People	gens	513	240	0.54
2	Beaufort*	Beaufort	392	174	0.41
3	Cow	Vaches	375	190	0.39
4	Maurienne	Maurienne	352	139	0.37
5	Milk	Lait	345	161	0.36
6	Time	Temps	263	119	0.28
7	Summer pasture	Alpages/alpage	393	155	0.23
8	Cooperative*	Coopérative	202	125	0.21
9	Production*	Production	157	70	0.16
10	Mountain/mountains	Montagnes	151	79	0.16
11	Hay*	Foin	144	65	0.15
12	Land	Terrain	140	67	0.15
13	Project/projects	Projets	136	35	0.14
14	Municipality	Commune/Commune	135	44	0.14
15	Land pastoral association	AFP	134	*50*	0.14
16	Council of municipalities	Comcom	124	*39*	0.13
17	*Machinery cooperatives (CUMA= (Coopérative d'Utilisation de Matériel Agricole)*	*CUMA*	*124*	-	*0.13*
18	*Zone*	*zone*	*122*	-	*0.13*
19	*Tourism*	*tourisme*	*117*	-	*0.12*
20	*Book (used to refer to the PDO specifications)*	*cahier*	*105*	-	*0.11*

	Terms of the OB group	**Terms in French (original language)**	Number of occurences	Number of coded occurences	Weighted Percentage (%)
1	People	Gens	521	200	0.45
2	Maurienne	Maurienne	521	141	0.45
3	Land pastoral association	AFP	373	254	0.3
4	Municipality	commune/communes	348	211	0.30
5	Cow	Vaches	305	66	0.26
6	Land	Terrain	287	183	0.25
7	Beaufort	Beaufort	281	75	0.24
8	Time	Temps	253	75	0.22
9	Water*	Eau	211	157	0.18
10	Council of municipalities	Comcom	197	104	0.17
11	Tourism*	Tourisme	196	104	0.17
12	Summer Pasture	Alpages	195	88	0.17
13	Mountain	Montagne/montagnes	184	92	0.16
14	Project	Projet/projets	179	117	0.15
15	Park*	Parc	171	*82*	0.17
16	Owner*	Propriétaires/propriétaire	139	*99*	0.12
17	*Irrigation*	*Irrigation*	*145*	-	*0.12*
18	*Place*	*Place*	*128*	-	*0.11*
19	*Region*	Région	*113*	-	*0.11*
20	*Production*	Production	*110*	-	*0.09*

Figure 1: Terms frequency and sentiment analysis for the different groups of actors. Sentiment analysis is presented in the first upper two panels for (A) the within Beaufort production group, and (B) the outside Beaufort production group. On the y-axis, total counts for each term are presented in parenthesis, followed by mean counts and standard deviation over all actors of the group. The terms highlighted in bold and italics are those that are specific to each group. The lower panel (C) shows quotes distribution in the three term categories (i.e. different terms were considered to calculate the frequencies in the two groups). We grouped the term park in the category institution, as actors predominantly referred to them as a regulatory authority. .



Supplementary materials 5: Qualitative description of the 16 most frequent terms

Table 2: Qualitative description of the 15 most frequent terms in the interviews. Terms in brackets correspond to the original French term.

Category	Terms	Description	# of quotes	Representative citations
Place	Land (terrain)	Not further specified land use class	WB: 67 OB: 183	*"Here, there is no piece of land left. Everything is used."(Int. 1, Farmer, WB, 07/2019)*
	Maurienne	The name of the studied valley	WB: 139 OB: 141	*"They have a really strong culture in the Maurienne here, for that the agricultural activity is still really dynamic". (Int. 8, State official, OB, 07/2019)*
	Mountain (montagne)	Significant landscape feature in the Alpine region	WB: 79 OB: 92	*"Today people can live in the mountains because they have a common economic activity". (Int. 43, Employee, OB, 04/2019)*
	Summer pasture (alpage)	Important land use class in Alpine agriculture and landscape aesthetics	WB: 155 OB: 88	*"One knows that the quality of cheese is related to the quality of the mountain pastures, for that we need to take care of them."(Int. 11, Employee, WB, 07/2019)*
Institutions	Beaufort	Cooperative cheese production system	WB: 174 OB: 75	*"Agriculture in the Maurienne is the Beaufort, it's like that!" (Int. 7, State official, OB, 07/2019)*
	Council of municipalities (communauté de communes)	Federation of municipality Specific French administrative system	WB: 39 OB: 104	*"But in general, in terms of agriculture the Comcom does nothing. They don't have the competence. It's a lot of tourism, waste management, but no agriculture." (Int. 41, Farmer, OB, 08/2019)*
	Municipality (commune)	Local administrative unit in France	WB: 44 OB: 211	*"For us, the cooperative, the municipality is our first contact partner." (Int. 39, WB, Employee, 08/2019)*
	Pastoral land association (AFP)	Association of public and private land owners to consolidate fragmented land	WB: 50 OB: 254	*"If there wouldn't be the pastoral land associations, we wouldn't have pasture land around the summits anymore". (Int. 16, Employee, OB, 07/2019)*
Resources	Cow (vache)	Mostly referred to as the low yielding local cattle breeds Abondance and Tarine. To a lesser extent other type of cattle	WB: 190 OB: 66	*"The only interest of a cow is that she can transform grass to milk, if you feed here cereals you lose the connection to the region immediately." (Int. 2, Employee, WB, 07/2019)*
	Time (temps)	Measured period of a process, situation or action	WB: 119 OB: 75	*"There are many farmers having a problem with time, but we don't have a solution for that." (Int. 39, Employee, WB, 08/2019)*

Other	People (gens)	General term to describe other, not further specified persons	WB: 240 OB: 200	*"Here, the people are very individualistic, they want to work alone." (Int.1, Farmer, WB, 07/2019)*
	Project (projet)	Specific individually or collectively coordinated activities	WB: 35 OB: 117	*"We don't have a project in common, but we still meet each other."(Int. 13, Employee, OB, 06/2019)*

Supplementary materials 6: Detailed chi-squared and fisher-exact tests

We analyzed whether term frequencies and sentiment levels varied between the two groups of actors (WB and OB groups) using Student t tests. The tests were computed with R, and the tidyverse (Wickham et al. 2019), ggpubr (Kassambara 2020a), rstatix (Kassambara 2020b) and viridis (Garnier 2018) packages.

*Table 3: Results of the Student t tests for each term separately (ns: non-significant, * p-value <0.05, ** p-value < 0.01). For each group, mean number of quotes by actor is calculated, as well as standard deviation (mean ± standard deviation).*

	Terms	**WB group**	**OB group**	**Adjusted p-value**	**Significativity**
1	Land	2 ± 3	4 ± 4	0.0842	ns
2	Maurienne	4 ± 4	1 ± 2	0.7150	ns
3	Mountain	14 ± 10	7 ± 6	0.3541	ns
4	Summer pasture	1 ± 1	6 ± 7	0.0546	ns
5	Tourism	7 ± 3	3 ± 2	0.3200	ns
6	Beaufort	9 ± 8	1 ± 1	0.0141	*
7	Cooperative	4 ± 4	1 ± 2	0.0141	*
8	Council of municipalities	11 ± 7	2 ± 4	0.4155	ns
9	Municipality	3 ± 5	9 ± 12	0.0074	**
10	Owner	2 ± 4	3 ± 6	0.3500	ns
11	Park	2 ± 3	4 ± 4	0.5400	ns
12	Pastoral land association	3 ± 3	8 ± 7	0.0383	*
13	Cow	2 ± 3	4 ± 8	0.0013	**
14	Hay	7 ± 8	1 ± 1	0.0304	*
15	Milk	10 ± 11	2 ± 2	0.0017	**
16	Time	3 ± 3	4 ± 4	0.0013	**
17	Water	9 ± 10	3 ± 4	0.0120	*
18	People	5 ± 4	3 ± 4	0.0383	*
19	Production	8 ± 7	9 ± 6	0.0141	*
20	Project	4 ± 3	7 ± 8	0.0766	ns

*Figure 21: Results of Student t tests with detailed sentiments levels for each term belonging to the "place" category (++=very positive, +=moderately positive, -=moderately negative, --=very negative, * p-value <0.05, ** p-value < 0.01, *** p-value < 0.001, **** p-value < 0.0001*

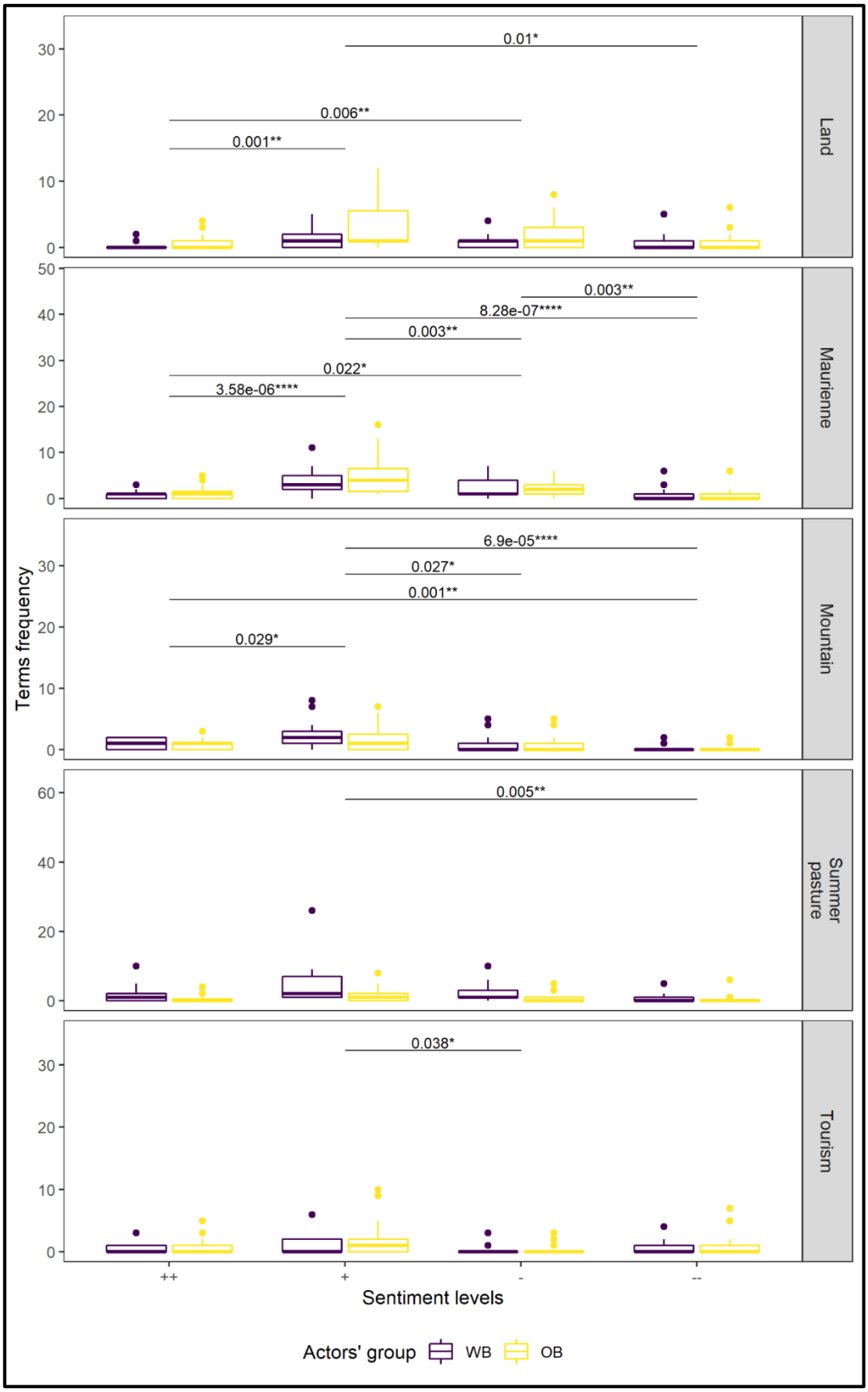


*Figure 3: Results of Student t tests with detailed sentiments levels for each term belonging to the "institutions" category (++=very positive, +=moderately positive, -=moderately negative, --=very negative, * p-value <0.05, ** p-value < 0.01, *** p-value < 0.001, **** p-value < 0.0001).*

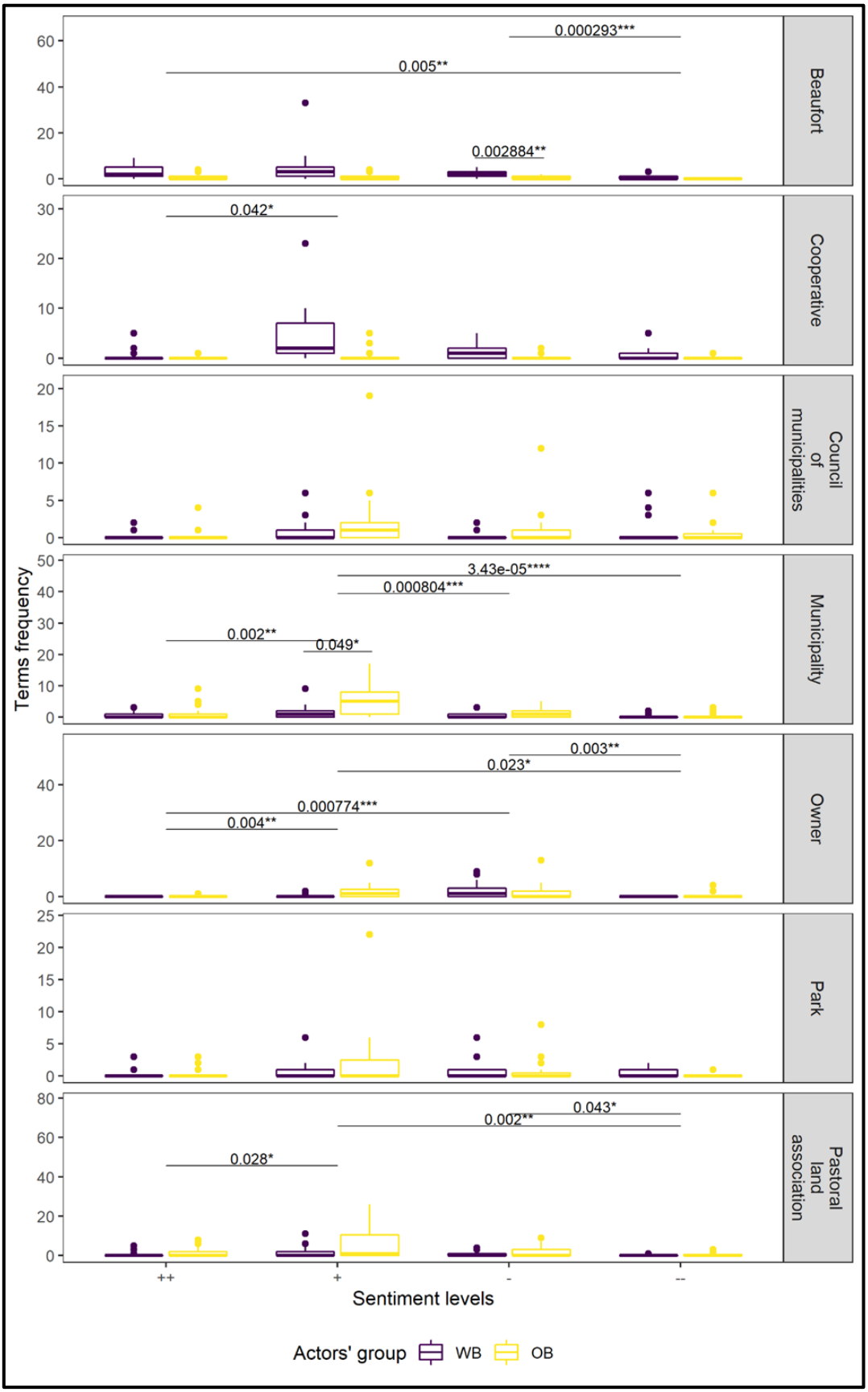
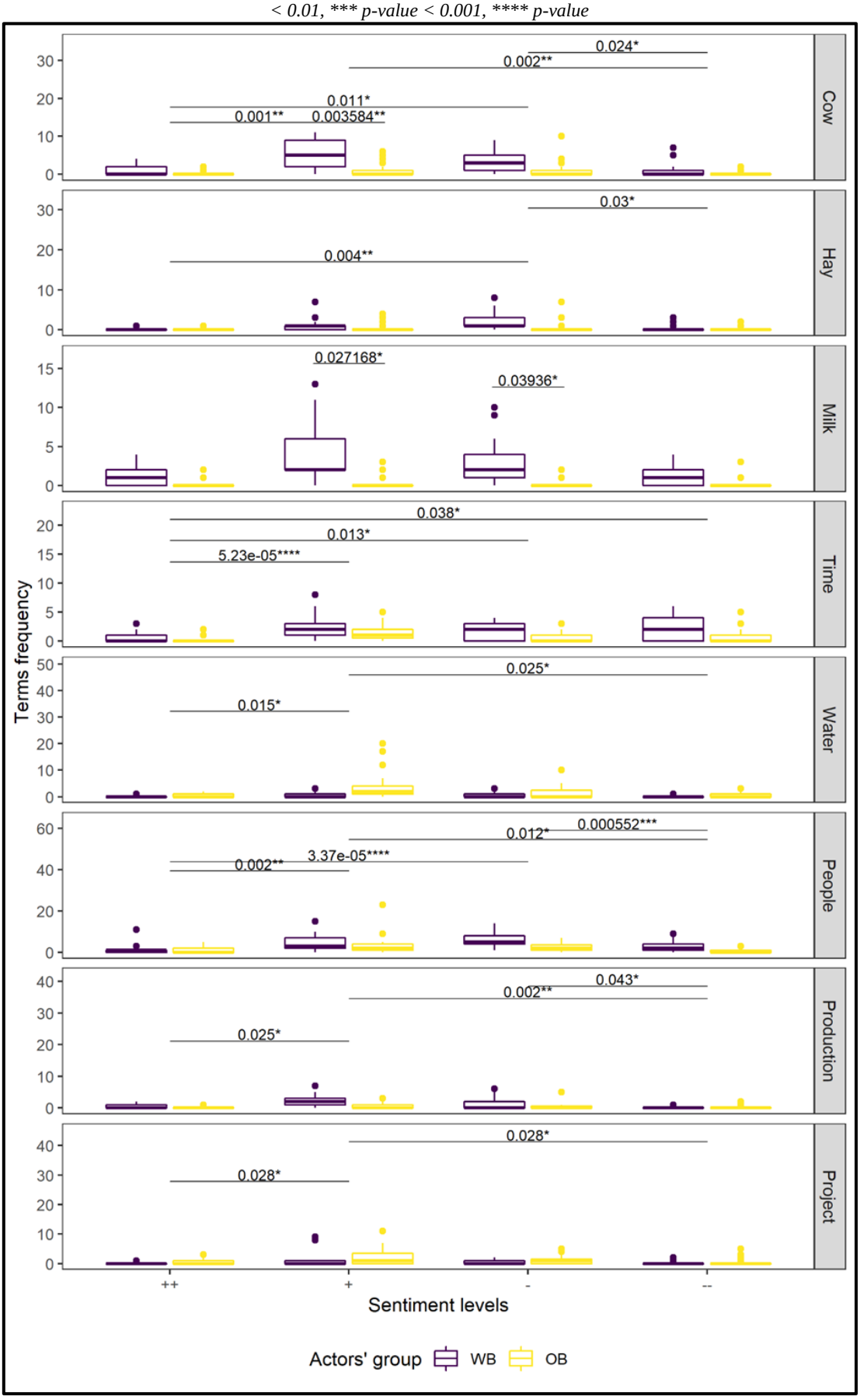


*Figure 4: Results of Student t tests with detailed sentiments levels for each term belonging to the "resources" and "other" categories (++=very positive, +=moderately positive, -=moderately negative, --=very negative, * p-value <0.05, ** p-value < 0.01, *** p-value < 0.001, **** p-value*



Supplementary materials references

Liu, B., and Zhang, L. (2012). A Survey of opinion mining and sentiment Analysis. In Mining Text Data, C.C. Aggarwal, and C. Zhai, eds. (Boston, MA: Springer US), pp. 415–463.

Neuendorf, K.A., and Skalski, P.D. (2009). Quantitative content analysis and the measurement of collective Identity. In Measuring Identity, R. Abdelal, Y.M. Herrera, A.I. Johnston, and R. McDermott, eds. (Cambridge: Cambridge University Press), pp. 203–236.

QSR International (2020). NVIVO (released in March 2020).

Chapter V- A quantitative comparison of the co-production of nature's contributions to people across a territory

Alpine valleys feature a variety of different landscape characteristics (credits: Bruno Locatelli/2018)

We translated the conceptual framework (see chapter III) and our findings of chapter IV that demonstrated the relevance of the Beaufort production system for local identities into a quantitative social-ecological resource analysis across the heterogeneous municipalities that fall within the boundaries of the Beaufort production system. In doing this, we were interested to answer the main scientific question: “What is the interplay of social-ecological resources for NCP co-production in a heterogeneous territory? “ We specifically enquired:

- Which social-ecological resources are involved in this NCP co-production?
- What is the role of the geographical, historical and social context of the associated NCP co-production chain?
- What is the role of community-based institutions in NCP co-production?

We showed that biophysical constraints and external drivers from tourism shape the agricultural management of ecosystems. Hierarchical clustering allowed us to establish a typology of three municipal archetypes. Our analysis showed that each of the three cooperatives assembles at least two of these archetypes. We showed that the cooperative production system could buffer biophysical and economic differences by a common rule set and the logics of production across a territory. These findings suggest the relevance of collective structures for fostering regional development at territorial scale.

This chapter is presented in the form of an article and is submitted to the Journal Mountain Research and Development.

Grosinger, J.; Grigulis, K.; Elleaume, N.; Buclet, N.; Lavorel S. Archetypes of co-production in a cooperative cheese system of a French Alpine valley. Mountain Research and Development (under revision)

Archetypes of co-production in a cooperative cheese system of a French Alpine valley

Grosinger Julia[1,2], Karl Grigulis[2], Nicolas Elleaume[2], Buclet Nicolas[1], Lavorel Sandra[2, 3]

Article is submitted to Mountain research and development.

[1] Université Grenoble Alpes, CNRS, Sciences Po Grenoble, PACTE, 38000 Grenoble, France
[2] Laboratoire d'Ecologie Alpine, CNRS – Université Grenoble Alpes – Université Savoie Mont-Blanc, 38000 Grenoble, France
[3]Manaaki Whenua – Landcare Research, Lincoln, New Zealand

Abstract

Livestock systems are vital to socioeconomic livelihoods in mountain territories, yet quantitative analyses of their diverse modes of production beyond farm level are missing. We used the concept of Nature's contributions to people (NCP) to account for these various society-ecosystem interactions. We investigated the role of biophysical constraints, resources and community based institutions (CBI) for agricultural production at municipal scale. We asked: what are the driving variables that govern the agricultural system at municipal scale in a mountain territory and what is the role of territorial community based institutions? Based on qualitative research with local informants we identified the most relevant resources for agricultural production in 56 municipalities that are part of a cheese producing CBI in the Maurienne valley (French Alps). Correlation analyses showed how biophysical constraints and external drivers from tourism shape the agricultural management of ecosystems. The inductive clustering to three municipal archetypes suggested that CBI could buffer resulting differences in economic outcomes. Our results display how such mixed-methods analyses can inform policy-making in heterogeneous mountain territories.

Keywords: mountain agriculture, social-ecological systems, community based institutions, nature's contributions to People (NCP), co-production

1. Introduction

Agricultural livelihoods in mountain areas are deeply embedded in unique social-ecological contexts. In the European Alps these local systems enact different society-ecosystem interactions against diverse biophysical and resource backgrounds (Martín-López et al. 2019a; Altaweel et al. 2015). These heterogeneous settings coupled with a variety of institutions at different scales and entry points complicate assessments of the functioning of agricultural systems at territorial scale. Comparative, bottom-up typologies offer solutions to facilitate territorial-level understanding beyond their social ecological heterogeneities.

The social-ecological systems (SES) perspective identifies societies and their associated production systems (e.g. agriculture) as embedded, interdependent actors on the biosphere (Folke 2006; Anderies, Janssen, and Ostrom 2004). Research needs to identify and analyse the different social and ecological components that underpin socioeconomic activities and their social ecological contexts (Ostrom 2009). In line with research on natural resource management we broadly term these components "resources", including social (e.g. infrastructure, knowledge) and ecological (e.g. biomass, livestock) elements (Anderies, Janssen, and Ostrom 2004; McGinnis 2011). Their use depends on social preferences and is frequently governed by formal or informal institutions with differing rule sets and management practices across spatial (e.g. local, regional, national) scales (Spangenberg et al. 2014; Ostrom 1990). We consider the intermediate scale of 'territories' (e.g. a mountain valley) as suited to consider these deep interlinkages (Ostrom 1990; Barreteau et al. 2016).

The concept of nature's contributions to people (NCP), defined as "all contributions, beneficial or harmful, that individuals, communities, societies, nations or humanity as a whole derive from nature" (Díaz et al. 2015) emphasises the social dynamics that underlies society-ecosystem-interactions (Chan, Gould, and Pascual 2018; Fedele, Locatelli, and Djoudi 2017). Social structures determine NCP desired by a society, and are actively involved in coordinating resources to manage ecosystems for NCP production (Spangenberg et al. 2014). This process is defined as NCP-co-production. It describes the ways societies organise and implement social resources to mobilise flows from nature to deliver NCP (Bruley et al. 2020; Palomo et al. 2016; Lele et al. 2013; Grosinger, Potts, et al. in review). We have previously shown how the cascade framework (Haines-Young and Potschin 2010; Fedele, Locatelli, and Djoudi 2017) can be implemented to structure the different resources and actors (e.g. institutions) in four successive steps of human intervention along an NCP co-production chain (Bruley et al. 2021; Grosinger, Potts, et al. in review). Co-production step 0 (CP0; organising) describes how society organises

a rule set for the following steps (Ostrom 1990). Co-production step 1 (CP1; management) describes ecosystem management, such as grazing livestock and, in agriculture, mainly takes place at farm level. Co-production step 2 (CP2; mobilisation) refers to the mobilisation of outputs from the SES, such as milking or haymaking. Co-production step 3 (CP3; appreciation) underpins the translation to a final NCP benefit, e.g. milk, and transformed dairy products.

Collective structures are key to the organisation of social resources in NCP co-production (Anderies, Janssen, and Ostrom 2004; Cumming et al. 2020). Institutions are defined as "the ways in which people and societies organise themselves and their interactions with nature at different scales" (Díaz et al. 2015). Higher-scale institutions (e.g. (supra) national, regional, local governments) are usually indirect drivers of NCP co-production at CP0 for instance by regulations, subsidies or technical support (Vatn 2005). At local scales community-based institutions (CBI) often play a crucial role by collectively agreeing to specific rule sets to organise resources within their SES (Ostrom 1990; Bennett et al. 2015; McGinnis 2011). These rule sets are specific and rarely transferable (Ostrom 2005; De Moor 2011). CBI can mitigate perceived power imbalances of local actors who feel overruled by higher-scale institutions (e.g. national parks) (Gómez-Baggethun et al. 2013; Vatn 2005; Maciejewski et al. 2015). Further they can buffer social-ecological differences across members, e.g. by providing infrastructure or trading opportunities (Ostrom 1990). CBI are crucial in European mountain livestock systems. Qualitative analyses have demonstrated their importance within agricultural territories (Schermer et al. 2016; Pachoud et al. 2020). However they have so far been poorly included in quantitative SES analyses (Muhar et al. 2018; Martín-López et al. 2019b). One of the reasons why CBI have remained underexplored might be their context dependency (Ostrom 1990). We contend that this could be alleviated by a comparative analysis across similar social-ecological contexts (Sietz et al. 2019).

Archetype analysis can help identifying and understanding recurrent patterns in variables and processes that shape SES dynamics (Oberlack et al. 2019). Inductive archetype analyses could facilitate sustainability theory development and applications, by distinguishing effects of social-ecological context from generic social-ecological processes (Rocha et al. 2020). They could help transfer management practices or certain innovations in NCP co-production systems across local SES (Eisenack et al. 2019). Thereby, they could advance generic understanding of SES functioning at territorial scale (Ostrom 1990; Rocha et al. 2020). Some local inductive typologies, such as for irrigation systems in Spain (Villamayor-Tomas, Iniesta-Arandia, and Roggero 2020) or mountain communities (Altaweel et al. 2015) describe constellations of

collective structures, but overall knowledge of how CBI play out in SES archetypes is missing (Rocha et al. 2020; Altaweel et al. 2015). Furthermore, the impact of a same CBI across heterogeneous local entities like municipalities has not yet been studied.

In this paper we aimed to analyse how agricultural production systems in different social-ecological contexts function within a common, homogenous CBI rule set, and to identify NCP co-production archetypes that coexist regionally. Specifically we asked in the case of a cooperative system of alpine cheese production:

(1) Which social-ecological resources are involved in tNCP co-production?

(2) What is the role of the geographical, historical and social context of the associated NCP co-production chain?

(3) What is the role of community-based institutions (CBI) in NCP-co-production?

2. Methodology

2.1. Study site

The Maurienne valley is located in the French Northern Alps (Figure 1). The valley spans almost 120 km and hosts ~ 40,000 people in 62 mainly rural municipalities (SPM 2020). Municipalities differ in wealth (gross domestic product/capita: 55,200–73.000 US$; unemployment rate: 2.7%–27.5%); size (50-1,640 km²); median altitude (500-2,700 m) and population density (3-85 inhabitants/km²). The territory's economy largely reflects the general picture of European mountain areas with strong winter tourism, some industry and to a far lesser extent agriculture (EC 2009; SPM 2020).

The main agricultural sector is the production of the Beaufort raw cow milk cheese by a cooperative system. Beef and small livestock (sheep, goat) are much less institutionalized (SPM 2020). 66% of small livestock grazing is based on transhumant herds from outside the valley (SPM 2020). Outside farmers have, despite the necessary land use contracts, little socioeconomic ties with the local population.

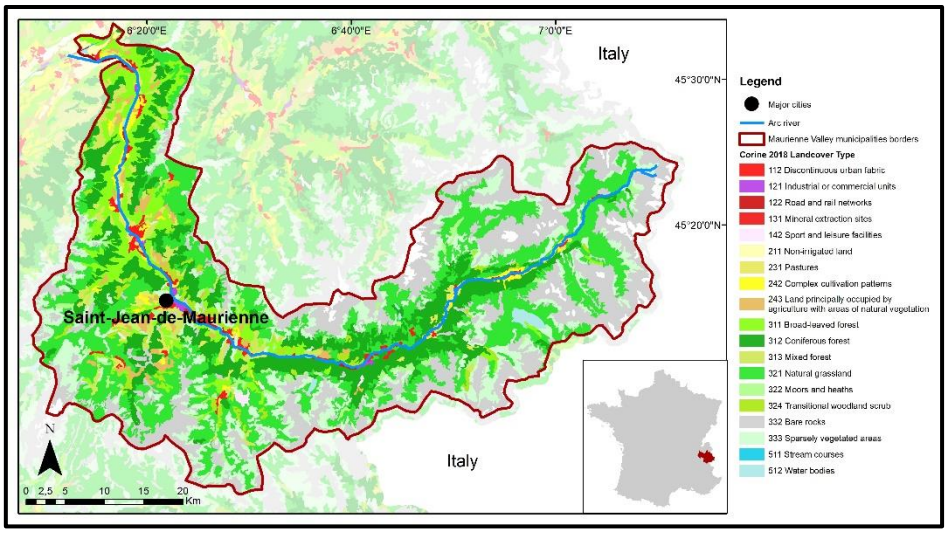


Figure 1: Location and land cover of the study area

2.2. Materials

We investigated the 56 municipalities as a heterogeneous set of local SES (Hanspach et al. 2016). We used qualitative methods to structure a quantitative analysis of municipality archetypes (Meinzen-Dick, DiGregorio, and McCarthy 2004).

We conducted 43 interviews with local actors to understand the functioning of the NCP co-production chain within the territory between February to September 2019 (Grosinger, Vallet, et al. in review; Grosinger, Potts, et al. in review). We combined this information with literature research and formalised it as a mental model of the different steps of co-production (Figure 2).

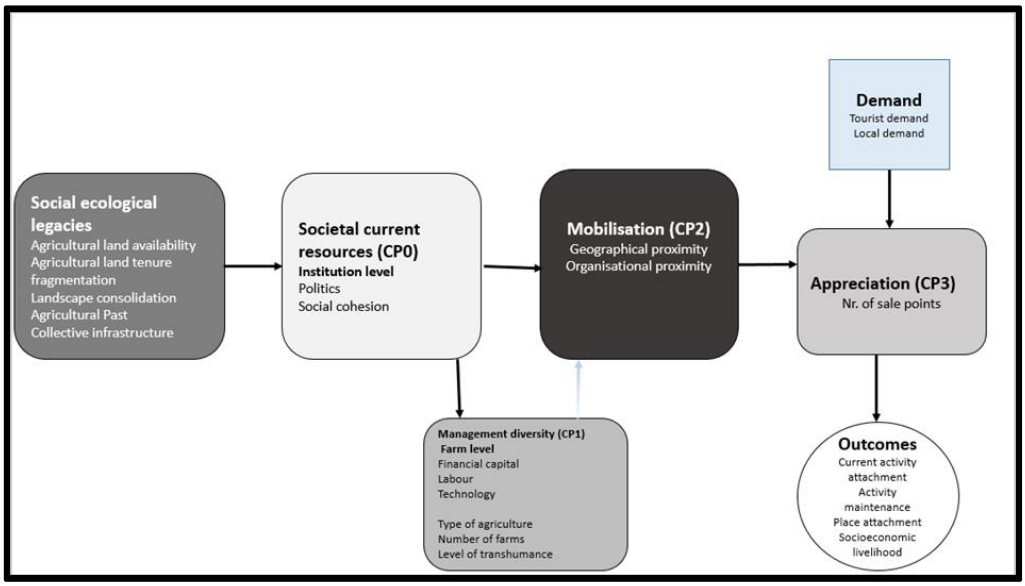


Figure 2: Mental model of the Beaufort co-production chain underpinning the quantitative analysis

Then we identified and quantified social-ecological indicators of NCP co-production steps (Table 1 / SM1). We selected indicators based on actor knowledge, their direct relations to agricultural production, their comprehensiveness and their ability to inform long-term trends (Windhorst, Müller, and Wiggering 2004). We prioritized indicators with readily available data at municipal scale and straightforward to replicate in comparable SES (Latruffe et al. 2016). We included the geographical context (mean altitude) and legacies (e.g. agricultural activities in 1988). For CP0 we chose indicators that depict institutions. CP1 broadly encompasses agricultural practices. For CP2 we calculated indicators that reflected potential mobilisation infrastructure. For CP3 we chose number of sale points. We included a variety of financial and other indicators to quantify demand and social and economic outcomes.

2.3. Data analysis

A preliminary exploration of value distributions and within CP group correlation structure across all indicators (Table 1 / SM 2)) selected a total of 15 parameters for further analysis of interrelationships along the co-production chain. We then examined pairwise Pearman correlations among these 15 indicators. Finally, we applied hierarchical clustering with Euclidian distance to the matrix of municipality values for the 15 parameters to identify co-production archetypes. All analyses were computed in R version 4.02.

3. Results

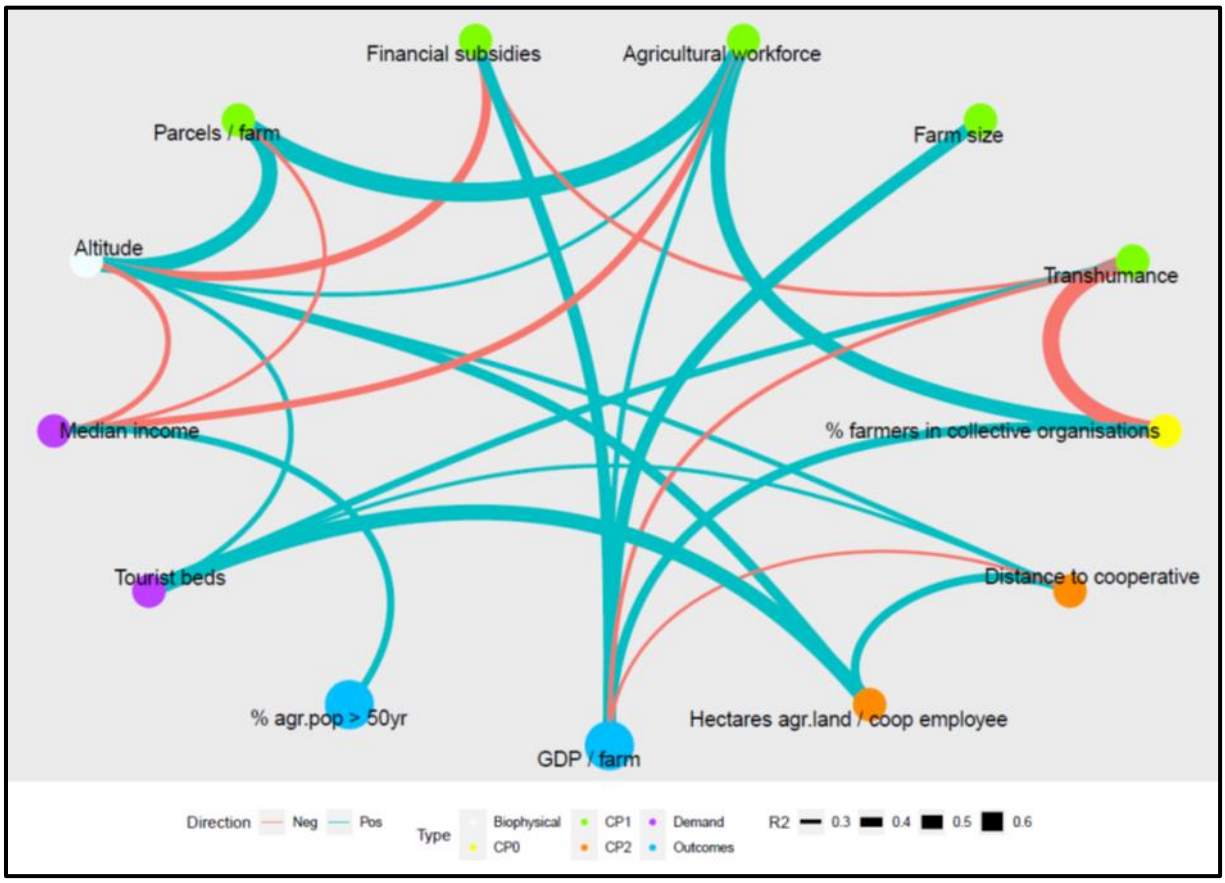


Figure 3: Significant relationships in the agricultural NCP co-production chain of the Maurienne valley: The different steps of co-production are represented by different colours. Blue arrows: positive correlation, Red arrows: negative correlation, arrow thickness is proportion al to the R^2 of the Spearman correlation.

3.1. Key variables along the NCP co-production chain

Figure 3 summarises significant relationships between selected variables. The outcome GDP/farm is related to at least one variable along each step of the NCP co-production chain. The outcome percentage agricultural population over 50 years is correlated with median income (demand). The percentage of work force in agriculture was not significantly related to any other variable.

Altitude was positively correlated with several co-production (CP1: agricultural parcels/farm, financial subsidies, agricultural workforce; CP2: distance to cooperative) and demand (median income, tourist beds) variables. Overall, actors expressed relief over their secured livelihood by the Beaufort cooperative. One remarked, "*Thanks to the cooperative I have money in my account and I know what I will do next year".*

In CP0, the percentage of farmers in collective organisations, which was tightly correlated with indicators of higher-scale institutions (farmers in municipal council, farmers as mayors; SM2)

was positively correlated with GDP/farm. Multiple actors emphasised the relevance of CBI for agriculture. One explained: *"But if there is no collective which fights, nobody can do agriculture here."*

For CP1 three variables (agricultural work force, financial subsidies, farm size) were positively correlated with GDP/farm. Number of agricultural parcels/farm (CP1) and agricultural work force were positively correlated. This suggests that labour is tied to biophysical constraints and might not be easily substituted by technology. Additionally mechanisation of agriculture has reached its biophysical and energetic limits in some parts of the Alps (Flury, Huber, and Tasser 2013; SPM 2020). The share of irrigated surface showed no correlation with other CP1 indicators (SM2), and was hence not retained in our final analyses, emphasising this non-substitutability of manual labour in mountains. Financial subsidies and farm size (CP1, CP1) were each positively correlated with GDP/farm, but were independent from each other. In general, actors seemed to be preoccupied with the general tendency of farm growth. One farmer summed up her worries about the associated structural changes *« If I have more land, I will have more cows, more money, more milk, more, more, more. But, you cannot increase the available labour, people break down".*

The negative correlation of transhumance with percentage of farmers in collective organisations, financial subsidies and farm GDP indicated that municipalities with a high share of transhumance overall host less intensive agricultural management requiring fewer social and financial resources, and are less profitable. Transhumant actors manage and maintain the ecological system (e.g. by grazing; CP1), but they don't partake in other steps of the NCP co-production chain. Transhumance compensates the lack municipal agricultural management activities at CP1, but it does not generate local farm GDP. The negative correlation of transhumance to percentage of farmers in collective organisations (CP0) and financial subsidies (CP1) suggests that CBI (and public institutions) are relevant for agricultural production at municipal level. Actors viewed transhumance rather critically. *"They come, they take they go, but their involvement in the valley's agriculture is zero, really zero".*

The CP2 variable distance to cooperative was positively correlated with GDP/farm. This suggests that the cooperative can mitigate geographical distances and associated biophysical constraints. The amount of agricultural land per cooperative employee, which denotes the efficiency of mobilisation, was positively correlated with distance to cooperative. This may indicate that municipalities that are more peripheral might have more agricultural activities (e.g. more available area) than is feasible in more central, valley-based municipalities with

potentially greater land competition. Actors underlined that access to transformation as crucial. "*For me, I bring the milk down to* the *cooperative every day, it's just down the road, but producing cheese, I really don't have the time."(Int. 27, Farmer, 07/2019)*

For demand, tourist beds and median income were correlated with selected steps of NCP co-production. Correlations with tourist beds reveal the mixed effects of tourism on agriculture. Contrary to our expectations, tourist beds were not correlated with GDP/farm. Tourist beds were correlated with cooperative proximity and area of agricultural land per cooperative employee (CP2), indicating co-location between mobilisation activities and tourism. Tourist beds were positively correlated with transhumance (CP1). Along with the negative association of the median income to agricultural work force with agricultural parcels per farm, this suggests that higher median income is obtained from other activities than agriculture, and that, where available, municipal work force favours tourism over agriculture. The positive relation between median income (Demand) and farmer age reinforces this hypothesis. Actors were fully aware of the relevance of tourism for agriculture, however they mostly worried about rapid aging among farmers: *"If we don't do anything now, in 10 years there are no farmers here. We're all more than 50 years; the landscape will be completely reforested."*

3.2. Municipality archetypes

The hierarchical clustering analysis identified three municipal SES archetypes (Figure 4). Median income was the first-order splitting variable, separating municipalities that are more affluent. The varying external demand determined the second split. This distinguished a second group of municipalities with numerous tourist beds at higher altitudes and, given correlations with agricultural systems more extensive farming, with a higher level of transhumance. The remaining group comprised lower altitude municipalities with varying levels of co-production intensity and outcomes, but overall highly productive and active (including at cooperative level and other collectives) systems.

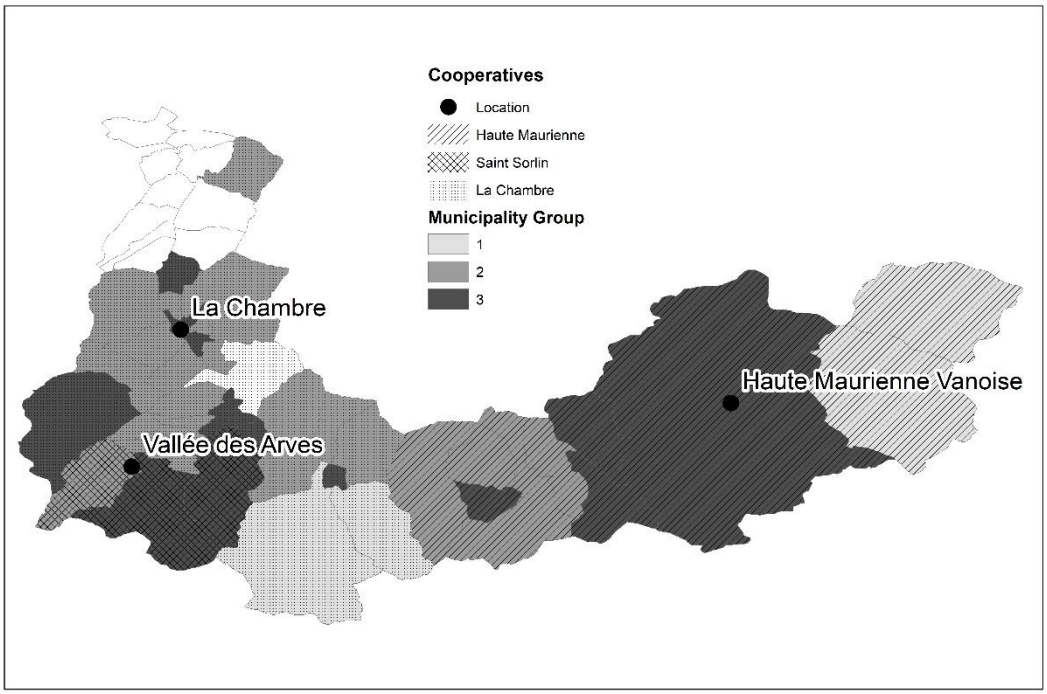
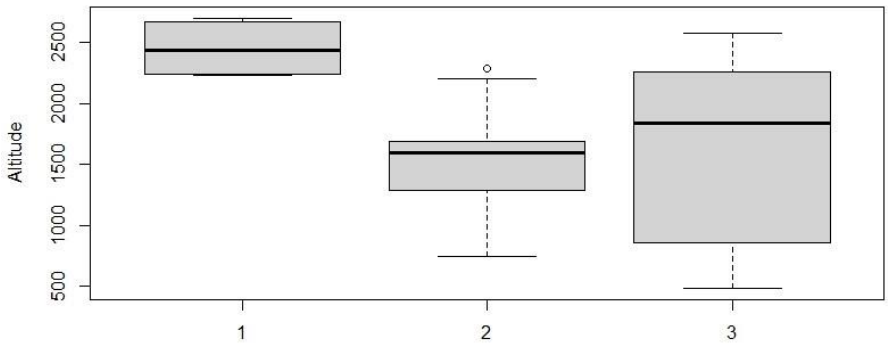
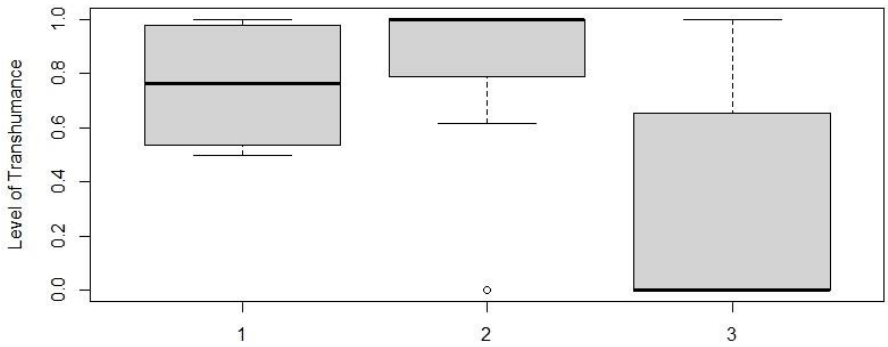
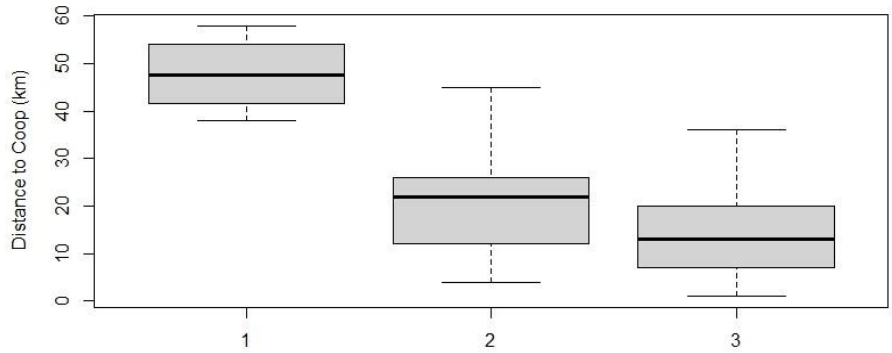
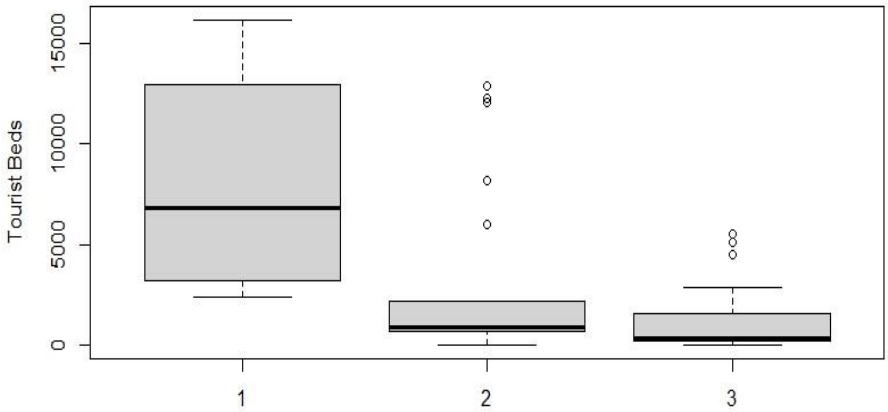


Figure 4: Map of the Maurienne valley with the three municipal archetypes (shades of grey) and the areas of the three cooperatives (overlays).

We overlaid the map of municipality types with the collection area of each of the three cooperatives (Figure 4). Each cooperative encompasses at least two of the three different SES archetypes. Thus, each combines municipalities with differing biophysical constraints and varying economic foci on tourism.

	SES 1	SES 2	SES 3
Biophysical constraints Altitude (m): p = 0.013 SES 1 vs. 2: p = 0.0095 SES 1 vs. 3: p = 0.020 SES 2 vs. 3: p = 0.090			
CP0	Same Beaufort rule set		
CP1 Level of transhumance: p < 0.001 SES 1 vs. 2: p = 0.91 SES 1 vs. 3: p = 0.039 SES 2 vs. 3: p < 0.001			
CP2 Distance to cooperative: p < 0.001 SES 1 vs. 2: p < 0.001 SES 1 vs. 3: p < 0.001 SES 2 vs. 3: p = 0.137			
Demand Tourist beds: p = 0.00365 SES 1 vs. 2: p = 0.026 SES 1 vs. 3: p = 0.0028 SES 2 vs. 3: p = 0.26			

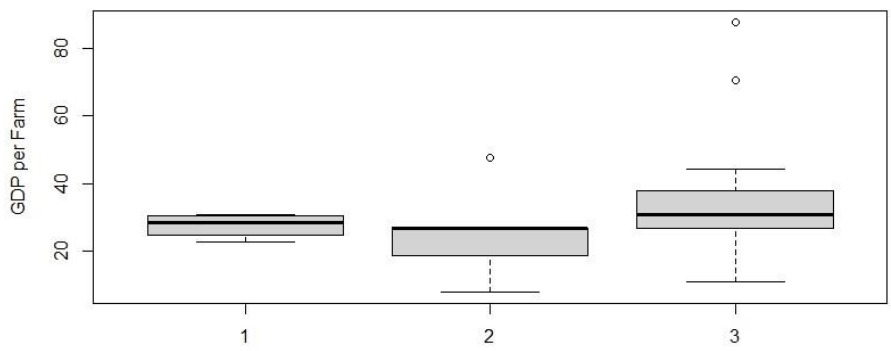
Outcomes GDP / farm (€): p = 0.019 SES 1 vs. 2: p = 0.85 SES 1 vs. 3: p = 0.50 SES 2 vs. 3: p = 0.014			
Exemplary quotes describing agricultural activities	*"Labour is really expensive and tractors cannot work above a certain slope. For that, everybody wants flat land, that we have here ».*	*"Here, there are only 3 farms left. The herders are coming from the South with their sheep, the cows from Montmélian [100 km from Maurienne]."*	*There is a lot of irrigation at the bottom of the valley, but here, everything is steep. There are trees, there are the roads, it wouldn't work here. It takes too much time."*

Table 2: Key co-production, demand and outcomes variables for the three archetypes.

Farmers in municipalities faced with varying conditions and sale opportunities (e.g. being close to a skiing resort) enjoy the same access to collection, processing and sales infrastructure (Table 2), while significantly differing for co-production resources (management, mobilisation), demand and outcomes. While further data collection and qualitative analyses would be required for supporting this formally, this result suggests the division of roles across the three municipality archetypes within the NCP co-production chain of a given cooperative.

4. Discussion

The analysis of the multiple variables of the NCP co-production chain in 56 municipalities of the Maurienne valley revealed that: (1) Biophysical constraints influence NCP co-production at municipal level. (2) Variables that represent CBI (CP0: percentage of farmers in collective organisations; CP2: distance to cooperative, area of agricultural land/cooperative employee) and external demand (tourist beds, median income) along the NCP co-production chain influence farm income. (3) The overall economic structure of municipalities is strongly influenced by external factors such as tourism through its effects on median income and on intensity of agriculture and financial subsidies. (4) Further, the cluster analysis and its mapping to cooperatives suggests that the CBI can buffer differences across three municipality archetypes.

4.1. The relevance of institutions along the NCP co-production chain

Our analysis showed that biophysical constraints affect the type of farming (CP1), but that CBI organise (CP0) and then provide equal access to infrastructure (CP2) and benefits (outcome). NCP co-production thus requires non-land based social resources (Meyfroidt et al. 2018). CBI can enable and support NCP co-production within territories by providing transformation and trading opportunities. Their relevance for agricultural mountain systems has been acknowledged, for instance in a social network analysis of cheese cooperatives in the Italian Alps (Pachoud et al. 2020) and qualitative assessments of the role of social capital and transformation infrastructure (Bruley et al. 2020; Madelrieux, Bergeret, and Fillion 2018). The specific territorial rule sets can support the introduction of stricter environmental regulations into already existing legal frameworks (Marescotti et al. 2020). CBI may induce social-ecological impacts beyond land-use effects, such as reinforcing collective structures, maintaining local economic activities and easing rural depopulation trends. For instance, the Beaufort production system was an instrument to avoid rural emigration in the 1960s (Lynch and Harvois 2016). Nevertheless, in our analyses the impact of financial subsidies highlighted the economic dependence of Alpine agriculture on external support, confirming higher-scale institutional impacts on mountain farming (Schermer et al. 2016). We still suggest that focusing agricultural policies on CP1 might not be sufficient and should further incorporate CBI.

4.2. Social-ecological archetypes

Inductive SES archetype analysis by hierarchical clustering can empirically contribute to advance middle range theories of land system change. These analyses are well suited for targeted SES with specific contexts like particular biophysical conditions, as in Alpine mountain territories (Meyfroidt et al. 2018; Oberlack et al. 2019). We suggest that municipal archetypes under a homogenous rule set address institutional theories of land use change at local level (Meyfroidt et al. 2018; Ostrom 1990). This can offset the inherent weakness of inductive typologies, such as the lack of causal explanations and their character as a “territorial snapshot” (George and Bennett 2005; Meyfroidt et al. 2018). The aggregation of municipal SES to archetypes may facilitate higher-scale policy making by targeting financial support (favouring less accessible, extensive agricultural systems) or urban planning (restricting construction on agricultural land) (Sietz et al. 2019). Recent descriptive archetypes produced at district level in France indicate the possible interest of public institutions to further operationalise these approaches (AGRESTE 2019).

4.3. Strengths and limitations of the study

This paper outlined a complementary mixed methods data-driven approach to better understand the functioning of SES and their actors and resources within territories (Meinzen-Dick, DiGregorio, and McCarthy 2004). Our quantitative indicators relied almost entirely on publicly available data. Thus, the entry barrier is relatively low and replicable in other agricultural systems (Rocha et al. 2020).

However, our study has several methodological limitations. The lack of ecological variables at municipal scale limits in-depth analysis of relationships between management practices, biophysical constraints and institutional influence. For future research, we suggest the integration of downscaled biodiversity indicators. It would be tempting to apply our approach to larger scales, but the high biophysical heterogeneity within relatively small spatial areas in mountain regions may lead to trivial and/or non-significant results. The influence of higher-scale institutions, like through financial subsidies and external factors such as tourism limits the capacity of municipal SES to influence their own functioning. For future research, we recommend a more thorough integration of cross-scale interactions, like the influence of higher-scale institutions and teleconnections on municipal SES (Meyfroidt et al. 2018; Pascual, Palomo, et al. 2017).

Lastly, our simplified definition of equity may limit our analyses. We considered CBI members as economically equal regardless of their contextual constraints or preferences (Sen 2003). However, social-ecological research has recognised that the benefits of NCP co-production like sense of belonging go beyond purely economic criteria, particularly in mountain areas (Pascual, Balvanera, et al. 2017; Hinojosa et al. 2016; Madelrieux, Bergeret, and Fillion 2018). We suggest that multidimensional approaches like the capability approach could enrich analyses by incorporating people's individual conditions (and objectives) into the analysis of mountain and other marginal regions (Sen 2000).

5. Conclusion

We demonstrated how the concept of NCP co-production facilitates the structured quantification and classification of society-ecosystem interactions across heterogeneous local contexts. Our analyses for the French Maurienne valley underlined the crucial role of CBI in buffering biophysical constraints across a territory. Further investigations of mountain territories could focus on local rule sets and associated governance systems. This research confirmed that the steps of NCP co-production can frame inductive archetype analysis of SES

at territorial scale. Such systematic approaches, which can be transferred to researchers and policy-makers, contribute to developing a comprehensive understanding of how heterogeneous mountain agricultural systems provide socioeconomic livelihoods for local populations across a heterogeneous territory.

Acknowledgements

This work was supported by the Université Grenoble Alpes Cross-Disciplinary Project Trajectories funded by the French National Research Agency "Investissements d'avenir" program (ANR-15-IDEX-02). This work was carried out within the eLSTER site Zone Atelier Alpes.

References

AGRESTE, R.A. (2019). Identité et diversité de l'agriculture régionale.

Altaweel, M., Virapongse, A., Griffith, D., Alessa, L., and Kliskey, A. (2015). A typology for complex social-ecological systems in mountain communities. Sustain. Sci. Pract. Policy 11, 1–13.

Anderies, J.M., Janssen, M.A., and Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. Ecol. Soc. 9.

Barreteau, O., Giband, D., Schoon, M., Cerceau, J., DeClerck, F., Ghiotti, S., James, T., Masterson, V.A., Mathevet, R., Rode, S., et al. (2016). Bringing together social-ecological system and territoire concepts to explore nature-society dynamics. Ecol. Soc. 21.

Bennett, E.M., Cramer, W., Begossi, A., Cundill, G., Díaz, S., Egoh, B.N., Geijzendorffer, I.R., Krug, C.B., Lavorel, S., Lazos, E., et al. (2015). Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr. Opin. Environ. Sustain. 14, 76–85.

Bruley, E., Locatelli, B., Vendel, F., Bergeret, A., Elleaume, N., Grosinger, J., and Lavorel, S. (2020). Past reconfigurations of a social-ecological system adapting to global changes in the French Alps. Reg. Environ. Change Rev.

Bruley, E., Locatelli, B., Vendel, F., Bergeret, A., Elleaume, N., Grosinger, J., and Lavorel, S. (2021). Historical reconfigurations of a social–ecological system adapting to economic, policy and climate changes in the French Alps. Reg. Environ. Change 21.

Chan, K.M., Gould, R.K., and Pascual, U. (2018). Editorial overview: relational values: what are they, and what's the fuss about? Curr. Opin. Environ. Sustain. 35, A1–A7.

Cumming, G.S., Epstein, G., Anderies, J.M., Apetrei, C.I., Baggio, J., Bodin, ö., Chawla, S., Clements, H.S., Cox, M., Egli, L., et al. (2020). Advancing understanding of natural resource governance: a post-Ostrom research agenda. Curr. Opin. Environ. Sustain. 44, 26–34.

De Moor, T. (2011). From common pastures to global commons: a historical perspective on interdisciplinary approaches to commons. Nat. Sci. Sociétés 19, 422–431.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., et al. (2015). The IPBES conceptual framework — connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16.

EC, (European Commission-DIRECTORATE-GENERAL FOR AGRICULTURE AND RURAL DEVELOPMENT) (2009). Peak performance - New insights into mountain farming in the European Union.

Eisenack, K., Villamayor-Tomas, S., Epstein, G., Kimmich, C., Magliocca, N., Manuel-Navarrete, D., Oberlack, C., Roggero, M., and Sietz, D. (2019). Design and quality criteria for archetype analysis. Ecol. Soc. 24.

Fedele, G., Locatelli, B., and Djoudi, H. (2017). Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst. Serv. 28, 43–54.

Flury, C., Huber, R., and Tasser, E. (2013). Future of mountain agriculture in the Alps. In The Future of Mountain Agriculture, S. Mann, ed. (Berlin, Heidelberg: Springer Berlin Heidelberg), pp. 105–126.

Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. Glob. Environ. Change 16, 253–267.

George, A.L., and Bennett, A. (2005). Case studies and theory development in the social sciences (Cambridge, Mass: MIT Press).

Gómez-Baggethun, E., Kelemen, E., Martín-López, B., Palomo, I., and Montes, C. (2013). Scale misfit in ecosystem service governance as a source of environmental conflict. Soc. Nat. Resour. 26, 1202–1216.

Grosinger, J., Potts, M.D., Buclet, N., and Lavorel, S. (in review). Memory over matter? – A conceptual framework to integrate social-ecological legacies in agricultural NCP co-production. Sustain. Sci.

Grosinger, J., Vallet, A., Palomo, I., Buclet, N., and Lavorel, S. (in review). How common perceptions shape the co-productio of nature's contribution to people in an Alpine French valle.

Haines-Young, R., and Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In Ecosystem Ecology, D.G. Raffaelli, and C.L.J. Frid, eds. (Cambridge: Cambridge University Press), pp. 110–139.

Hanspach, J., Loos, J., Dorresteijn, I., Abson, D.J., and Fischer, J. (2016). Characterizing social-ecological units to inform biodiversity conservation in cultural landscapes. Divers. Distrib. 22, 853–864.

Hinojosa, L., Napoléone, C., Moulery, M., and Lambin, E.F. (2016). The "mountain effect" in the abandonment of grasslands: insights from the French Southern Alps. Agric. Ecosyst. Environ. 221, 115–124.

INAO, (Institut national de l'origine et de la qualité) (2015). Cahier des charges de l'appellation d'origine « Beaufort ».

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., Ryan, M., and Uthes, S. (2016). Measurement of sustainability in agriculture: a review of indicators. Stud. Agric. Econ. 118, 123–130.

Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., and Dash, P. (2013). Ecosystem services: origins, contributions, pitfalls, and alternatives. Conserv. Soc. 11, 343.

Lynch, E., and Harvois, F. (2016). Le Beaufort: réinventer le fruit commun (Lyon: Libel).

Maciejewski, K., De Vos, A., Cumming, G.S., Moore, C., and Biggs, D. (2015). Cross-scale feedbacks and scale mismatches as influences on cultural services and the resilience of protected areas. Ecol. Appl. 25, 11–23.

Madelrieux, S., Bergeret, A., and Fillion, L. (2018). Forms of territorial embeddedness in dairy value chains- Case of the Chartreuse massif (French Alps): geographical and historical perspectives. Open Agric. 3, 618–631.

Marescotti, A., Quiñones-Ruiz, X.F., Edelmann, H., Belletti, G., Broscha, K., Altenbuchner, C., Penker, M., and Scaramuzzi, S. (2020). Are protected geographical indications evolving due to environmentally related justifications? An analysis of amendments in the fruit and vegetable sector in the European Union. Sustainability 12, 3571.

Martín-López, B., Leister, I., Lorenzo Cruz, P., Palomo, I., Grêt-Regamey, A., Harrison, P.A., Lavorel, S., Locatelli, B., Luque, S., and Walz, A. (2019a). Nature's contributions to people in mountains: A review. PLOS ONE 14, e0217847.

Martín-López, B., Leister, I., Lorenzo Cruz, P., Palomo, I., Grêt-Regamey, A., Harrison, P.A., Lavorel, S., Locatelli, B., Luque, S., and Walz, A. (2019b). Nature's contributions to people in mountains: A review. PLOS ONE 14, e0217847.

McGinnis, M.D. (2011). An introduction to IAD and the language of the Ostrom workshop: A simple guide to a complex framework. Policy Stud. J. 39, 169–183.

Meinzen-Dick, R., DiGregorio, M., and McCarthy, N. (2004). Methods for studying collective action in rural development. Agric. Syst. 82, 197–214.

Meyfroidt, P., Roy Chowdhury, R., de Bremond, A., Ellis, E.C., Erb, K.-H., Filatova, T., Garrett, R.D., Grove, J.M., Heinimann, A., Kuemmerle, T., et al. (2018). Middle-range theories of land system change. Glob. Environ. Change 53, 52–67.

Muhar, A., Raymond, C.M., van den Born, R.J.G., Bauer, N., Böck, K., Braito, M., Buijs, A., Flint, C., de Groot, W.T., Ives, C.D., et al. (2018). A model integrating social-cultural concepts of nature into frameworks of interaction between social and natural systems. J. Environ. Plan. Manag. 61, 756–777.

Oberlack, C., Sietz, D., Bürgi Bonanomi, E., de Bremond, A., Dell'Angelo, J., Eisenack, K., Ellis, E.C., Epstein, G., Giger, M., Heinimann, A., et al. (2019). Archetype analysis in sustainability research: meanings, motivations, and evidence-based policy making. Ecol. Soc. 24.

Ostrom, E. (1990). Governing the commons: the evolution of institutions for collective action (Cambridge ; New York: Cambridge University Press).

Ostrom, E. (2005). Understanding institutional diversity (Princeton: Princeton University Press).

Ostrom, E. (2009). A generalframework for analyzing sustainability of social-ecological systems. Science 325, 419–422.

Pachoud, C., Delay, E., Da Re, R., Ramanzin, M., and Sturaro, E. (2020). A relational approach to studying collective action in dairy cooperatives producing mountain cheeses in the Alps: the case of the Primiero cooperative in the Eastern Italians Alps. Sustainability 12, 4596.

Palomo, I., Felipe-Lucia, M.R., Bennett, E.M., Martín-López, B., and Pascual, U. (2016). Disentangling the pathways and effects of ecosystem service co-production. In Advances in Ecological Research, (Elsevier), pp. 245–283.

Pascual, U., Palomo, I., Adams, W.M., Chan, K.M.A., Daw, T.M., Garmendia, E., Gómez-Baggethun, E., de Groot, R.S., Mace, G.M., Martín-López, B., et al. (2017a). Off-stage ecosystem service burdens: A blind spot for global sustainability. Environ. Res. Lett. 12, 075001.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Başak Dessane, E., Islar, M., Kelemen, E., et al. (2017b). Valuing nature's contributions to people: the IPBES approach. Curr. Opin. Environ. Sustain. 26–27, 7–16.

Rocha, J., Malmborg, K., Gordon, L., Brauman, K., and DeClerck, F. (2020). Mapping social-ecological systems archetypes. Environ. Res. Lett. 15, 034017.

Schermer, M., Darnhofer, I., Daugstad, K., Gabillet, M., Lavorel, S., and Steinbacher, M. (2016). Institutional impacts on the resilience of mountain grasslands: an analysis based on three European case studies. Land Use Policy 52, 382–391.

Sen, A. (2000). Development as freedom (New York: Anchor Books).

Sen, A. (2003). On ethics and economics (Oxford: Blackwell).

Sietz, D., Frey, U., Roggero, M., Gong, Y., Magliocca, N., Tan, R., Janssen, P., and Václavík, T. (2019). Archetype analysis in sustainability research: methodological portfolio and analytical frontiers. Ecol. Soc. 24.

Spangenberg, J.H., Görg, C., Truong, D.T., Tekken, V., Bustamante, J.V., and Settele, J. (2014). Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 10, 40–53.

SPM, (Syndicat du pays de Maurienne) (2020). Schéma de cohèrence territoriale.

Vatn, A. (2005). Rationality, institutions and environmental policy. Ecol. Econ. 55, 203–217.

Villamayor-Tomas, S., Iniesta-Arandia, I., and Roggero, M. (2020). Are generic and specific adaptation institutions always relevant? An archetype analysis of drought adaptation in Spanish irrigation systems. Ecol. Soc. 25.

Windhorst, W., Müller, F., and Wiggering, H. (2004). Umweltziele und Indikatoren für den Ökosystemschutz. In Umweltziele und Indikatoren, H. Wiggering, and F. Müller, eds. (Berlin, Heidelberg: Springer Berlin Heidelberg), pp. 345–373.

Annexes

- Supplementary materials 1 Materials and methods
- Supplementary materials 2 Supplementary materials 2: Selection of indicators for correlation analysis

Supplementary materials 1: Materials and methods

Each municipality counts as one administrative unit with various characteristics. We chose as a reference year 2014. From this year onwards, the French administration merged a large number of municipalities. These administrative considerations could blur the possible differences in agricultural production between formerly separated municipalities.

Co-production step	**Indicator**	**Variables**	**Explanation**	**Source**
Biophysical constraints	Geographic	Mean direct insolation	Shows exogenous, non modifiable conditions	(IGN-F 2021a)
	Impact of solar power	Mean altitude level of municipality	Shows exogenous, non modifiable conditions	(IGN-F 2021a)
Social-Ecological legacies	Agricultural land availability	Pastoral land to total surface (%)	Agricultural land is a crucial factor of production.	(SPM and SEA 2015)
	Agricultural land tenure fragmentation	Nr. of agricultural parcels	Indicates agricultural management history and can impact the access to land	(IGN-F 2021b)
	Landscape consolidation	Consolidated land (ha)	Indicates former efforts to consolidate land	(SMB 2020)
	Agricultural Past	Nr. agricultural holdings in 1988	Indicates the amount of existing private infrastructure, but also the associated agricultural history of a local community at farm level	(AGRESTE 2010)
	Collective infrastructure	Nr. production facilities in 1985-1990	Indicates the amount of existing private infrastructure, but also the associated common values of a local community at municipal level	(Lynch and Harvois 2016)
CP0 Organise	Power	Nr. mayors who are farmers 2015-2020	Indicates power in decision making over agricultural land use	www.mon-maire.fr (last access : 18/12/2020)

	Interest	Nr. farmers active in the municipal council 2015-2020	Indicates interest to participate in local governance processes	www.mon-maire.fr (last access : 18/12/2020)
	Legitimacy	Pastoral land management organisation	Willingness to maintain agriculture of local population	(SEA), 2019
	Social relations	Farmers in collective organisations (%)	Willingness to be adhere to collective local organisations indicates good social relations. *Calculation: Total membership of six leading agricultural organisations/ total farmers in municipality.(We balanced the varying degrees of involvement of these association at the steps of NCP co-production by assigning ascending values for increasing involvement, e.g. Beaufort cooperative involved in CP1,CP2,CP3 = 1 point, Pastoral land management association involved in CP1= 0.3 point*	pers. communication with secretaries of six leading agricultural organisations
CP1 Manage	Financial subsidies	Financial subsidies (US$)	Factor of production at farm level	(MAA 2016)
	Agricultural work force	Agricultural work force (hr/week)	Factor of production at farm level	(AGRESTE 2010)
	Irrigation	Irrigated area (%)	Factor of production at farm level	(Clavel 2013)
	Type of agriculture	Farm size (ha)	Type of management conditions at municipal level	(AGRESTE 2010)
		Number of farms		(AGRESTE 2010)
		Agricultural parcels/farm		(IGN-F 2021b)
	Transhumance	Transhumance (% area)		(SMB 2020)
CP2 Mobilisation	Geographical proximity	Distance to cooperative (minutes)*	Indicates if time resources (driving distance) make a difference to adhere to cooperative Distance between municipality and repective cooperative facilities.	(Google n.d.)
	Organisational proximity	Agricultural land/ coop employee (ha)*	Indicates the efficiency of cooperative to convert agricultural land at municipal level to a product	pers. communication

				with three cooperatives, (SMB 2020)
CP3 Appreciation	Purchase possibility	Nr. sale points	Indicates how product serves as value construction	pers. communication with each cooperative
Outcomes	Current activity attachment	Nr. museums related to agriculture	Indicates if society considers agriculture as valuable to municipal identity	(SPM 2020)
	Activity maintenance	% agricultural population > 50 yrs.	Indicates the medium durability of the system	(INSEE 2017b)
	Place attachment	Natura 2000 sites maintained by agricultural activities (%total area)	Protected sites which that require regular agricultural activities	(INPN 2020)
	Socioeconomic livelihood	GDP/farm	Indicates if farms are economically viable	(INSEE 2017b)
Demand	Tourist demand	Tourist beds	Indicates potential tourist demand	(INSEE 2017a)
	Local demand	Median household income (US$)	Indicates local potential purchase powser	(INSEE 2019)
		% of tertiary education	Indicates potential willingness to buy the product	(INSEE 2015)

Table 1: Overview of indicators

Supplementary materials 2: Selection of indicators for correlation analysis

We first examined value distributions for individual parameters in order to identify those whose value distributions were highly skewed and/or qualitative variables whose values could be captured by a correlated quantitative variable. Secondly, in order to limit redundancy among parameters and to select leading variables for a parsimonious analysis of linkages across steps in the co-production chain, we analysed pairwise Spearman correlations within each co-production group. This lead to a final selection of 15 variables for further analysis (Table 2).

Biophysical	**CP0**	**CP1**	**CP2**	**CP3**	**Outcome**	**Demand**
Altitude	% farmers in collective organisations	Number or farms	Distance to cooperative	Nr. of Sale points	GDP per farm	Tourist beds
		Farm size	Number of hectares per cooperative member	% agricultural population > 50 yrs	% agricultural population > 50 yrs	Median income
		Number of parcels per farm		% Agricultural work force	% Agricultural work force	
		Agricultural workforce				
		Proportion Transhumance				
		Financial subsidies				

Table 2: The 15 variables for the analysis

Among legacies, insolation showed no correlations with other parameters. Percentage pastoral land was strongly negatively correlated with altitude, which was the retained structuring variable due to its multiple correlations with other parameters.

There were strong correlations among farm system variables including number of parcels (with a non-normal distribution), number of farms, work hours and number of production facilities (the latter with a skewed distribution to 0's). We thus retained number of farms and calculated number of parcels per farm. Proportion of irrigated land showed no correlation with any other variable. The number of livestock units per farm was negatively correlated with % transhumance, but with a poorer value distribution and we thus retained % transhumance.

Parcel size showed no correlations with other parameters, and the discontinuous distribution of values for consolidation led to their removal from the data set. The number of pastoral organisations showed no correlation with other social variables and was dropped due to its skewed and discontinuous value distribution.

The numbers of farmers in councils and in collective organisations were correlated with the number of farms, and were thus not retained. The numbers of farmers as maires and in councils were correlated with the retained variable of number of farmers in collective organisations, which had a more normal statistical distribution.

Distance to cooperative and land area (hectares) per cooperative employee did not have clear relationships with any of the system legacy / system resources and were retained as hypothesised explanatory variables for CP2.

For demand, number of tourist beds, % Tertiary education, number of sale points and number of museums (with a skewed distribution) were correlated, leading us to retaining number of tourist beds with the most normal statistical distribution.

GDP per farm, % agricultural workers and proportion of agricultural workers over 50-year-old were not correlated and thus all retained as independent outcome variables. Proportion of land conserved (Natura 2000) showed no correlations with other parameters and was thus dropped from further analysis.

References for supplementary materials

AGRESTE (2010). Données communales - résultats des recensements agricoles par commune.

Clavel, C. (2013). L'irrigation aujourd'hui (Aussois).

Google Google Maps.

IGN-F, I. national de l'information géographique et forestière (2021a). Géoservices.

IGN-F, I. national de l'information géographique et forestière (2021b). Registre parcellaire graphique (RPG) : contours des parcelles et îlots culturaux et leur groupe de cultures majoritaire.

INPN, I.N. du P.N. (2020). Natura 2000.

INSEE, Institut national de la statistique et des études économiques. (2015). Les niveaux de formation de la population en 2015.

INSEE, Institut. national de la statistique et des études économiques. (2017a). Emploi-Activité en 2017- Recensement de la population.

INSEE, Institut national de la statistique et des études économiques. (2017b). Capacité d'accueil touristique de 2003 à 2017.

INSEE, Institut. national de la statistique et des études économiques. (2019). Indicateurs de distribution des revenus déclarés par les ménages - Pour l'ensemble des ménages et par catégorie de ménages- Fichier Localisé Social et Fiscal (FiLoSoFi) - Année 2015.

Lynch, E., and Harvois, F. (2016). Le Beaufort: réinventer le fruit commun (Lyon: Libel).

MAA, (Ministère de l'agriculture et de l'Alimentation) (2016). Telepac - Publication des bénéficiaires d'aides PAC- 2016 -2017.

SEA, (Société d'économie d'Alpestre de Savoie) (2019). Plan pastoral du pays de Maurienne 2015-2019.

SMB, (Savoie Mont Blanc). (2020). Espace observatoire.

SPM, (Syndicat du pays de Maurienne) (2020). Culture et patrimoine.

SPM, (Syndicat du pays de Maurienne), and SEA, (Société d'économie d'Alpestre de Savoie) (2015). Plan pastoral du pays de Maurienne 2015-2019.

Chapter VI Discussion

Maurienne valley (Credits: Bruno Locatelli/2018)

Social-ecological dynamics shapes the ways in which ecosystems contribute to the diverse aspects of a good quality of life. In the previous chapters, I showed that the Beaufort cheese production system rests on shared views about fundamental aspects of co-production, as collectively agreed rule sets for management practices, and about its associated benefits. I proposed various approaches to comprehend the underlying flows between society and ecosystems to better conceptualise, quantify and analyse this complexity.

In order to understand the various material and non-material flows that contribute to a good quality of life in a social-ecological system at territorial scale my thesis focused on three major components of the territorial system. In chapter III, I specifically questioned the role of social-ecological legacies and proposed to embed socioeconomic NCP co-production in the social-ecological context. This highlights the interplay of social-ecological legacies, and the current resources and social dynamics of the Beaufort production system. I found that the organisation of social-ecological legacies could affect the entire production system In Chapter IV, I investigated the role of collective capabilities in NCP co-production. I found that a better recognition of relational values could facilitate the understanding of a territorial system. In Chapter V, I specifically asked how the interplay of social-ecological resources functions across a heterogeneous territory. This article then showed quantitatively the crucial role of the biophysical context and collective structures for NCP co-production of the Beaufort. In the following discussion, I further develop these main results. I first discuss the relevance of the framework of this thesis for real world situations. Furthermore, I include critical reflections about my mixed methodological approach. Secondly, I link this discussion to current concepts to assess non-monetary value systems and implications for further assessments. Thirdly, I propose to consider the Beaufort production system as a territorial capability to further integrate the social dimension in social-ecological interactions. Fourthly, I complement my findings by investigating the multiple cross-scale interactions of my research area. Finally, I reflect on the various terminologies and associated misunderstandings I encountered during my research in an interdisciplinary field.

1. NCP co-production and collective capabilities

The SES framework I developed provides the means to focus on the embeddedness of NCP co-production in the social-ecological context. I briefly present a synthetic version of my conclusions in Figure 1 and discuss selected aspects in the following. In particular I highlight that the concept of territorial systems, which concentrates on actors' non-material dimensions such as values, identities and associated rules appears more appropriate than the SES concept when applying the framework (Barreteau et al., 2016). On the other hand, the incorporation and development of the co-production concept aligns with systemic approaches of the social-ecological system concept (McGinnis and Ostrom, 2014) and enables quantifying social-ecological interactions with a mix of qualitative and quantitative indicators. In contrast to other, relatively precisely defined frameworks focusing on social dimensions, such as the institutional analysis and development framework that includes well-defined suggestions for variables, I expect my framework to rather serve as a template for inspiring further research (McGinnis and Ostrom, 2014). integration of NCP co-production in a defined social-ecological setting by incorporating social- This should support further reflections on the ecological legacies,and associated collective action structures

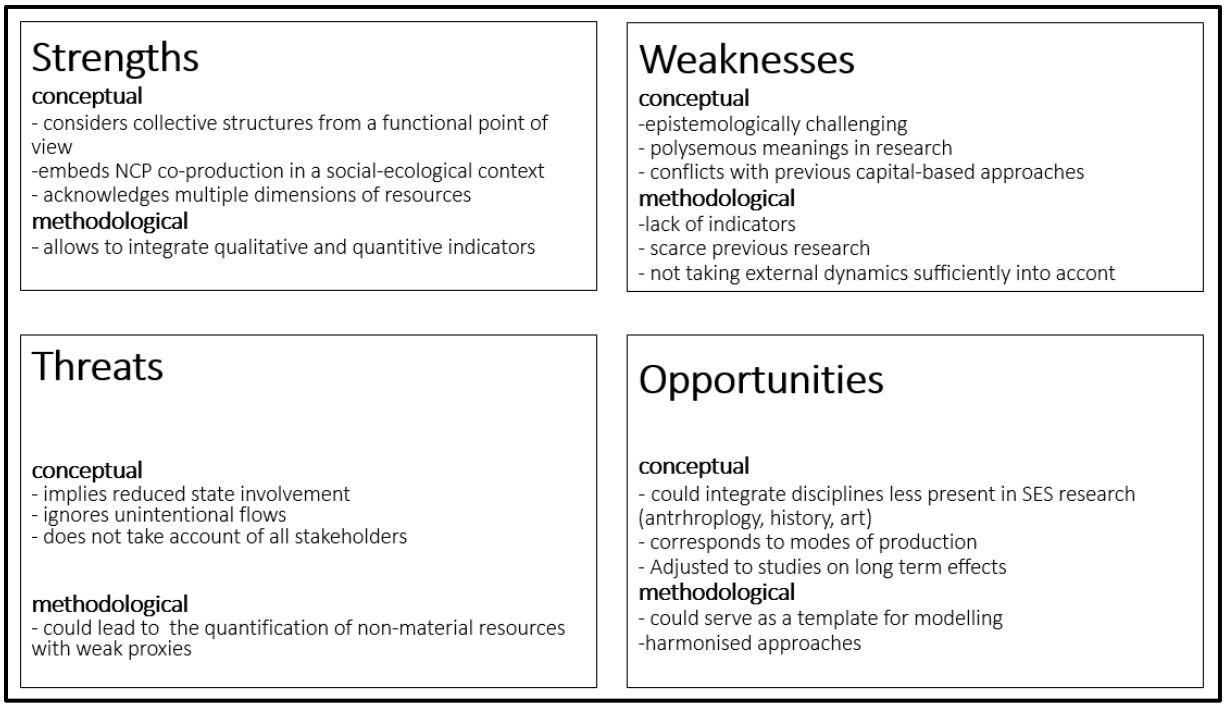


Figure 1: A SWOT (strengths, weaknesses, opportunities threats) analysis of the framework (not exhaustive)

The framework presented in chapter III reflects the logic of economic modes of production (organisation, management, mobilisation/extraction, consumption). For that it could complement ongoing economic assessments by considering different steps of production from a social-ecological perspective. Research has acknowledged the crucial role of institutions on the use of ecosystems by people since the 1980s (Blaikie, 2015; Ostrom, 1990), but the IPBES framework was the first to anchor them as an integral component in ecosystem service research. The already complex IPBES framework does not allow to (or rather is not meant to) go into the internal functionings of institutions and their role in value creation. Disaggregating the roles of institutions along the NCP co-production cascade allows a more nuanced understanding of their roles in their governing functions of NCP co-production processes. The underpinning, non-ecosystem based mechanism (CP0, organising) allows to see how collective structures structure and agree over values and consequently rule sets based on social-ecological legacies. Following conceptualisations of territorial systems it could be applied to other production systems that are demarcated by non-material characteristics (such as social relations) and that feature tight interlinkages to the surrounding ecosystems. For example, it would be interesting to compare the differing social-ecological legacies and associated governance systems in other agricultural cooperative systems carrying GI labels, such as the cheese *tome de Bauges* with a comparable small production quantity 700 ton/ year located close by the Beaufort zone (CNAOL, 2016; Delfosse, 2007). In addition it could be applied on other products or regions, such as *serrano* cheese in Southern Brazil (Pachoud, 2019), olive oil in Spanish Andalusia (Sanz Cañada and Macías Vázquez, 2005) or coffee in the mountains of Bali (Fournier, 2008). On the other hand, territorial analysis emphasizes local governance of the surrounding ecosystem. It is not clear if this conceptualisation could work in other farming systems, or even quality labelled production systems that are governed by outside players. For example, the *roquefort* or *camembert* cheeses are considered as high quality local specialities. However, local producers only exert limited control over their modes of production, as rule sets and the possible associated value systems are largely controlled by international companies (Léraud and Kronlund, 2020). On the other hand, it might be interesting to see what type of value sets emerge in these differently organised value systems. This can advance the analyses of agricultural development and regional governance systems by focusing on the contextual specifics of these systems. The scientific focus on regional governance systems shall not compensate, but rather complement the responsibility of higher scale institutions at national or supranational scale in present and future social-ecological interactions.

My thesis applied methods coming from sociological traditions favouring the meanings of words over actions. This approach greatly facilitated the emergence of non-material aspects that contribute to the quality of life of people. It helped me to uncover that socioeconomic modes of production are deeply connected to underlying value sets. However, such qualitative research that focuses on these multidimensional aspects is often self-limiting due to its requirement for time-intensive methods (Hernández-Morcillo et al., 2013) In addition, I believe that the integration of new types of communication allows to shed more light on the social self-representation of actors to a greater public, than in a simple one-on-one interview setting. For example the use of social media (e.g. Twitter, Instagram) permits to treat large data sets with more actors from various backgrounds (Hale et al., 2019; Mascareño et al., 2020). For future research, I believe that the integration of humanities (other than sociology, political science), but anthropology, history or even fine arts could greatly contribute to the understanding of these social-ecological systems at territorial scale. These approaches would enable to unravel and explore the fine details of the construction of relational values in a given setting. For example the functioning of social-ecological systems can also be assessed by local literature (Kim, Vaswani, and Lee 2017), theatre (Brown et al., 2017) or art installations (Bendor et al., 2017). Other action-based applications could include the establishment of local social-ecological histories for communities e.g. by oral history approaches (Crane, 2010) or the domain of "strollology" (the science of strolling) which means learning to understand the SES by community walks. (Burckhardt, 2015). These unconventional approaches might offer methods to further understand the subtle components of relational values.

The framework is epistemologically challenging. In particular, the division of social-ecological legacies in social and ecological systems remains difficult. In addition, while collective capabilities seem to provide a valuable analytical foundation, this strand of thought lacks empirical research on formal institutions (Pelenc et al., 2015). It is therefore difficult to advance this field as research in social-ecological system mainly uses capital-based approaches. Combining social-ecological legacies and collective capabilities into a single framework can lead to an excessively complex framework. This opposes the intention of frameworks to provide an accessible heuristics. In addition, these two ideas carry both polysemous meanings. For future research, I would thus suggest to conduct research combining social-ecological legacies and collective capabilities in a chronological three-step methodology. First analysing the collective capabilities, secondly their social-ecological resources and thirdly analysing and comparing their respective findings. While my study only provides a snapshot of the Maurienne

territorial system, the framework encourages specifically considering the feedback loops over the long term by the component social-ecological legacies. This is in particular interesting as social and ecological processes function at disparate time scales. The recognition of values in the framework coupled with collective capabilities also integrates the fact that human needs can evolve over time (Farber et al., 2002).

The decision of analysing a socially defined territorial system with beforehand selected actors leads to numerous omissions of flows, other actors and external factors that are out of scope. The framework only captures the intentional activities of a society; it does not explicitly consider unintentional activities of actors between the ecological and the social system, in particular waste disposal (from society). In addition, while it is useful to examine at the internal dynamics of a regional governance system, at the same time this excludes other stakeholders like other farmers, transhumant herders or tourists. This reflects the major limitation of this framework, the certainly insufficient inclusion of external flows. This is in contrast to previous territorial analysis, that applies material flow-based methodologies to consider these external factors (Barles, 2007). For a precise evaluation of a territorial system in the current global system it is indispensable to include these diverse, complex flows. I discuss this shortcoming in detail I chapter VI, section 3.

Being aware of these limitations, I nevertheless consider that the focus at territorial scale greatly contributes to the understanding of social-ecological interactions as it allows capturing the multiple aspects that an upscaling would render invisible. In particular, it highlights the crucial importance of non-material aspects of those relations. I suggest to explicitly integrating social-ecological legacies as a new term to account for the social-ecological context of a system.

2. Relational values along the NCP co-production chain

In this work, I emphasized the value set that governs the co-production of Beaufort cheese. Thus, I highlighted the multiple non-material dimensions of a product that is primarily conceived in most research on farming systems as a material result of agricultural production. I stated that the Beaufort cheese is not a mere dairy product, but that it also ensures the maintenance of a territorial system and associated identities and lifestyles. In the following, I focus on three perspectives of how relational values could be further integrated in research on NCP co-production. First, I focus on the dual material and non-material character of resources. Secondly, I expand this thinking to landscape level and discuss how social values can be viewed as non-material dimensions of a landscape. Third, I discuss how these relational values play a role in relations within society that are in this case presented as a formalised rule set.

2.1 The dual character of resources

The acknowledgement of the non-material dimensions of material resources is in line with the NCP concept that explicitly acknowledges that one material flow (cheese in this case) can encompass a variety of other non-material aspects, such as relational values (Díaz et al., 2018; MEA, 2005; Pascual et al., 2021). I further strengthened this idea by explicating how its plays out along the NCP co-production chain and assumed that all material resources have non-material components. The idea of the dual nature of resources is of particular interest for the field of Science and Technology Studies. In the early 1980s, Winner (1980) already stated that simple objects (in his example public infrastructure) can express an underlying value set. Briefly after, actor-network theory further formalised these thoughts (Latour, 2003). Some early social-ecological precursors were e.g. Lewis Mumford who considered technology as a social choice that leads to certain production systems and not as a development driven by needs or innovation (Mumford, 2010). Conceptualisations of co-production have considered values as separated from anthropogenic assets (e.g. infrastructure) (Díaz et al., 2015b; Fedele et al., 2017). This might be owed to the use of the capital-based approach (Palomo et al. 2016, Jones et al. 2015) that separates non-material resources (known under the term social capital) from material categories (manufactured capital) or even natural capital (Guerry et al., 2015). The Beaufort production system cannot exist without collective values, conversely those cannot exist without the material components are reciprocally related to these values. At CP1, these collective values might be best exemplified in the management practices, in particular, the manual labour people are willing and able to dedicate. At CP2, the material transformation infrastructure incorporates the values of small-scale agricultural holdings and ensures a localized economic value production system with farmers. The daily transfer of milk from farm to cooperative level leads to local labour division. More drastically rephrased, one could say that these material resources determine a certain way of production and even lifestyles. At CP3, the local control of sale facilitates the maintenance of socioeconomic livelihoods and the associated dimensions of local identities (Lynch and Harvois, 2016). However, from this brief analysis it is not clear if these values are truly relational, or if they can be considered as held values, that means abstract values, exemplified in the used resources (Chan et al., 2018). The emerging literature on relational values in NCP co-production research has not yet fully incorporated the idea of the dual character of resources. The explicit integration of this thought in ongoing research could nurture the understanding of the relations between value sets, available resources and activities.

2.2. Values and landscapes

From a broader perspective, relational values can be considered as the non-material social mirror of the material cultural landscape. Thus, the social-ecological legacies of the ecosystem stand in mutual interdependence with the collective social-ecological value set of a society. Recent research focuses increasingly on the interdependences between values and landscapes (García-Martín et al., 2020; Plieninger et al., 2015b). For example, the role of collective values in shaping grassland plant biodiversity was strikingly demonstrated by the comparative study between protestant and catholic communities and their associated heritage traditions (Maurer et al., 2006). In addition research indicates that the simplification of landscape by global drivers can lead to the loss of relational values, such as identities and sense of place (Riechers et al., 2020). At policy level the EU acknowledges these interlinkages by the High Nature Value (HNV) farming concept (Oppermann et al., 2012) and at supranational they became known as "Gobally Important Agricultural Heritage systems (GIAHS)" (Koohafkan, 2019; Quiñones Ruiz et al., 2018). At economic level "geographical indications (GI)" present the formalised link between products and a specified place of origin (Marie-Vivien and Biénabe, 2017). In the context of European mountain farming system, the PDO quality label links a spatially defined area to specific management practices (and assumed underlying collective values) (Quiñones Ruiz et al., 2018). In the Alpine context, since 2012, the European quality label "mountain products" acknowledges the strong cultural identity and tradition of mountain regions (Santini et al., 2013). Further the compulsory linkage to a specific spatial area can be termed landscape products (García-Martín et al., 2020). Thus, these products offer an interesting starting point to analyse the relations between the non-material (values) and material (physical landscape) logics of regional farming systems. In addition, an identical production system within a region can reconcile biophysical heterogeneities and revive rural marginalized areas. Thus, the integration and analysis of relational values can play a crucial role in the establishment of these landscape products. However, these values have frequently co-evolved over a long period of time and product quality labels are only the institutionalized recognition of these linkages local actors are well aware of (Belletti et al., 2017). This raises the question: How can societies establish comparable, economic viable farming systems if they cannot rely on former efforts to organise these social-ecological legacies? In particular regional societies with disruptive trajectories, such as in formerly collectivized landscapes in the Former Soviet Union or regions who had undergone great social instability (Baird and Le Billon, 2012) might lack common value sets or shared interests and possibly the associated social cohesion. A possible solution might be to foster the role of collective structures in these regions. Building on this reasoning, the EU-

supported project High Nature Value-Link (HNV-Link) explicitly investigated collective action in the context of high nature farming (Beaufoy and HNV Link Partners, 2017). The continued focus of European policies on collective actors is thus warranted, as with the European Agricultural Fund for Rural Development (EAFRD) for regional initiatives like irrigation associations. However, within and outside the EU, in light of rapid land abandonment, agricultural intensification and decreasing small-scale agriculture, interlinkages between cultural landscapes and collective structures and their contributions to a good quality of life have remained underexplored (Egarter Vigl et al., 2016; Hinojosa et al., 2016; Santini et al., 2013). The coupling of landscapes with prevailing value systems could contribute to the simultaneous maintenance of ecosystems and of the social fabric in rural areas, thus fully encompassing the multidimensionality of NCP co-production.

2.3. Values and local governance systems

The focus on relational values in the IPBES framework can be considered as an implicit recognition that values determine the actions of society (Schwartz, 2012). Without doubt, social-ecological research must embrace the multidimensionality of values in the appreciation of NCP (Pascual et al. 2021), but it is not yet clear if these values translate into activities that correspond to these values and has yet remained a knowledge gap (Duraiappah et al., 2014). For example, the preference to live in a clean environment does not automatically translate into using less fossil fuel powered modes of transport. I showed that relational values such as local identities are crucial for collective capabilities in extensive farming systems. However, on an individual level, research about behavioural economics regularly and recently NCP research assert the strong dissonance among different values and activities (Duraiappah et al., 2014; Oliver, 2015). What my study suggested is that local collective rule systems can formalise these relational value sets into binding rule sets local actors apply in their daily activities. I found that the collective rule system (e.g. 75% local fodder requirement, local cattle breeds), appears to mainly govern social-ecological legacies rather than controlling current resources (INAO, 2015). The use of the regional, low-yielding cattle coupled with the local fodder requirement effectively limits any large-scale increases in farm size. In addition, the simple requirement of providing milk at a certain temperature in order to ensure a homogenous bacteria development in the further transformation process discourages automatic milking machines. From the perspective of relational values and based on the above reflections of the dual nature of landscapes as values and resources, this aligns with other studies that argue that local

governance systems can maintain and preserve the landscape and the associated local identities (Edge and McAllister, 2009; Stenseke, 2009).

3. Contextualising collective capabilities in a territorial system

In the following, I discuss to what extent the collective capability approach coupled with the NCP co-production concept enables understanding a territorial system. Based on approaches of territorial ecology and the concept of NCP co-production I propose to consider the Beaufort production system as a territorial capability. I recall, that my large definition of collective capabilities was based on Comim and Carey (2001) and Ibrahim (2006) that defined collective capabilities as the capabilities that can be achieved only by social interactions. Freedom in this context is achieved by social interaction. .

3.1. Collective capability

Following previous research on collective capabilities, the Beaufort production system can be considered as a collective capability, because it creates new capabilities for their members to choose a life they consider as meaningful (Ibrahim, 2006). Their members organise and coordinate local resources, such as cattle breed, pastureland, local labour and the further transformation process according to their own values (Lynch and Harvois, 2016). In the Beaufort production system, this collective capability can affect the way people view their personal goals. For example, the rule set prevents increasing productivity and large scale farming extensions. However, there is also no perceived need for these, as the cooperative pays an above-market price for milk. In addition, cooperatives are largely responsible for their own sales. Although there is wholesale to contracted clients, there is no large enterprise involved in the preceding steps of co-production. This aligns with early reflections on the collective capability approach, of Evans (2002) imagining that collective capabilities could act as a counterweight to large-scale homogenous modes of production and associated unequal power relations. However, these identities do not unfold exclusively within an exclusive social context, but they emerge from social-ecological interactions.

3.2. Territorial capability

I align with recent approaches in territorial ecology, and define the Beaufort production system as a territorial capability. This means it is a "collective capability anchored in a territorial context" (Buclet, 2021). The results of this work showed that the capability set of the Beaufort production system is intrinsically tied to the territory and is fully embedded in the social-ecological context. The Beaufort production system presents the result of these social-ecological interactions, which have evolved over time. Based on Loubet et al. (2011) Dissart, (2012) contextualised collective capabilities in a territorial system by two dimensions; collective action and the "structures of living together", that constitutes the territorial system. Buclet (2021) further developed and specified the components of this territorial system by explicitly naming them "social-ecological resources" and considering their legacies. Relational values, hereby emphasized by local identities could be interpreted as achievements of these social-ecological interactions generated by the Beaufort production system. These identities, which imply "a sense of belonging" in the sense of Roberto Esposito cannot thought neither without social structures, nor without the ecosystems (Buclet, 2021; Esposito et al., 2019). The Beaufort production system is a territorial capability that generates values evolving out of social-ecological interactions over a long period. This sets them apart from collective capabilities that are generated by collective action without a specific social-ecological context e.g. the collective capabilities in collective currencies are mainly generic and easily to transfer to similarly themed groups of collective action (Rauschmayer et al., 2018). The acquired identities through territorial capabilities also shape what people consider as achievements, but it can also shape how they use their resources (Davis, 2015; Rauschmayer et al., 2018).

3.3. Territorial capability and sustainability

The notion of territorial capabilities accentuates that the maintenance of ecosystems is crucial and foundational for a good quality of life (Polishchuk and Rauschmayer, 2012). This allows in a further step to take the long-term consequences for capabilities of future generations into account. Coupled with the NCP co-production approach it could allow to assess and quantify the consequences of current activities on future capabilities at territorial scale (Buclet, 2021). In particular, the notion of relational values and legacies can prove to be useful markers for orientating the analysis. Summed up, the territorial capability of the Beaufort production system is based on (1) members who decide their adherence to this system based on free will and not economic nor social constraints (2) a collectively agreed rule set over the management and mobilisation of social-ecological resources (3) practices that are in line with socially desired ecosystem structures. Territorial capabilities can facilitate the understanding of the roles and

types of local governance systems that maintain desired social-ecological interactions in the long term (Bennett et al., 2015). The approach highlights the ways local actors reconcile by a collectively agreed rule set across different actors within a biophysically heterogeneous landscape (Barreteau et al., 2016). I found that these institutions could partly buffer biophysical constraints like altitude and external drivers such as varying sale opportunities across the territory. For example, the Beaufort production system incorporates different types of municipalities, some of them closer to the sale market by their skiing resorts, while others provide large pasture areas. The collective level allows actors in each of these heterogeneous municipalities to make the best achievements out of their surrounding system. Further, the analysis also highlighted the relevance of proximity of social resources (infrastructure) for the co-production system. A possible precondition for territorial capabilities might be the moderate size of the PDO labelled area and the resulting production quantity. This aligns with theories of common pool resource management, that favour a moderate group size with a shared interest (Ostrom, 1990). The small size can render the brand possible less attractive for larger market partners to intervene, although this cannot be always guaranteed. For example, Lactalis, the largest player in the dairy market controls some production of the Reblochon cheese in the adjacent valleys. From the perspective of quality characteristics, the strict adherence to a raw milk product might affect the willingness of export-oriented market partners in view of different hygiene regulations at international level as well.

Research on cooperative production systems frequently characterise their specificity by the ties to the territory and the collective dimension of the modes of production (Belletti et al., 2017). Existing studies on these agricultural systems frequently focus on economic considerations (Cei et al., 2018), collective action ranging from wine and coffee (Belletti et al., 2017), to Italian cheese (Pachoud et al., 2020) or aspects of identity-construction for French cheese, such as the Comté cheese (Bérard et al., 2008; Dos Santos, 2017). None of them integrates explicitly social-ecological interactions in their results. However, studies that focus on the possible environmental benefits of quality labels (Belletti et al., 2017; Lamarque and Lambin, 2015; Marescotti et al., 2020), suggest that these niche products can foster extensive modes of production and contribute to the maintenance of HNV farming systems. The approach of territorial capabilities could facilitate to couple social-ecological interactions with the notion of freedom and related them to sustainability aspects (Buclet, 2021).

The approach of territorial capabilities shares some analytical overlaps with the commons pool rescources (CPR) approach with Elinor Ostrom (Buclet, 2021; Ostrom, 1990). Both strongly

insist on the importance of governance arrangements at territorial and local scale. However, while the two approaches exhibit large similarities in terms of emphasizing social dynamics and collective rule sets in social-ecological interactions, a profound difference is to be found in in particular in the explicit notion of freedom. This translates to differing conceptual approaches. CPR research deliberately scrutinizes collective rule systems for example in the management of pastureland, inshore fisheries or irrigations systems, but it puts less emphasis on the conceptually challenging notion of freedom , that derives out of these collective structures. Thus, the view of territorial capabilities ties approaches of collective capabilities to the social-ecological context and allows to reanalyse the regional development strategies from another angle (Dissart, 2012).

But territorial capabilities might require external recognition (e.g. by the labelling of external institutions). External labelling of collective action facilitates and contributes to collective capabilities. I suggest that these institutions with their existing, widely accepted specific rule sets could develop and implement territorial responses to future challenges like climate change or economic insecurities, through tightening environmental regulations or instituting revenues based on individual needs(Buclet, 2021; Marescotti et al., 2020; Ostrom, 1990).

4. Analysing cross-scale dynamics by the telecoupling framework

My results suggested the relevance of institutional, economic and social cross-scale interactions for territorial systems. For example, factors such as the European quality label PDO and markets, emphasized as the external demand in my framework are crucial for the maintenance of the Beaufort production system. In addition, the steady decrease of agricultural holdings cannot be understood without taking larger social transformation trends into account. Rephrased, a territorial capability that is based on proximity depends on external recognition in an increasingly interconnected, modern world. My research focus did not allow to investigate these interlinkages to external systems. This aligns with previous criticism of territorial and social-ecological systems approaches for not taking external flow dynamics sufficiently into account (Barreteau et al., 2016). In the following I briefly discuss these interdependencies using the telecoupling framework (Liu et al., 2013)

4.1. The telecoupling framework

The telecoupling framework presents one of the attempts to investigate multiple flows between distant SES. It strives to fill out the knowledge of present research that highlights the importance of the interdependencies between spatially separated, yet coupled SES (Fischer et al., 2015). Several research paths have already proposed to integrate these interdependencies with different

terminologies and focal points. For example in the field of land use change, these interactions are called land-use spill overs (Meyfroidt et al., 2018) or embodied human appropriation of net primary production (HANPP) (Erb et al., 2009), in industrial ecology hidden flows (Ayres and Ayres, 2002) or in social and political ecology externalities or environmental burdens (Martinez-Alier, 2009). Ecosystem service research terms the detrimental effects of these flows on other SES in ecosystem services "leakages" or off-stage ecosystem service burdens (Pascual et al., 2017b). The more positive concept of relational values, NCP could be extended to other distant SES than one's own surrounding as well (Chan et al., 2018).

	National Trade	**PDO certification**	**Winter tourism**	**Lifestyle**
System type	Sending	Receiving	Receiving	Receiving
Agents	Whole sale, market partners	EU institutions, INAO	Tourists	Global societies
Distance	economic	institutional	economic	social
Main CP	CP3	CP0	CP3	CP0
Values	Instrumental (economic)	Relational and instrumental (economic)	Instrumental (economic)	Relational
Causes	Economic: Consumer interest in premium products	Political: Interest in maintaining rural development	Economic: Regular inflow of winter tourists.	Social: Increasing individual lifestyle modes Economic: Diversified livelihood opportunities/ , Work related structural changes
Effects	Economic local value creation Maintenance of socioeconomic livelihoods and agriculture	Cultural: Maintenance of local livelihoods and identities	Economic local value creation Maintenance of socioeconomic livelihoods and agriculture Secondary income sources for individual farmers in the tourism sector	Socioeconomic: Decline of collective action Economic: Decrease of agricultural activities Cultural: Landscape simplification due to land abandonment Ecological: Modification

Table 1: Overview of the major telecouplings that influence the territorial capability of the Beaufort production system

I consider the emerging telecoupling concept, which encompasses all types of social and ecological material and non-material flows (Liu et al., 2013), as the most comprehensive and adapted approach for my research area. It describes socioeconomic and environmental interactions between different, distant SES along five components, systems, agents, flows, causes, and effects (Liu et al., 2013). Interacting systems are classified into either "sending" or "receiving" flows. Sending systems are those who present the origin of the flow and receiving systems are the recipients of these flows. For the sake of simplicity and to focus on the role of distant systems for territorial capabilities I deliberately exclude spill over systems, that are affected or that affect the interactions between the sending and the receiving system (Liu et al., 2013). In the context of agricultural systems the telecoupling approach has been mainly applied to global cash crops such as maize and coffee (Eakin et al., 2017) or soybeans (Liu et al., 2013), accentuating disproportions in land use change at global scale. Despite some notable exceptions, such as case studies in Peru, the USA and Morocco that highlight the relevance of public and private institutions at various interlined scales on smallholders (Zimmerer et al., 2018), studies using the telecoupling framework have not yet focused on flows impacting small-scale localized unique farming systems. I'm not aware of other research using the telecoupling concept to investigate localized unique food production system that emphasize the non-material value dimensions of agricultural production systems.

I define the system as the Beaufort production system. The main agent, thus the body that facilitates the flows is the Beaufort production system and composed of the three cooperatives (that encapsulates all members) and the consortium which oversees the entire brand (Liu et al., 2013; Lynch and Harvois, 2016). Other agents, effects and causes may vary according to the observed flows (Table 1). Current research on telecoupling surrounds various large themes such as institutions, materials, information, migration and tourism disease spread, (Hull and Liu, 2018). For the following I selected four major flows, which I deem to be of relevance for the maintenance of the territorial capability; tourism, trade, the PDO certification and lifestyle (see chapter VI, section 3). I do not include agricultural subsidies and the various impacts (e.g. regulations) of other higher-scale institutions other then the PDO-label (see chapter II, section 1.4.4) in this exploratory analysis. I consider them as universal to Alpine agricultural mountain systems and they might lack the explanatory power to explain in this case study the territorial capability. However, their crucial influence on the socioeconomic viability of these systems must not be neglected. .

4.2. Trade and tourism

National trade and tourism are predominantly financial flows, thus mainly instrumental values to the receiving Beaufort production system. Depending on their history and sales orientation the three cooperatives in the Maurienne valley have a share respectively of 16%, 30% and 60% direct sale on total sale. The remaining parts represents wholesale, with few, regular major, long-term clients in France. The Beaufort cheese is a luxury product, with prices ranging up to 50 Euro/kg in high-income areas such as Paris. It is thus not a product of necessity and accommodates a valuable niche in national and international food production. Thus, this linkage to urban consumption patterns facilitates the livelihoods of an otherwise marginalized, rural area, as observed local coffee production in Colombia (Rueda and Lambin, 2013). This coupling appears to be influential on CP3, however indirect effects on the ecosystems, such as local land degradation due to a higher consumer demand cannot be excluded. However, the PDO restrictions effectively limit the production quantity at the levels of livestock, farm and cooperative, thus large-scale changes appear to be of less risk. On the other hand, a decrease in consumer demand (e.g. economic recession) can severely impact the territorial viability.

The Beaufort production system, settled in a mountain environment in a highly industrialized, stable European country relies on the local winter tourism industry. This ensures revenues (instrumental values) from the wholesale, but also higher revenues from direct sales. The 21 sale points of the cooperatives are conveniently scattered close to the 22 skiing resorts. Further, this sale also allows to spread knowledge about the Beaufort brand to a wider public and acts as a facilitator for wholesale in distant SES. Similar to trade, tourism influences CP3 by monetary values. However, European winter tourism patterns might undergo major transformation due to the anticipated detrimental impacts of climate change in the European Alps (Haeberli and Beniston, 2021; IPCC, 2014) and structural changes in recreational sports, such as stagnating or decreasing demand for smaller skiing resorts (Bourdeau, 2009). Nevertheless, the current setting of this coupling is beneficial for the system.

4.3. PDO certification

The Beaufort production system is the receiving system for PDO certification. The inflows are of mainly regulatory nature coming from higher scale institutions. PDO certification promotes distinct regional agricultural products through a market-based economic mechanism and is thus related to trade (Quiñones Ruiz et al., 2018). The overall aim of the PDO system and other GI-labels is to maintain rural agricultural livelihoods by upholding high quality standards and protecting them from competition of inferior products (Belletti et al., 2017). In a certain way

these could be regarded as relational values, although the underlying economic mechanism is definitely an instrumental value. This coupling is predominantly evident at CP0, however it protects the collectively agreed rule set at regional level. Thus it pervades all levels of co-production and is crucial for the entire NCP co-production. At national level, the INAO a sub organisation of the French ministry of agriculture is the main contact for PDO labelled products in France. This can considered side as institutional fragmentation (Bodin, 2017) with lengthy amendment and administration processes. On the other hand, those are in certain regards beneficial, as they ensures relatively stable regulations with few fundamental changes in production processes. Currently, amendments need be initiated from the receiving systems. However an easing or tightening of current regulations or a systemic institutional change of the PDO label such as the reduction of the 75% fodder requirement might inflict large-scale changes to the current territorial capability by modifying agricultural practices (e.g. reduction of grazing). Aesthetic landscape features such as summer pastures are used for marketing and communication purposes (www.maurienne-tourisme.com). Furthermore explicit links between the Beaufort production system and the tourism sector, such as guided tours of production facilities, are proposed by some Beaufort cooperatives (Durrande-Moreau, 2017).

4.4. Lifestyle

I consider here the Beaufort production system as a receiving system for lifestyle. I define the non-material flows as information that can affect goals and values of individual actors of the Beaufort production system. I tentatively suggest that these are of relational values and underline their multiple, heterogeneous dimensions. One could interpret the ongoing current decline of agricultural holdings in mountain regions as the effect of evolving social value systems. In addition current modes of production have steadily evolved and societies find more diversified livelihood incomes today, without the need to leave their region (Löffler et al., 2014). Further, the Maurienne valley hosts a number of international companies and the unemployment rate is relatively low (SPM, 2020). The aging farming population, with one of three farms without successor, confirms that agricultural activities with their various constraints in flexible time management are considered as less desirable options. In my field research, actors cited as possible solutions, compatible with the evolving lifestyle patterns forms of collective management of farm holdings, but simultaneously they regretted the prevailing lack of individual involvement in already existing structures. In a short-term perspective, the impact of this coupling is certainly most visible at CP1 and CP2 with the lack of physical labour in a region with limited possibilities to compensate by technological factors of production (Flury et

al., 2013). However, in a longer perspective they threaten the entire production system based on a collective value system. This coupling possibly poses the most problem for the Beaufort production system.

In summary, these four coupling mechanisms appear to be particularly powerful at CP0 of the Beaufort production system through its higher scale governance mechanism. The Beaufort production systems acts thereby as a receiving, benefitting system. The two couplings, national trade and tourism indicates that can act complementary. However, the coupling lifestyle appears to be the coupling with the least beneficial outcomes for the Beaufort production system. On the other hand the inflow of new wealthy rural residents by evolving work patterns (home office) could increase the direct sale at territorial scale. This tentative analysis identifies the external drivers of the system. However, although I presented each telecoupling flows separately I emphasize the strong interactions between them (Liu et al., 2013). Telecoupling can offer an excellent systematic, structured framework to better understand territorial capabilities to at least partly buffer the spatial and temporal interdependencies frequently emerging in research on NCP /ecosystem services (Winkler et al., 2021). The analysis of telecoupling shows that the territorial capability of the Beaufort production system also depends on larger institutional and social mechanisms outside the sphere of influence. .

5. Some reflections on interdisciplinarity

Sustainability research faces in general an underrepresentation of social sciences (Herrero-Jáuregui et al. 2018). Some social scientists state they are frequently seen as in the role of finding solutions, but are not sufficiently involved in the analysis of specific environmental problems (Hysing and Lidskog, 2021). In the context of the IPBES framework Stenseke and Larigauderie (2018) named as main reasons for this deficiency institutional barriers, missing relationships between social scientists and governmental bodies who nominate IPBES authors and the lack of self-identification with IPBES research themes. Other attempts to explain this underrepresentation range from different research objectives (LéLé and Norgaard, 2005), research focal points (MacLeod and Nagatsu, 2018) to different time and spatial scales (Stevens et al., 2007). These diverse observations confirm that sustainability research integrates and converges increasingly multiple perspectives and disciplines (Droste, D'Amato, and Goddard 2018). Another relatively overlooked, but seemingly obvious difference is the terminology (Hyland, 2004).

The reasoning of my qualitative approach to understand society-ecosystem relations is based on the idea that reality is constructed on the sharing of same language. Underlying values and

subsequent activities might be deeply intertwined with the used terms. During the course of the last four years I have been constantly challenged with choices of which and why terms deemed to be more appropriate than others. I thus propose to briefly revisit the disciplines I frequently encountered, their etymological meaning, their focus and their most relevant terms in social-ecological research (Table 3). Without being endowed with refined, nor trained linguistic capacities, I only suggest to rethink the terms we apply to ensure a wider readability and understanding among disciplines and the wider audience. I did not explicitly consider interdisciplinary fields such as political ecology, ecological economics or landscape ecology. The increasing jargonized language is not a unique feature of social-ecological research. A synthesis that investigated the readability of 700,000 biomedical and life science related articles dating from 1881 to 2015 suggested as well that the readability of scientific articles has considerably decreased (Plavén-Sigray et al., 2017).

A very modest result of my certainly not exhaustive, in some aspects even caricatured comparison is that the original meanings of the disciplines exhibit commonalities, but their terms have largely dispersed in different epistemological directions. This might be explained by the "great divide" at the beginning of the 20th century between social and natural sciences reflected by Snow in the 1950s (Snow and Collini, 1993). Another interesting finding was that for example that truly interdisciplinary terms such as 'landscape' don't have any equivalent terminologies in the compared disciplines. This might indicate that interdisciplinarity is already ceating its own specific terminology. However as previous research strongly insists, there is an urgent need to reconcile these different disciplines in order to ensure the viability of social-ecological interactions at all scales (Fischer-Kowalski and Weisz, 2016). If social-ecological scientists choose to have an active role in public and in particular in science-policy interfaces, they must, maybe more than other disciplines aware of their language use (Crouzat et al., 2018). The vibrant research around the IPBES framework might offer a valid platform for academic, policy and social actors to continue engaging in this discourse.

My thesis	Ecology	Economics	Sociology	Political science	Territorial ecology
Defining the disciplines					
Etymology	Greek: eco: household," "home," or "place to live."	Greek: eco meaning: "house"; "home," or "place to live." nomos: accounts .	Latin: socius, meaning "companion"	Greek: affairs of the cities'	French: territoire "a space that is socially constructed, culturally marketed and institutionally regulated."(Lopéz and Muchnik, 1997).
Objective	The whole science of the relations of the organism to the environment including, in the broad sense, all the "conditions of existence. (Haeckel, 1866, (Egerton, 2013).	The study of how people and society choose, with or without the use of money, to employ scarce productive resources which could have alternative uses, to produce various commodities over time and distribute them for consumption now and in the future among various persons and groups of society. (Samuelson and Nordhaus, 2005)	The science whose object is to interpret the meaning of social action and thereby give a causal explanation of the way in which the action proceeds and the effects which it produces (Weber, 1978).	The branch of knowledge that deals with the state and systems of government; the scientific analysis of political activity and behaviour(Lexico, 2021).	The systemic study of linking ecological issues with territorial issues based on questions related to thermodynamics (Barles 2004).
Interactions	Between living organisms and within living organisms and their abiotic environment	Actors on the market	Within society	Different groups of power	Within societies and with the ecosystem
Boundaries	Ecosystem	Markets	Groups, agents	Administrative boundaries	Territorial
Selected examples of the varying terms					
Social-ecological system	Ecosystem	Bioeconomy	Environment	Sphere of influence	Territory
Social-ecological legacies	Legacies	Capital	Heritage	Legacies	Heritage

Values	Behaviour	Attitudes /Preferences	Beliefs/ Nonmaterial culture	Strategies	Non material resources
Relevance	Sensitivity /Dominance	Importance	Authority	Power	-
Compensate	Buffer/bet hedging	Subsidies	Balance/solidarity	Democratize	-
Resources	Disturbance	Goods and services	-	Private and public property	
Social dynamics	Human	Households/firms/regulatory authorities	Agents	Groups of interest	Actors
Steps of co-production	Mechanisms	Labour division	-	-	-
Landscape	-	-	-	-	Paysage
Telecoupling	Teleconnections	Externalisation	-	Globalisation	Politics of proximity
Collective capabilities	Interference	Social capital	Social relations	-	Non material resources
Mobilise	Consume	Extract	Create	Generate	Activate
Trade-off	Trade-off	-	Reconciliation	Compromise	-

Table 3: An exploratory overview of terminologies of different disciplines

Conclusion

In this research, I analysed the various material and non-material flows of an agricultural cooperative production system at territorial scale by deliberately focusing on the social dimensions of social-ecological interactions.

Good quality of life was at the centre of my work. The objective of further knitting this seemingly abstract concept into the contextual fabric of the real world allowed me to unravel the multiple aspects that render life meaningful to people. My interdisciplinary analysis across the social-ecological co-production chain showed the deep interlinkages of societies and ecosystems. It highlighted that relational values that go beyond commonly used metrics of human well-being are constitutive for the understanding of these interactions. I showed how the analysis of the interplay of the various components of social-ecological systems, such as the biophysical context, social dynamics and current resources can help identifying and naming these non-material aspects. This can broaden current scientific discourses on valuation systems, democratize these non-material aspects by recognising them as crucial conceptualisations that broaden the analysis for sustainability related research questions. More research in this field is certainly needed though to draw any final conclusion from this case study.

The choice of seeing societies as a network of social beings and not as a group of isolated individuals embedded the links between collective governance and relational value systems in NCP-co-production. This analysis highlighted the importance for territorial societies to engage in collective action that results in the freedom of people to choose what they consider as worthwhile. At the same time, this freedom in the sense of Roberto Esposito, defined as a "sense of belonging" also comes with responsibility for other human and non-human beings (Esposito et al., 2019; Latour, 1993). By making the temporal scale in social-ecological interactions explicit, the emphasis on social-ecological legacies acknowledges that current activities become the legacies of future societies, emphasizing society's responsibility for non-yet born generations.

Future research on collective capabilities coupled with the IPBES framework can greatly facilitate further analysis on regional institutional structures. This approach can raise the awareness about the multiple values of ecosystems among local societies and could complement ongoing economic assessments on regional development from a holistic perspective. Regional governance regimes cannot only influence the activities of their members; they can also be crucial in the shaping of values. At larger scale, these findings could incite current incentive and subsidy schemes to foster collective structures that align with people's needs to lead a

meaningful life. However, my proposed focus on collective systems neglects neither the role of the individual nor that of public policies in outlining the agenda for the future. Thus, consistent with sustainability thinking, one must not forget the interconnectedness of all systems at all scales.

This work can be criticised for deliberately favouring self-organised governance systems over liberal, individual-based conceptions on society, by emphasizing relational, non-material aspects over instrumental values, by considering good quality of life as the emergent result of social-ecological interactions and not as a checklist of performance-based individual achievements. On the other hand, in light of the current large-scale social, ecological and climatic changes that will penetrate and affect our lives in the not so distant future maybe one needs to rethink and readjust formerly conventional conceptions of how societies can ensure a good quality of life for all.

Acronyms

AC Alpine Convention

CA Capability Approach

CAP Common Agricultural Policy

CD Cambridge Dictionary

CNAOL Conseil national des appellation d'origine laitières

CP Co-production

CPR Common pool resources

EAFRD European Agricultural Fund for Rural Development

EEA European Environment Agency

EC European commission

ES Ecosystem Service

EU European Union

FAO Food and Agriculture Organisation of the United Nations

GDP Gross Domestic Product

GI Geographical Indication

GIAHS Globally Important Agricultural Heritage Systems

HANPP Human Appropriation of Net Primary Production

HNV High Nature Value

INAO Institut national de l'origine de la qualité

INSEE Institut national de la statistique et des études économiques

IPBES International Intergovernmental Platform on Biodiversity and Ecosystem Services

IPCC International Panel for Climate Change

NCP Nature's Contributions to People

MEA Millenium Ecosystem Assessment

PDO Protected Designation of Origin

PES Payment for Ecosystem Services

RGP Registre Parcellaire Graphique

SCOT Schéma de Cohérence Territoriale

SES Social-Ecological System

SDB Syndicat de Défense du Beaufort

SMB Savoie Mont Blanc

SPM Syndicat du Pays de Maurienne

STS Science and Technology studies

TBL Tripple bottom line

TEEB The Economics of Ecosystems and Biodiversity

UNESCO United Nations Educational, Scientific and Cultural Organisation

References (chapter I, II and VI)

AC AC. 2006. Protocol on the implementation of the 1991 Alpine Convention in the field of mountain farming Mountain Farming Protocol. https://www.alpconv.org/en/home/convention/protocols-declarations/.

Alkire S. 2008. The capability approach to the quality of Life.

Alliance in the Alps. 2020. Alliance in the Alps -The community network. https://alpenallianz.org/en/about-us/.

Ayres R, Ayres L. 2002. A Handbook of Industrial Ecology. Edward Elgar Publishing. [accessed 2021 May 5]. http://www.elgaronline.com/view/9781840645064.xml.

Baird IG, Le Billon P. 2012. Landscapes of political memories: War legacies and land negotiations in Laos. Polit Geogr. 31(5):290–300. doi:10.1016/j.polgeo.2012.04.005.

Ballet J, Dubois J, Mahieu F. 2007. Responsibility for Each Other's Freedom: Agency as the Source of Collective Capability. J Hum Dev. 8(2):185–201. doi:10.1080/14649880701371000.

Ballet J, Marchand L, Pelenc J, Vos R. 2018. Capabilities, identity, aspirations and ecosystem services: an integrated framework. Ecol Econ. 147:21–28. doi:10.1016/j.ecolecon.2017.12.027.

Barles S. 2007. Mesurer la performance écologique des villes et des territoires : le métabolisme de Paris et de l'Ile-de-France.

Barreteau O, Giband D, Schoon M, Cerceau J, DeClerck F, Ghiotti S, James T, Masterson VA, Mathevet R, Rode S, et al. 2016. Bringing together social-ecological system and territoire concepts to explore nature-society dynamics. Ecol Soc. 21(4). doi:10.5751/ES-08834-210442. [accessed 2021 Apr 10]. http://www.ecologyandsociety.org/vol21/iss4/art42/.

Beaufoy G, HNV Link Partners. 2017. THE HNV LINK COMPENDIUM Comparative collection of High Nature Value innovations, experiences, needs and lessons from 10 European "Learning Areas" A thematic network on High Nature Value farming Learning, Innovation & Knowledge T.

Becattini G, Bellandi M, Dei Ottati G, Sforzi F. 2003. From industrial districts to local development: an itinerary of research. Cheltenham: Elgar.

Belletti G, Marescotti A, Touzard J-M. 2017. Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies. World Dev. 98:45–57. doi:10.1016/j.worlddev.2015.05.004.

Bendor R, Maggs D, Peake R, Robinson J, Williams S. 2017. The imaginary worlds of sustainability: observations from an interactive art installation. Ecol Soc. 22(2). doi:10.5751/ES-09240-220217. [accessed 2021 May 20]. https://www.ecologyandsociety.org/vol22/iss2/art17/.

Bennett EM, Cramer W, Begossi A, Cundill G, Díaz S, Egoh BN, Geijzendorffer IR, Krug CB, Lavorel S, Lazos E, et al. 2015. Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. Curr Opin Environ Sustain. 14:76–85. doi:10.1016/j.cosust.2015.03.007.

Bérard L, Marchenay P, Voinson J. 2008. From Localized Products to Geographical Indications- Awareness and Action. Bourg-en-Bresse: CNRS, Ressources des terroirs-Cultures, usages, sociétés.

Berbés-Blázquez M, González JA, Pascual U. 2016. Towards an ecosystem services approach that addresses social power relations. Curr Opin Environ Sustain. 19:134–143. doi:10.1016/j.cosust.2016.02.003.

Berkes F. 2017. Environmental governance for the Anthropocene? Social-ecological systems, resilience, and collaborative learning. Sustainability. 9(7):1232. doi:10.3390/su9071232.

Berkes F, Colding J, Folke C. 2000. Rediscovery of Traditional Ecological Knowledge as adaptive management. Ecol Appl. 10(5):1251. doi:10.2307/2641280.

Berlin I. 1969. Four essays on liberty. London, New York [etc.]: Oxford U.P (Oxford paperbacks, 116).

Bevione M. 2021. L'analyse des interactions entre flux et acteurs pour la compréhension des enjeux socio-écologiques à l'échelle d'un territoire : application à la production du fromage AOP Beaufort dans la vallée de la Maurienne. Université Grenoble-Alpes Project Trajectories.

Blaikie P. 2015. Land degradation and society. 1st ed. Routledge. [accessed 2020 Oct 12]. https://www.taylorfrancis.com/books/9781315685366.

Bodin Ö. 2017. Collaborative environmental governance: achieving collective action in social-ecological systems. Science. 357(6352):eaan1114. doi:10.1126/science.aan1114.

Bourdeau P. 2009. De l'après-ski à l'après-tourisme, une figure de transition pour les Alpes ?: Réflexions à partir du cas français. Rev Géographie Alp.(97–3). doi:10.4000/rga.1049. [accessed 2021 May 23]. http://journals.openedition.org/rga/1049.

Braat LC, de Groot R. 2012. The ecosystem services agenda:bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosyst Serv. 1(1):4–15. doi:10.1016/j.ecoser.2012.07.011.

Brown K, Eernstman N, Huke AR, Reding N. 2017. The drama of resilience: learning, doing, and sharing for sustainability. Ecol Soc. 22(2). doi:10.5751/ES-09145-220208. [accessed 2021 May 20]. https://www.ecologyandsociety.org/vol22/iss2/art8/.

Bruley E, Locatelli B, Lavorel S. 2021. Nature's contributions to people: coproducing quality of life from multifunctional landscapes. Ecol Soc. 26(1). doi:10.5751/ES-12031-260112. [accessed 2021 Apr 26]. https://www.ecologyandsociety.org/vol26/iss1/art12/.

Brundtland GH. 1987. Report of the World Commission on Environment and Development: Our Common Future. United Nations General Assembly document A/42/427.

Buclet N. 2021. Territorial ecology.

Buclet N, Barles S. 2011. Écologie industrielle et territoriale: stratégies locales pour un développement durable. Villeneuve d'Ascq: Presses universitaires du Septentrion.

Burckhardt L. 2015. Why is Landscape Beautiful?: The Science of Strollology. Schmitz M, editor. DE GRUYTER. [accessed 2021 May 23]. https://www.degruyter.com/document/doi/10.1515/9783035604139/html.

Carney D, Great Britain, Department for International Development. 2003. Sustainable livelihoods approaches: progress and possibilities for change. London: Department for International Development.

CD CD. 2021. Cambridge Dictionnary. [accessed 2021 Jan 21]. https://dictionary.cambridge.org/fr/.

Cei L, Defrancesco E, Stefani G. 2018. From geographical indications to rural development: a review of the economic effects of European Union policy. Sustainability. 10(10):3745. doi:10.3390/su10103745.

Chan KM, Gould RK, Pascual U. 2018. Editorial overview: relational values: what are they, and what's the fuss about? Curr Opin Environ Sustain. 35:A1–A7. doi:10.1016/j.cosust.2018.11.003.

Chan KMA, Balvanera P, Benessaiah K, Chapman M, Díaz S, Gómez-Baggethun E, Gould R, Hannahs N, Jax K, Klain S, et al. 2016. Opinion: Why protect nature? Rethinking values and the environment. Proc Natl Acad Sci. 113(6):1462–1465. doi:10.1073/pnas.1525002113.

Cheese. 2021. Cheese. Wikipedia. [accessed 2021 May 26]. https://en.wikipedia.org/wiki/Cheese.

CIPRA. 2020. Living in the Alps. https://www.cipra.org/en/about/members.

CNAOL C national des appellation d'origine laitières. 2016. Chiffres clés 2016- Des produits sous signes de la qualité et de l'origine Produits laitiers AOP et IGP.

Colding J, Barthel S. 2019. Exploring the social-ecological systems discourse 20 years later. Ecol Soc. 24(1). doi:10.5751/ES-10598-240102. [accessed 2021 Feb 26]. https://www.ecologyandsociety.org/vol24/iss1/art2/.

Comim F, Carey F. 2001. Social capital and the capability approach : are Putnam and Sen incompatible bedfellows ? Work Pap St Edmund's Coll.

Copernicus Land Monitoring Service. 2018. Corine Land Cover (CLC) Version 2020_20u1. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=metadata.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, et al. 1997. The value of the world's ecosystem services and natural capital. Nature. 387(6630):253–260. doi:10.1038/387253a0.

Crane TA. 2010. Of Models and Meanings: Cultural Resilience in Social–Ecological Systems. Ecol Soc. [accessed 2021 May 23]. http://www.ecologyandsociety.org/vol15/iss4/art19/.

Crawley MJ, Odum HT. 1984. Systems ecology. An introduction. J Anim Ecol. 53(2):695. doi:10.2307/4547.

Crouzat E, Arpin I, Brunet L, Colloff MJ, Turkelboom F, Lavorel S. 2018. Researchers must be aware of their roles at the interface of ecosystem services science and policy. Ambio. 47(1):97–105. doi:10.1007/s13280-017-0939-1.

Daly H. 2007. Ecological Economics and Sustainable Development, Selected Essays of Herman Daly. Edward Elgar Publishing. [accessed 2021 May 22]. http://www.elgaronline.com/view/9781847201010.xml.

Daly HE. 1997. Georgescu-Roegen versus Solow/Stiglitz. Ecol Econ. 22(3):261–266. doi:10.1016/S0921-8009(97)00080-3.

Davis JB. 2015. Agency and the Process Aspect of Capability Development: Individual Capabilities, Collective Capabilities, and Collective Intentions. Filos Econ Forthcom. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2625673.

de Schutter, Giljum, Häyhä, Bruckner, Naqvi, Omann, Stagl. 2019. Bioeconomy transitions through the lens of coupled social-ecological Systems: a framework for lace-based responsibility in the global resource system. Sustainability. 11(20):5705. doi:10.3390/su11205705.

Del Biaggio C. 2015. Territory beyond the anglophone tradition. In: Agnew J, Mamadouh V, Secor AJ, Sharp J, editors. The Wiley Blackwell Companion to Political Geography: Agnew/The Wiley Blackwell Companion to Political Geography. Chichester, UK: John Wiley & Sons, Ltd. [accessed 2021 Jan 20]. http://doi.wiley.com/10.1002/9781118725771.

Delfosse C. 2007. La France fromagère (1850-1990). Paris: Boutique de l'histoire (Mondes ruraux contemporains).

Delfosse C. 2012. La diffusion mondiale de la consommation de fromage, de l'ingrédient de pizza au produit de terroir. GREP N° 215-216.:p.123-129.

Di Méo G. 2017. Préface. In: Au coeur des territoires créatifs - Proximités et ressources territoriales. Glon Eric, Pecqueur, Bernard.

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, et al. 2015a. The IPBES conceptual framework — connecting nature and people. Curr Opin Environ Sustain. 14:1–16. doi:10.1016/j.cosust.2014.11.002.

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, et al. 2015b. The IPBES Conceptual Framework — connecting nature and people. Curr Opin Environ Sustain. 14:1–16. doi:10.1016/j.cosust.2014.11.002.

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, et al. 2018. Assessing nature's contributions to people. Science. 359(6373):270–272. doi:10.1126/science.aap8826.

Dissart J-C. 2012. Co-construction des capacités et des ressources territoriales dans les territoires touristiques de montagne: Étude de cas sur l'Oisans. Rev Géographie Alp.(100–2). doi:10.4000/rga.1781. [accessed 2021 Apr 28]. http://journals.openedition.org/rga/1781.

Dos Santos A. 2017. Labelling mountain food products in Europe- Beyond the simple quality distinction, an opportunity to join forces and build resilient food systems. [Netherlands]:

Wageningen University. [accessed 2020 Sep 24]. https://www.euromontana.org/en/our-approche/euromontanas-publications/.

Duraiappah AK, Asah ST, Brondizio ES, Kosoy N, O'Farrell PJ, Prieur-Richard A-H, Subramanian SM, Takeuchi K. 2014. Managing the mismatches to provide ecosystem services for human well-being: a conceptual framework for understanding the New Commons. Curr Opin Environ Sustain. 7:94–100. doi:10.1016/j.cosust.2013.11.031.

Durrande-Moreau A. 2017. S'appuyer sur un produit agroalimentaire AOP pour innover en tourisme : le cas du fromage de beaufort.

Eakin H, Rueda X, Mahanti A. 2017. Transforming governance in telecoupled food systems. Ecol Soc. 22(4). doi:10.5751/ES-09831-220432. [accessed 2021 Mar 1]. https://www.ecologyandsociety.org/vol22/iss4/art32/.

EC EC. 2018. Economy-wide material flow accounts handbook. [accessed 2021 May 19]. https://doi.org/10.2785/158567.

Edge S, McAllister ML. 2009. Place-based local governance and sustainable communities: lessons from Canadian biosphere reserves. J Environ Plan Manag. 52(3):279–295. doi:10.1080/09640560802703058.

EEA EEA. 2010. Europe's ecological backbone: recognising the true value of our mountains. Luxembourg: Off. for Off. Publ. of the Europ. Union (EEA report).

Egarter Vigl L, Schirpke U, Tasser E, Tappeiner U. 2016. Linking long-term landscape dynamics to the multiple interactions among ecosystem services in the European Alps. Landsc Ecol. 31(9):1903–1918. doi:10.1007/s10980-016-0389-3.

Egerton FN. 2013. History of Ecological Sciences, Part 47: Ernst Haeckel's Ecology. Bull Ecol Soc Am. 94(3):222–244. doi:10.1890/0012-9623-94.3.222.

Ehrlich P, Ehrlich A. 1981. Extinction: the causes and consequences of the disappearance of species. New York: RandomHouse.

Elmi M. 2018. The Alps in 25 maps. Bolzano; = Bozen: Permanent Secretariat of the Alpine Convention.

Erb K-H, Krausmann F, Lucht W, Haberl H. 2009. Embodied HANPP: Mapping the spatial disconnect between global biomass production and consumption. Ecol Econ. 69(2):328–334. doi:10.1016/j.ecolecon.2009.06.025.

Erkman S. 2004. Vers une écologie industrielle. Paris: C.L. Mayer.

Ernstson H. 2013. The social production of ecosystem services: a framework for studying environmental justice and ecological complexity in urbanized landscapes. Landsc Urban Plan. 109(1):7–17. doi:10.1016/j.landurbplan.2012.10.005.

Esposito R, Neyrat F, Chamayou B. 2019. Communauté, immunité, biopolitique: repenser les termes de la politique.

Evans P. 2002. Collective capabilities, culture, and Amartya Sen's development as freedom. Stud Comp Int Dev. 37(2):54–60. doi:10.1007/BF02686261.

FAO F and AO of the UN. 2013. Mountain farming is family farming: a contribution from mountain areas to the International Year of Family Farming 2014. Rome: FAO.

Farber SC, Costanza R, Wilson MA. 2002. Economic and ecological concepts for valuing ecosystem services. Ecol Econ. 41(3):375–392. doi:10.1016/S0921-8009(02)00088-5.

Faure M. 1999. Un produit agricole « affiné » en objet culturel: Le fromage Beaufort dans les Alpes du Nord. Terrain.(33):81–92. doi:10.4000/terrain.2703.

Fedele G, Locatelli B, Djoudi H. 2017. Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst Serv. 28:43–54. doi:10.1016/j.ecoser.2017.09.011.

Fischer A, Eastwood A. 2016. Coproduction of ecosystem services as human–nature interactions—An analytical framework. Land Use Policy. 52:41–50. doi:10.1016/j.landusepol.2015.12.004.

Fischer J, Gardner TA, Bennett EM, Balvanera P, Biggs R, Carpenter S, Daw T, Folke C, Hill R, Hughes TP, et al. 2015. Advancing sustainability through mainstreaming a social–ecological systems perspective. Curr Opin Environ Sustain. 14:144–149. doi:10.1016/j.cosust.2015.06.002.

Fischer-Kowalski M, Haberl H. 2007. Conceptualizing, observing and comparing socioecological transitions. In: Socioecological Transitions and Global Change. Edward Elgar Publishing. [accessed 2021 Feb 3]. http://www.elgaronline.com/view/9781847203403.00008.xml.

Fischer-Kowalski M, Hüttler W. 1998. Society's metabolism.: the intellectual history of materials flow analysis, part II, 1970-1 998. J Ind Ecol. 2(4):107–136. doi:10.1162/jiec.1998.2.4.107.

Fischer-Kowalski M, Weisz H. 2016. The Archipelago of Social Ecology and the Island of the Vienna School. In: Haberl H, Fischer-Kowalski M, Krausmann F, Winiwarter V, editors. Social Ecology. Cham: Springer International Publishing. p. 3–28. [accessed 2021 May 15]. http://link.springer.com/10.1007/978-3-319-33326-7_1.

Flury C, Huber R, Tasser E. 2013. Future of mountain agriculture in the Alps. In: Mann S, editor. The Future of Mountain Agriculture. Berlin, Heidelberg: Springer Berlin Heidelberg. p. 105–126. [accessed 2020 Oct 8]. http://link.springer.com/10.1007/978-3-642-33584-6_8.

Folke C, Biggs R, Norström AV, Reyers B, Rockström J. 2016. Social-ecological resilience and biosphere-based sustainability science. Ecol Soc. 21(3). doi:10.5751/ES-08748-210341. [accessed 2021 Jan 20]. http://www.ecologyandsociety.org/vol21/iss3/art41/.

Forsyth T. 2015. Ecological Functions and Functionings: Towards a Senian Analysis of Ecosystem Services: Ecological Functions and Functionings. Dev Change. 46(2):225–246. doi:10.1111/dech.12154.

Foster JB. 1999. Marx's Theory of Metabolic Rift: Classical Foundations for Environmental Sociology. Am J Sociol. 105(2):366–405. doi:10.1086/210315.

Fournier S. 2008. Les Indications géographiques : une voie de pérennisation des processus d'action collective au sein des Systèmes agroalimentair. Cah Agric. 17(6):547–551. doi:10.1684/agr.2008.0250.

France: Declaration of the Right of Man and the Citizen. 1789. France: Declaration of the Right of Man and the Citizen. [accessed 2021 May 26]. https://www.refworld.org/docid/3ae6b52410.html.

Fromage. 2021. Fromage. Wikipedia. [accessed 2021 May 26]. https://fr.wikipedia.org/wiki/Fromage.

García-Martín M, Torralba M, Quintas-Soriano C, Kahl J, Plieninger T. 2020 Dec 8. Linking food systems and landscape sustainability in the Mediterranean region. Landsc Ecol. doi:10.1007/s10980-020-01168-5. [accessed 2021 May 3]. http://link.springer.com/10.1007/s10980-020-01168-5.

Gervais D. 2015. International Intellectual Property. Edward Elgar Publishing. [accessed 2021 May 28]. http://www.elgaronline.com/view/9781782544791.xml.

Gobiet A, Kotlarski S, Beniston M, Heinrich G, Rajczak J, Stoffel M. 2014. 21st century climate change in the European Alps—A review. Sci Total Environ. 493:1138–1151. doi:10.1016/j.scitotenv.2013.07.050.

Gómez-Baggethun E, de Groot R, Lomas PL, Montes C. 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecol Econ. 69(6):1209–1218. doi:10.1016/j.ecolecon.2009.11.007.

Gomez-Baggethun E, Martin-Lopez B. 2015. Ecological economics perspectives on ecosystem services valuation. In: Martinez-Alier J, editor. Handbook of Ecological Economics. Edward Elgar Publishing. p. 260–282. [accessed 2021 Jan 12]. http://www.elgaronline.com/view/9781783471409.00015.xml.

Griewald Y, Rauschmayer F. 2014. Exploring an environmental conflict from a capability perspective. Ecol Econ. 100:30–39. doi:10.1016/j.ecolecon.2014.01.001.

Guerry AD, Polasky S, Lubchenco J, Chaplin-Kramer R, Daily GC, Griffin R, Ruckelshaus M, Bateman IJ, Duraiappah A, Elmqvist T, et al. 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proc Natl Acad Sci. 112(24):7348–7355. doi:10.1073/pnas.1503751112.

Haeberli W, Beniston M. 2021. Icy mountains in a warming world: Revisiting science from the end of the 1990s in the early 2020s: This article belongs to Ambio's 50th Anniversary Collection. Theme: Climate change impacts. Ambio. 50(6):1130–1132. doi:10.1007/s13280-021-01513-1.

Haines-Young R, Potschin M. 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli DG, Frid CLJ, editors. Ecosystem Ecology. Cambridge: Cambridge University Press. p. 110–139. [accessed 2021 Jan 18].

https://www.cambridge.org/core/product/identifier/CBO9780511750458A013/type/book_part.

Hale RL, Cook EM, Beltrán BJ. 2019. Cultural ecosystem services provided by rivers across diverse social-ecological landscapes: A social media analysis. Ecol Indic. 107:105580. doi:10.1016/j.ecolind.2019.105580.

Henriques A, Richardson J. 2013. The Triple Bottom Line: Does It All Add Up. Hoboken: Taylor and Francis. [accessed 2021 May 22]. http://grail.eblib.com.au/patron/FullRecord.aspx?p=430036.

Hernández-Morcillo M, Plieninger T, Bieling C. 2013. An empirical review of cultural ecosystem service indicators. Ecol Indic. 29:434–444. doi:10.1016/j.ecolind.2013.01.013.

Hinojosa L, Napoléone C, Moulery M, Lambin EF. 2016. The "mountain effect" in the abandonment of grasslands: insights from the French Southern Alps. Agric Ecosyst Environ. 221:115–124. doi:10.1016/j.agee.2016.01.032.

Hobbes T. 1996. Hobbes: Leviathan. 1st ed. Tuck R, editor. Cambridge University Press. [accessed 2021 May 26]. https://www.cambridge.org/core/product/identifier/9780511808166/type/book.

Hull V, Liu J. 2018. Telecoupling: a new frontier for global sustainability. Ecol Soc. 23(4). doi:10.5751/ES-10494-230441. [accessed 2021 Mar 1]. https://www.ecologyandsociety.org/vol23/iss4/art41/.

Hyland K. 2004. Disciplinary Discourses, Michigan Classics Ed.: Social Interactions in Academic Writing. Ann Arbor, MI: University of Michigan Press. [accessed 2021 May 23]. http://www.press.umich.edu/6719.

Hysing E, Lidskog R. 2021. Do conceptual innovations facilitate transformative change? The case of biodiversity governance. Front Ecol Evol. 8. doi:10.3389/fevo.2020.612211. [accessed 2021 Apr 18]. https://www.frontiersin.org/articles/10.3389/fevo.2020.612211/full.

Ibrahim SS. 2006. From individual to collective capabilities: the capability approach as a conceptual framework for self-help. J Hum Dev. 7(3):397–416. doi:10.1080/14649880600815982.

IGN-F I national de l'information géographique et forestière. 2006. BD Carthage Version 3.0. http://www.sandre.eaufrance.fr/sites/default/files/IMG/pdf/1-DC_BDCARTHAGE_3_0.pdf.

IGN-F I national de l'information géographique et forestière. 2019. BD TOPO® -Base de Données Topographiques. https://geoservices.ign.fr/ressources_documentaires/Espace_documentaire/BASES_VECTORIELLES/BDTOPO/IGNF_BDTOPOr_3-0.html.

INAO (Institut national de l'origine et de la qualité). 2015. Cahier des charges de l'appellation d'origine « Beaufort ».

IPBES IIP on B and ES. 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Popul Dev Rev. 45(3):680–681. doi:10.1111/padr.12283.

IPBES IS-PP on B and ES. 2018. The regional assessment report on biodiversity and ecosystem services for Europe and Central Asia: summary for policymakers.

IPCC. 2014. Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [. 2014.

Jaume M. 2019. Patrimoine et metabolisme territorial-Essai d'analyse systémique appliquée à la vallée de la Maurienne. [Grenoble]: Université Grenoble-Alpes Project Trajectories. Supervised by Nicolas Buclet , Laurent Rieutort and Pierre Antoine Landel.

Kallis G, Gómez-Baggethun E, Zografos C. 2013. To value or not to value? That is not the question. Ecol Econ. 94:97–105. doi:10.1016/j.ecolecon.2013.07.002.

Kebir L, Crevoisier O. 2004. Dynamique des ressources et milieux innovateurs. In: Ressources naturelles et culturelles, milieux et d❓veloppement local. Neuch❓tel: GREMI et EDES. (R. Camagni, D. Maillat, A. Matteaccioli, editors. Ressources naturelles et culturelles, milieux et d❓veloppement local).

Klein JA, Tucker CM, Nolin AW, Hopping KA, Reid RS, Steger C, Grêt-Regamey A, Lavorel S, Müller B, Yeh ET, et al. 2019. Catalyzing Transformations to Sustainability in the World's Mountains. Earths Future. 7(5):547–557. doi:10.1029/2018EF001024.

Koohafkan P. 2019. Globally important agricultural heritage systems (GIAHS): a legacy for food and nutrition security. In: Burlingame B, Dernini S, editors. Sustainable diets: linking nutrition and food systems. Wallingford: CABI. p. 204–214. [accessed 2021 Apr 7]. http://www.cabi.org/cabebooks/ebook/20183377475.

Kosoy N, Corbera E. 2010. Payments for ecosystem services as commodity fetishism. Ecol Econ. 69(6):1228–1236. doi:10.1016/j.ecolecon.2009.11.002.

Lachello R. 2021. Une histoire des socio-écosystèmes forestiers alpins: le cas de la vallée de la Maurienne de 1815-1940 (Savoie, France). [Grenoble]: Université Grenoble-Alpes Project Trajectories.

Lamarque P, Lambin EF. 2015. The effectiveness of marked-based instruments to foster the conservation of extensive land use: The case of Geographical Indications in the French Alps. Land Use Policy. 42:706–717. doi:10.1016/j.landusepol.2014.10.009.

Latour B. 1990. Postmodern? No, simply amodern! Steps towards an anthropology of science. Stud Hist Philos Sci Part A. 21(1):145–171. doi:10.1016/0039-3681(90)90018-4.

Latour B. 1993. The pasteurization of France. First Harvard University Press paperback ed. Cambridge, Mass.: Harvard Univ. Press.

Latour B. 2003. Science in action: how to follow scientists and engineers through society. 11. print. Cambridge, Mass: Harvard Univ. Press.

Lavorel S, Colloff MJ, Locatelli B, Gorddard R, Prober SM, Gabillet M, Devaux C, Laforgue D, Peyrache-Gadeau V. 2019. Mustering the power of ecosystems for adaptation to climate change. Environ Sci Policy. 92:87–97. doi:10.1016/j.envsci.2018.11.010.

LéLé S, Norgaard RB. 2005. Practicing Interdisciplinarity. BioScience. 55(11):967. doi:10.1641/0006-3568(2005)055[0967:PI]2.0.CO;2.

Lele S, Springate-Baginski O, Lakerveld R, Deb D, Dash P. 2013. Ecosystem services: origins, contributions, pitfalls, and alternatives. Conserv Soc. 11(4):343. doi:10.4103/0972-4923.125752.

Léraud I, Kronlund S. 2020. Épisode 3 : Roquefort: La main mise de Lactalis. Pieds Sur Terre. https://www.franceculture.fr/emissions/series/enquete-lait-toxique.

Lexico O university press. 2021. Political Science. [accessed 2021 May 30]. https://www.lexico.com/definition/political_science.

Liu J, Hull V, Batistella M, DeFries R, Dietz T, Fu F, Hertel TW, Izaurralde RC, Lambin EF, Li S, et al. 2013. Framing Sustainability in a Telecoupled World. Ecol Soc. 18(2). doi:10.5751/ES-05873-180226. [accessed 2021 May 5]. http://www.ecologyandsociety.org/vol18/iss2/art26/.

Löffler R, Beismann M, Walder J, Steinicke E. 2014. New Highlanders in Traditional Out-migration Areas in the Alps: The Example of the Friulian Alps. Rev Géographie Alp.(102–3). doi:10.4000/rga.2546. [accessed 2021 May 15]. http://journals.openedition.org/rga/2546.

Lopéz É, Muchnik J. 1997. Petites entreprises et grands enjeux : le développement agroalimentaire local. L'Harmattan. Paris.

Loubet F, Dissart J-C, Lallau B. 2011. Contribution de l'approche par les capacités à l'évaluation du développement territorial. Rev D'Économie Régionale Urbaine. octobre(4):681.

Lynch E, Harvois F. 2016. Le Beaufort: réinventer le fruit commun. Lyon: Libel.

MacLeod M, Nagatsu M. 2018. What does interdisciplinarity look like in practice: Mapping interdisciplinarity and its limits in the environmental sciences. Stud Hist Philos Sci Part A. 67:74–84. doi:10.1016/j.shpsa.2018.01.001.

Marescotti A, Quiñones-Ruiz XF, Edelmann H, Belletti G, Broscha K, Altenbuchner C, Penker M, Scaramuzzi S. 2020. Are protected geographical indications evolving due to environmentally related justifications? An analysis of amendments in the fruit and vegetable sector in the European Union. Sustainability. 12(9):3571. doi:10.3390/su12093571.

Marie-Vivien D, Biénabe E. 2017. The Multifaceted Role of the State in the Protection of Geographical Indications: A Worldwide Review. World Dev. 98:1–11. doi:10.1016/j.worlddev.2017.04.035.

Martinez-Alier J. 2009. Social Metabolism, Ecological Distribution Conflicts, and Languages of Valuation. Capital Nat Social. 20(1):58–87. doi:10.1080/10455750902727378.

Martín-López B, Leister I, Lorenzo Cruz P, Palomo I, Grêt-Regamey A, Harrison PA, Lavorel S, Locatelli B, Luque S, Walz A. 2019. Nature's contributions to people in mountains: A review. Saunders ME, editor. PLOS ONE. 14(6):e0217847. doi:10.1371/journal.pone.0217847.

Mascareño A, Henríquez PA, Billi M, Ruz GA. 2020. A Twitter-Lived Red Tide Crisis on Chiloé Island, Chile: What Can Be Obtained for Social-Ecological Research through Social Media Analysis? Sustainability. 12(20):8506. doi:10.3390/su12208506.

Mastrángelo ME, Pérez-Harguindeguy N, Enrico L, Bennett E, Lavorel S, Cumming GS, Abeygunawardane D, Amarilla LD, Burkhard B, Egoh BN, et al. 2019. Key knowledge gaps to achieve global sustainability goals. Nat Sustain. 2(12):1115–1121. doi:10.1038/s41893-019-0412-1.

Maurer K, Weyand A, Fischer M, Stöcklin J. 2006. Old cultural traditions, in addition to land use and topography, are shaping plant diversity of grasslands in the Alps. Biol Conserv. 130(3):438–446. doi:10.1016/j.biocon.2006.01.005.

Max-Neef M, Elizalde A, Hopenhayn M. 1989. Human scale development: an option for the future. Dev Dialogue.:1–136.

McGinnis MD, Ostrom E. 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol Soc. 19(2). doi:10.5751/ES-06387-190230. [accessed 2020 Oct 23]. http://www.ecologyandsociety.org/vol19/iss2/art30/.

MEA MEA (Porgram). 2005. Ecosystems and human well-being. Washington, D.C: Island Press.

Meyfroidt P, Roy Chowdhury R, de Bremond A, Ellis EC, Erb K-H, Filatova T, Garrett RD, Grove JM, Heinimann A, Kuemmerle T, et al. 2018. Middle-range theories of land system change. Glob Environ Change. 53:52–67. doi:10.1016/j.gloenvcha.2018.08.006.

Miller CA, Wyborn C. 2020. Co-production in global sustainability: histories and theories. Environ Sci Policy. 113:88–95. doi:10.1016/j.envsci.2018.01.016.

Moine A. 2006. Le territoire comme un système complexe : un concept opératoire pour l'aménagement et la géographie. L'Espace Géographique.:p.11-132.

Mumford L. 2010. Technics and civilization. Chicago ; London: The University of Chicago Press.

Muraca B. 2011. The Map of Moral Significance: A New Axiological Matrix for Environmental Ethics. Environ Values. 20(3):375–396. doi:10.3197/096327111X13077055166063.

Oliver A. 2015. Nudging, shoving, and budging: behavioural economic-informed policy: behavioural economic-informed policy. Public Adm. 93(3):700–714. doi:10.1111/padm.12165.

Oppermann R, Beaufoy G, Jones G. 2012. High nature value farming in Europe. Ubstadt-Weiher: verlag regionalkultur.

Ostrom E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge ; New York: Cambridge University Press (The Political economy of institutions and decisions).

Ostrom E. 1996. Crossing the great divide: coproduction, synergy, and development. World Dev. 24(6):1073–1087. doi:10.1016/0305-750X(96)00023-X.

Ostrom E. 1999. Social capital : a fad or a fundamental concept? In: Social capital : a multifaceted perspective. World Bank. Washington, D.C: Dasgupta Partha, Serageldin Ismail. p. 172–214.

Outeiro L, Ojea E, Garcia Rodrigues J, Himes-Cornell A, Belgrano A, Liu Y, Cabecinha E, Pita C, Macho G, Villasante S. 2017. The role of non-natural capital in the co-production of marine ecosystem services. Int J Biodivers Sci Ecosyst Serv Manag. 13(3):35–50. doi:10.1080/21513732.2017.1415973.

Ozouf-Marignier, M-V. 2008. Fromage et politique. La recherche. https://larecherche.typepad.fr/le_blog_des_livres/2008/06/fromage-et-poli.html.

Pachoud C. 2019. Identity, feeling of belonging and collective action in localized agrifood systems. Example of the Serrano cheese in the Campos de Cima da Serra, Brazil. Cah Agric. 28:28. doi:10.1051/cagri/2019028.

Pachoud C, Delay E, Da Re R, Ramanzin M, Sturaro E. 2020. A relational approach to studying collective action in dairy cooperatives producing mountain cheeses in the Alps: the case of the Primiero cooperative in the Eastern Italians Alps. Sustainability. 12(11):4596. doi:10.3390/su12114596.

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U. 2016. Disentangling the pathways and effects of ecosystem service co-production. In: Advances in Ecological Research. Vol. 54. Elsevier. p. 245–283. [accessed 2020 Aug 25]. https://linkinghub.elsevier.com/retrieve/pii/S0065250415000276.

Pandeya B, Buytaert W, Zulkafli Z, Karpouzoglou T, Mao F, Hannah DM. 2016. A comparative analysis of ecosystem services valuation approaches for application at the local scale and in data scarce regions. Ecosyst Serv. 22:250–259. doi:10.1016/j.ecoser.2016.10.015.

Pascual U, Adams WM, Díaz S, Lele S, Mace GM, Turnhout E. 2021 Mar 25. Biodiversity and the challenge of pluralism. Nat Sustain. doi:10.1038/s41893-021-00694-7. [accessed 2021 Apr 21]. http://www.nature.com/articles/s41893-021-00694-7.

Pascual U, Balvanera P, Díaz S, Pataki G, Roth E, Stenseke M, Watson RT, Başak Dessane E, Islar M, Kelemen E, et al. 2017. Valuing nature's contributions to people: the IPBES approach. Curr Opin Environ Sustain. 26–27:7–16. doi:10.1016/j.cosust.2016.12.006.

Pascual U, Palomo I, Adams WM, Chan KMA, Daw TM, Garmendia E, Gómez-Baggethun E, de Groot RS, Mace GM, Martín-López B, et al. 2017. Off-stage ecosystem service burdens: A blind spot for global sustainability. Environ Res Lett. 12(7):075001. doi:10.1088/1748-9326/aa7392.

Pecqueur B. 2001. Qualité et développement territorial: l'hypothèse du panier de biens et de services territorialisés. Économie Rurale. 261(1):37–49. doi:10.3406/ecoru.2001.5217.

Pelenc J, Bazile D, Ceruti C. 2015. Collective capability and collective agency for sustainability: a case study. Ecol Econ. 118:226–239. doi:10.1016/j.ecolecon.2015.07.001.

Permanent Secretariat of the Alpine Convention. 2015. Demographic changes in the Alps, Report on the state of the Alps, Alpine signals, special edition 5,. [accessed 2021 May 18]. https://issuu.com/alpconv/docs/rsa5_en_web.

Pirgmaier E. 2021. The value of value theory for ecological economics. Ecol Econ. 179:106790. doi:10.1016/j.ecolecon.2020.106790.

Plavén-Sigray P, Matheson GJ, Schiffler BC, Thompson WH. 2017. The readability of scientific texts is decreasing over time. eLife. 6. doi:10.7554/eLife.27725. [accessed 2021 Apr 28]. https://elifesciences.org/articles/27725.

Plieninger T, Bieling C, Fagerholm N, Byg A, Hartel T, Hurley P, López-Santiago CA, Nagabhatla N, Oteros-Rozas E, Raymond CM, et al. 2015. The role of cultural ecosystem services in landscape management and planning. Curr Opin Environ Sustain. 14:28–33. doi:10.1016/j.cosust.2015.02.006.

Plieninger T, Kizos T, Bieling C, Le Dû-Blayo L, Budniok M-A, Bürgi M, Crumley CL, Girod G, Howard P, Kolen J, et al. 2015. Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. Ecol Soc. 20(2). doi:10.5751/ES-07443-200205. [accessed 2020 Oct 16]. http://www.ecologyandsociety.org/vol20/iss2/art5/.

Polishchuk Y, Rauschmayer F. 2012. Beyond “benefits”? Looking at ecosystem services through the capability approach. Ecol Econ. 81:103–111. doi:10.1016/j.ecolecon.2012.06.010.

Potschin-Young M, Haines-Young R, Görg C, Heink U, Jax K, Schleyer C. 2018. Understanding the role of conceptual frameworks: reading the ecosystem service cascade. Ecosyst Serv. 29:428–440. doi:10.1016/j.ecoser.2017.05.015.

Price MF, Borowski D, Macleod C, Rudaz G, Debarbieux B. 2012. Sustainable Mountain Development in the Alps From Rio 1992 to Rio 2012 and beyond.

Quiñones Ruiz XF, Forster H, Penker M, Belletti G, Marescotti A, Scaramuzzi S, Broscha K, Braito M, Altenbuchner C. 2018. How are food geographical indications evolving? – An analysis of EU GI amendments. Br Food J. 120(8):1876–1887. doi:10.1108/BFJ-02-2018-0087.

Ramsar RC on W of IIE as WH. 2020. Ramsar Sites around the World. https://www.ramsar.org/sites-countries.

Rauschmayer F, Polzin C, Mock M, Omann I. 2018. Examining collective action through the capability approach: the example of community currencies. J Hum Dev Capab. 19(3):345–364. doi:10.1080/19452829.2017.1415870.

Raworth K. 2017. Doughnut economics: seven ways to think like a 21st-century economist. London: Random House Business Books.

Ricard D. 2015. Dairy Cooperatives in the French Mountains: Heritage, Diversity of Structures, Dynamics of Movement. Rev Géographie Alp.(103–1). doi:10.4000/rga.2751. [accessed 2021 Apr 28]. http://journals.openedition.org/rga/2751.

Riechers M, Balázsi Á, Betz L, Jiren TS, Fischer J. 2020. The erosion of relational values resulting from landscape simplification. Landsc Ecol. 35(11):2601–2612. doi:10.1007/s10980-020-01012-w.

Robeyns I. 2006. The capability approach in practice. J Polit Philos. 14(3):351–376. doi:10.1111/j.1467-9760.2006.00263.x.

Rockström J, Steffen W, Noone K, Persson Å, Chapin FSI, Lambin E, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, et al. 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecol Soc. 14(2). doi:10.5751/ES-03180-140232. [accessed 2021 Jan 7]. http://www.ecologyandsociety.org/vol14/iss2/art32/.

Røpke I. 2004. The early history of modern ecological economics. Ecol Econ. 50(3–4):293–314. doi:10.1016/j.ecolecon.2004.02.012.

Rousseau J. 2009. Discourse on the origin and foundations of inequality among men. In: Discourse on the Origin of Inequality. Oxford University Press. [accessed 2021 May 26]. https://oxfordworldsclassics.com/view/10.1093/owc/9780199555420.001.0001/isbn-9780199555420-book-part-2.

Rueda X, Lambin EF. 2013. Linking Globalization to Local Land Uses: How Eco-Consumers and Gourmands are Changing the Colombian Coffee Landscapes. World Dev. 41:286–301. doi:10.1016/j.worlddev.2012.05.018.

Samuelson PA, Nordhaus WD. 2005. Economics. 18th ed. Boston: McGraw-Hill/Irwin.

Santini F, Guri F, Gomez y Paloma S, Institute for Prospective Technological Studies. 2013. Labelling of agricultural and food products of mountain farming. Luxembourg: Publications Office. [accessed 2020 Sep 24]. http://dx.publications.europa.eu/10.2791/67942.

Sanz Cañada J, Macías Vázquez A. 2005. Quality certification, institutions and innovation in local agro-food systems: Protected designations of origin of olive oil in Spain. J Rural Stud. 21(4):475–486. doi:10.1016/j.jrurstud.2005.10.001.

Schermer M, Darnhofer I, Daugstad K, Gabillet M, Lavorel S, Steinbacher M. 2016. Institutional impacts on the resilience of mountain grasslands: an analysis based on three European case studies. Land Use Policy. 52:382–391. doi:10.1016/j.landusepol.2015.12.009.

Schlager E. 2019. A comparison of frameworks, theories, and models of policy processes. In: Sabatier PA, editor. Theories of the Policy Process. 1st ed. Routledge. p. 293–319. [accessed 2021 Jan 15]. https://www.taylorfrancis.com/books/9781000607482/chapters/10.4324/9780367274689-10.

Scholz RW. 2011. Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge: Cambridge University Press. [accessed 2021 May 14]. http://ebooks.cambridge.org/ref/id/CBO9780511921520.

Schröter M, Başak E, Christie M, Church A, Keune H, Osipova E, Oteros-Rozas E, Sievers-Glotzbach S, van Oudenhoven APE, Balvanera P, et al. 2020. Indicators for relational values of nature's contributions to good quality of life: the IPBES approach for Europe and Central Asia. Ecosyst People. 16(1):50–69. doi:10.1080/26395916.2019.1703039.

Schumpeter JA. 1954. History of economic analysis. Allen & Unwin. London.

Schwartz SH. 2012. An Overview of the Schwartz Theory of Basic Values. Online Read Psychol Cult. 2(1). doi:10.9707/2307-0919.1116. [accessed 2021 Apr 27]. https://scholarworks.gvsu.edu/orpc/vol2/iss1/11.

Sen A. 2000. Development as freedom. 1. Anchor Books ed. New York: Anchor Books.

Sheperd P. 2020. Connecting vulnerability and capability: a quantitative study of socio-ecological vulnerability to climate change in a French Alpine valley, la Vallée de la Maurienne. [Grenoble]: Université Grenoble-Alpes Project Trajectories. Supervised by Jean-Christophe Dissart.

Singh SJ, Haas W. 2016. Complex Disasters on the Nicobar Islands. In: Haberl H, Fischer-Kowalski M, Krausmann F, Winiwarter V, editors. Social Ecology. Cham: Springer International Publishing. p. 523–542. [accessed 2021 May 20]. http://link.springer.com/10.1007/978-3-319-33326-7_27.

SMB SMB. 2020 Dec 18. Espace observatoire. Httpsprosavoie-Mont-BlanccomObservatoire.

Snow CP, Collini S. 1993. The Two Cultures. 1st ed. Cambridge University Press. [accessed 2021 May 15]. https://www.cambridge.org/core/product/identifier/9780511819940/type/book.

Spangenberg JH, Görg C, Truong DT, Tekken V, Bustamante JV, Settele J. 2014. Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manag. 10(1):40–53. doi:10.1080/21513732.2014.884166.

Spash CL. 2008. How much is that ecosystem in the window? The one with the bio-diverse trail. Environ Values. 17(2):259–284. doi:10.3197/096327108X303882.

SPM (Syndicat du pays de Maurienne). 2020. Schéma de cohèrence territoriale.

Stenseke M. 2009. Local participation in cultural landscape maintenance: Lessons from Sweden. Land Use Policy. 26(2):214–223. doi:10.1016/j.landusepol.2008.01.005.

Stevens CJ, Fraser I, Mitchley J, Thomas MB. 2007. Making ecological science policy-relevant: issues of scale and disciplinary integration. Landsc Ecol. 22(6):799–809. doi:10.1007/s10980-007-9092-8.

Stiglitz JE. 1997. Georgescu-Roegen versus Solow/Stiglitz. Ecol Econ. 22(3):269–270. doi:10.1016/S0921-8009(97)00092-X.

Stiglitz JE, Fitoussi J-P, Durand M. 2018. Beyond GDP: Measuring What Counts for Economic and Social Performance. OECD. [accessed 2021 May 19]. https://www.oecd-ilibrary.org/economics/beyond-gdp_9789264307292-en.

Tappeiner U, Borsdorf A, Tasser E. 2008. Mapping the Alps: society, economy, environment/ Alpenatlas. Heidelberg: Spektrum Akademischer Verlag.

TEEB. 2010. Mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. Geneva: UNEP (The economics of ecosystems & biodiversity).

Turner B, Meyfroidt P, Kuemmerle T, Müller D, Roy Chowdhury R. 2020. Framing the search for a theory of land use. J Land Use Sci. 15(4):489–508. doi:10.1080/1747423X.2020.1811792.

UNESCO UNE Scientific and Cultural Organization. 2020a. World Heritage List. https://whc.unesco.org/en/list/&order=region.

UNESCO UNE Scientific and Cultural Organization. 2020b. Biosphere reserves in Europe and North America. https://en.unesco.org/biosphere/eu-na.

Vallet A, Locatelli B, Levrel H, Dendoncker N, Barnaud C, Quispe Conde Y. 2019. Linking equity, power, and stakeholders’ roles in relation to ecosystem services. Ecol Soc. 24(2). doi:10.5751/ES-10904-240214. [accessed 2020 Aug 25]. https://www.ecologyandsociety.org/vol24/iss2/art14/.

Väre H, Lampinen R, Humphries C, Williams P. 2003. Taxonomic diversity of vascular plants in the European Alpine areas. In: Nagy L, Grabherr G, Körner C, Thompson DBA, editors. Alpine Biodiversity in Europe. Vol. 167. Berlin, Heidelberg: Springer Berlin Heidelberg. (Baldwin IT, Caldwell MM, Heldmaier G, Lange OL, Mooney HA, Schulze E-D, Sommer U, editors.). p. 133–148. [accessed 2020 Oct 27]. http://link.springer.com/10.1007/978-3-642-18967-8_5.

Vatn A. 2005. Rationality, institutions and environmental policy. Ecol Econ. 55(2):203–217. doi:10.1016/j.ecolecon.2004.12.001.

Weber M. 1978. Max Weber: Selections in Translation. 1st ed. Runciman WG, editor; Matthews E, translator. Cambridge University Press. [accessed 2021 May 14]. https://www.cambridge.org/core/product/identifier/9780511810831/type/book.

Winkler KJ, Dade MC, Rieb JT. 2021 Mar 16. Mismatches in the ecosystem services literature—a review of spatial, temporal, and functional-conceptual mismatches. Curr Landsc Ecol Rep. doi:10.1007/s40823-021-00063-2. [accessed 2021 Mar 25]. http://link.springer.com/10.1007/s40823-021-00063-2.

Winner L. 1980. Do artifacts have politics? In: Marchant GE, Wallach W, editors. Emerging Technologies: Ethics, Law and Governance. 1st ed. Routledge. p. 15–30. [accessed 2021 Mar 23]. https://www.taylorfrancis.com/books/9781000108927/chapters/10.4324/9781003074960-3.

Zimmerer KS, Lambin EF, Vanek SJ. 2018. Smallholder telecoupling and potential sustainability. Ecol Soc. 23(1). doi:10.5751/ES-09935-230130. [accessed 2021 May 6]. https://www.ecologyandsociety.org/vol23/iss1/art30/.

Annexes

Summary/ English version

Multiple aspects of wealth creation in a social-ecological system of the French Alps

Many socioeconomic activities that contribute to people's good quality of life are intrinsically linked to ecosystems. Ecosystems provide indispensable material benefits (e.g. food, shelter, etc.), but their production can simultaneously greatly contribute to deterioration of natural capital, decrease of finite resources, and reinforce social disparities. In order to achieve a good quality of life for all within ecological limits, novel approaches that go beyond exclusive monetary analyses are needed. In the last decades, interdisciplinary research on coupled social-ecological systems (SES) has increasingly linked ecosystems to the multidimensional aspects that contribute to a good quality of life. Yet, the role of social dynamics in SES has remained underexplored. These can help focusing on value generation as part of interactions between societies and ecosystems.

This thesis is anchored in the field of ecological economics and the associated field of territorial ecology. I aimed to understand how the dynamic interplay of various resources and social dynamics underpin socioeconomic activities in their social-ecological context. For this, I combined the concept of nature's contributions to people (NCP) with the development-based capability approach. I proposed a conceptual framework that structures how societies co-produce with ecosystems aspects they consider as meaningful. In particular, I explored how such co-production processes are embedded in a specific social-ecological setting that has co-evolved over a long period. I hypothesised that social dynamics constitute crucial factors in regulating different stages of co-production.

I operationalised this conceptual framing in the territorial agricultural system of the Maurienne valley, in the Northern French Alps. Specifically, I analysed the functioning of the cooperative production system of the premium quality cow cheese Beaufort and its associated actors. The moderate size of this territory enabled a thorough integration of qualitative and quantitative information. To attain a comprehensive understanding, I applied a mixed methods approach. Based on 43 semi structured qualitative interviews with local stakeholders I explored the multiple resources that govern the co-production of this cheese. I used a systematic content analysis to investigate non-material components of co-production, namely common perceptions across actors. Further, I analysed quantitative linkages between components of co-production and social and economic outcomes at the municipality level. The combination of these two

approaches allowed me to analyse the Beaufort cheese production system from an explicit interdisciplinary perspective.

Social-ecological dynamics shapes the ways in which ecosystems contribute to the diverse aspects of a good quality of life. I showed that the Beaufort cheese production system rests on shared common perceptions about fundamental aspects of co-production, like collectively agreed rule sets for management practices, and about its associated benefits. Further, I found that these institutions could partly buffer biophysical constraints like altitude and external drivers such as varying sale opportunities across the territory. In addition, the analyses also highlighted the relevance of proximity of social resources (infrastructure) for the co-production system. I suggest that these institutions with their existing, widely accepted specific rule sets could develop and implement territorial responses to future challenges like climate change or economic insecurities, through tightening environmental regulations or instituting revenues based on individual needs. Plenty of research is still needed to fully grasp the impact of institutional dynamics on society-ecosystem interactions. In particular, my results suggested the relevance of cross-scale interactions for territorial dynamics. For example, external factors such as European quality labels or external demand are crucial for the maintenance of the Beaufort production system. I suggest considering the Beaufort production system as a territorial capability structured by the complex interactions between ecosystems and societies, and within societies. This social dynamics combines local biophysical constraints, unique social-ecological capital and universal production factors towards an outcome that contributes to multiple aspects of quality of life and its long-term persistence. The results of this thesis support a stronger role of social sciences in interdisciplinary research on social-ecological system to fully account for their complexity.

Resumé/ version française

Les multiples aspects de la création de richesse dans un système socio-écologique des Alpes françaises

Cette thèse est ancrée dans le domaine de l'économie écologique et le domaine associé de l'écologie territoriale. J'ai cherché à comprendre comment l'interaction dynamique de diverses ressources et les dynamiques sociétales sous-tendent les activités socio-économiques dans leur contexte socio-écologique. Pour ce faire, j'ai combiné le concept de contribution de la nature aux populations (NCP) avec l'approche des capabilités basée sur le développement. J'ai proposé

un cadre conceptuel qui structure la manière dont les sociétés co-produisent avec les écosystèmes les aspects qu'elles considèrent comme significatifs. En particulier, j'ai exploré comment de tels processus de co-production s'inscrivent dans un cadre socio-écologique spécifique qui a co-évolué sur une longue période. J'ai émis l'hypothèse que les dynamiques sociétales constituent des facteurs cruciaux dans la régulation des différentes étapes de la co-production.

J'ai opérationnalisé ce cadrage conceptuel dans le système agricole territorial de la vallée de la Maurienne, dans les Alpes françaises du Nord. Plus précisément, j'ai analysé le fonctionnement du système de production coopératif du fromage de vache de qualité supérieure Beaufort et ses acteurs associés. La taille modérée de ce territoire a permis une intégration approfondie des informations qualitatives et quantitatives. Pour atteindre une compréhension globale, j'ai appliqué une approche de méthodes mixtes. Sur la base de 43 entretiens qualitatifs semi-structurés avec des acteurs locaux, j'ai exploré les multiples ressources qui régissent la co-production de ce fromage. J'ai étudié les composantes non matérielles de la co-production, à savoir les perceptions communes des acteurs, à l'aide d'une analyse de contenu systématique. En outre, j'ai analysé les liens quantitatifs entre les composantes de la co-production et les résultats sociaux et économiques au niveau de la municipalité. La combinaison de ces deux approches m'a permis d'étudier en profondeur le système de production du fromage Beaufort dans une perspective interdisciplinaire explicite.

La dynamique socio-écologique façonne la manière dont les écosystèmes contribuent aux divers aspects d'une qualité de vie. J'ai montré que le système de production du fromage de Beaufort repose sur des perceptions communes partagées concernant des aspects fondamentaux de la co-production, comme des ensembles de règles convenues collectivement pour les pratiques de gestion et les avantages qui y sont associés. En outre, j'ai constaté que ces institutions pouvaient en partie amortir les contraintes biophysiques telles que l'altitude et les facteurs externes tels que les opportunités de vente variables sur le territoire. En outre, les analyses ont également mis en évidence la pertinence de la proximité des ressources sociétales (infrastructure) pour le système de co-production. Je suggère que ces institutions, avec leurs ensembles de règles spécifiques existantes et largement acceptées, pourraient développer et mettre en œuvre des réponses territoriales au changement climatique ou aux insécurités économiques futures, par exemple en renforçant les réglementations environnementales ou en instituant des revenus basés sur les besoins individuels. De nombreuses recherches sont cependant encore nécessaires pour saisir pleinement l'impact de la dynamique institutionnelle

sur les interactions société-écosystème. En particulier, mes résultats suggèrent la pertinence des interactions entre échelles pour les dynamiques territoriales. Par exemple, des facteurs externes, tels que les labels de qualité européens ou la demande extérieure, sont cruciaux pour le maintien du système de production de Beaufort. Je suggère de considérer le système de production de Beaufort comme une capabilité territoriale structurée par les interactions complexes entre les écosystèmes et les sociétés, et au sein des sociétés. Cette dynamique sociétale combine des contraintes biophysiques locales, un capital socio-écologique unique et des facteurs de production universels vers un résultat qui contribue à de multiples aspects de la qualité de vie et à sa persistance à long terme. Les résultats de cette thèse justifient de développer le rôle des sciences sociales dans la recherche interdisciplinaire sur les systèmes socio-écologiques afin de rendre pleinement compte de leur complexité.

Co-authorship

Historical reconfigurations of a social–ecological system adapting to economic, policy and climate changes in the French Alps

Enora Bruley[1] Bruno Locatelli[2,3], François Vendel[1] & Agnès Bergeret[1], Nicolas Elleaume[1], Julia Grosinger [1,4] & Sandra Lavorel[1,5]

Regional Environmental Change (2021) 21:34
https://doi.org/10.1007/s10113-021-01760-8

[1] Laboratoire d'Ecologie Alpine, CNRS – Université Grenoble Alpes – Université Savoie Mont-Blanc, 38000 Grenoble, France
[2] Cirad, University of Montpellier, Montpellier 34398, France
[3] Cifor, Lima 15024, Peru
[4] Université Grenoble Alpes, CNRS, Sciences Po Grenoble, PACTE, 38000 Grenoble, France

Abstract

To ensure their quality of life, people adapt to multiple changes by maintaining or transforming the structure and functions of their socio-ecological systems (SES). A better understanding of mechanisms underpinning SES adaptation, especially the contribution of changes in human–nature interactions, is crucial to facilitate adaptation to future challenges. Using a chronosystemic timeline and based on literature, archives and local knowledge of inhabitants, we explored the past trajectory of a mountain SES (Pays de la Meije, French Alps) since 1900 by analysing drivers, impacts and responses. We hypothesised that adaptation has occurred through changes in the co-production of nature's contributions to people (NCP). We identified four historical periods of combined changes in agriculture and tourism with associated changes in NCP. Results show which and how drivers of changes have influenced NCP co-production, how NCP have been mobilised in adaptive responses and how human and natural capitals involved in NCP co-production have been reconfigured for adaptation. We show that drivers of change have been mainly exogenous and out of the control of local actors, like public policies, markets and consumption patterns. These drivers can directly impact the capitals involved in NCP co-production like amount of workforce, knowledge or skills, creating not only threats but also opportunities for the livelihood of the local community. Depending on the intensity of capital reconfiguration and the type of NCP involved, adaptive responses range from resistance

to transformation of the governance system and socioeconomic sectors. This analysis highlights existing path dependencies that could hinder future adaptation.

Keywords co-production . adaptation . transformation . ecosystem services . past trajectories . social-ecological system

Introduction

Under global changes, social–ecological systems (SES) must adapt to maintain livelihoods and the natural resources they depend on (IPBES 2018). Adaptation is driven by changes in the interactions between social and natural systems over time and space (Nelson et al. 2014; Chhetri et al. 2019; Fedele et al. 2019). The adaptive capacity of a SES is strongly influenced by its past trajectory, as it shapes its current state (Dearing et al. 2015; Egan and Price 2017) and will constrain its future dynamics through legacy effects (Nelson et al. 2014; Plieninger et al. 2015; Antoni et al. 2019). Studying historical SES trajectories provides valuable information not only on how drivers of change have affected SES and led to adaptive responses (Costanza et al. 2012; Adamson et al. 2018) but also inform about future adaptive capacity (Bussey et al. 2012; Grier et al. 2017) and adaptation options (Fazey et al. 2015). One critical dimension of changing human–nature interactions for adaptation regards nature's contributions to people (NCP), defined as the contributions of living nature to people's good quality of life, which can be material, non-material and regulating contributions (Diaz et al. 2015). To adapt to changes, societies can modify their interactions with nature to ensure the provision of important benefits to human quality of life by changing land uses, redefining natural resource governance or using new natural resources. These actions can aim to sustain the provision of existing NCP despite changes (i.e., NCP resilience) or to develop new NCP in changing contexts (i.e., transformation) (Lavorel et al. 2019).

Most assessments of NCP or ecosystem services have focused on a time snapshot, but there has been an increased interest in historical trajectories of NCP (Renard et al. 2015; Rau et al. 2018). Studies have linked increasing supply and demand of NCP over history with changing land use (Stürck et al. 2015; Egarter Vigl et al. 2016; Lavorel et al. 2017). Other studies highlight how historical analyses can help understand NCP synergies and trades-off (Tomscha and Gergel 2016), showing that NCP bundles depend on local biophysical and socio-economic context (Renard et al. 2015; Egarter Vigl et al. 2017), or assessing changing landscape capacity to supply NCP (Bürgi et al. 2015; Locatelli et al. 2017). While most studies consider socio-economic and institutional drivers (Dittrich et al. 2017), land use, landscape or SES dynamics (e.g., Munteanu et al. 2014, Ianni et al. 2015, Jepsen et al. 2015, Meyfroidt et al. 2018), few consider how these drivers of change of NCP have supported adaptation, or how NCP were involved in adaptive responses (Colloff et al. 2020).

Historical studies of NCP trajectories and their drivers rarely address a critical dimension of adaptation, which is agency, i.e., the capacity of people to make choices and act consciously,

both individually and collectively (Davidson 2010; Fedele et al. 2017). For historical changes in NCP to be understood with an adaptation lens that can inform future adaptation, we need to document not only how NCP have changed but also the mechanisms underlying these changes, including human agency. Indeed, NCP are the joint outcome of social and ecological processes, constituting a process of NCP coproduction that involves human intervention to deliver social benefits (Diaz et al. 2015; Palomo et al. 2016). Three steps of co-production can be distinguished along the benefit chain of NCP (Lavorel et al. 2020; Bruley et al. 2021): (CP1) ecosystem management (i.e., modifying ecosystem structure and function in order to obtain benefits, such as planting cereals or trees), (CP2) mobilisation, harvest and physical access (e.g., collecting plants or visiting a scenic place), and (CP3) appropriation and appreciation of benefits (e.g., transforming and selling dairy products, enjoying local products or feeling attached to a place). Different natural, human, social, manufactured and financial capitals are required in each of these steps (Palomo et al. 2016). This novel perspective complements socio-technical studies of transitions (e.g., Geels and Schot 2007) by explicitly considering the role of natural capital and its management.

We posit that the characterisation of adaptive responses over time through the reconfiguration of NCP co-production will advance the understanding of adaptation mechanisms. Reconfiguration is the process by which people modify their actions to alter ecosystems, NCP and ultimately quality of life. This analysis requires to understand how human-derived and natural capitals are impacted by internal and external drivers of change and the resulting vulnerabilities or opportunities. It also requires understanding how people's adaptive responses reconfigure capitals and the co-production of NCP to maintain livelihood. This perspective on adaptation improves our understanding of coupled social–ecological historical interactions and human agency involved in ecosystem-based adaptation to inform future responses and create opportunities for agency (Nelson et al. 2014; Fazey et al. 2015; Grier et al. 2017).

Mountain regions provide fruitful contextual settings to study adaptive capacity (Egan and Price 2017; Klein et al. 2019). Indeed, while they provide key NCP (Martín-López et al. 2019) and are biodiversity hotspots (Körner et al. 2005), they are also vulnerable to both environmental and socio-economic changes, like land use change, infrastructure, tourism development and climate change, with an important role of external drivers (Grêt-Regamey et al. 2012). Because of their remoteness, harsh topographical and climatic conditions, they have undergone continuous adaptation (Klein et al. 2019) and are experiencing rapid changes in response to current and anticipated global change (Palomo 2017). This study aimed to understand past SES

adaptation mechanisms as sets of causal relationships between drivers of change and social–ecological responses by reconfigurations through human agency for a mountain social–ecological system. We identified periods of historical adaptation and hypothesised that adaptation occurred through changes in NCP co-production. Using the NCP co-production approach to better understand past adaptation trajectories we asked the following: (1) Which drivers of changes have affected the SES and led to adaptive responses? (2) How have drivers influenced NCP co-production? (3) On which NCP have adaptive responses relied? (4) How have capitals involved in NCP coproduction been reconfigured for adaptation? Our results allowed us to characterise different types of adaptive responses and further discuss how such knowledge of adaptation mechanisms along historical trajectories of NCP can inform research on current dynamics and future adaptation.

Study site

Pays de la Meije, at the head of the Romanche valley in the central French Alps, covers 205 km2 and ranges from 1135 to 3984 m. Located at the edge of two administrative regions the two municipalities, La Grave (484 inhabitants) and Villar d'Arène (322 inhabitants), have a low population density (less than 5 people/km2), across two villages and seven hamlets with numerous secondary and touristic residences (~60% of the accommodation capacity). The region reached its largest population (2500 inhabitants) at the beginning of the nineteenth century followed by a strong rural exodus from 1850 to 1970. Tourism has become an essential sector since 1970 and is now at the core of the local economy, with large contributions to off-farm jobs and incomes (Schermer et al. 2016). It is based on mountain sports and on cultural tourism enhanced by the Ecrins National Park, created in 1973. A traditional mountain livestock farming system based on fodder self-sufficiency and summer transhumance, is the second pillar of the local economy and identity (Quétier et al. 2010). Local life strongly depends on surrounding regions for jobs (in nearby ski resorts) and services (education, health and retail). The climate is alpine withMediterranean influences. Forest exploitation in the Middle Ages produced an open landscape on the south-facing slopes, shaped by terrace cultivation. Subsistence agriculture changed to livestock farming during the early twentieth century and now maintains a cultural landscape of terraced grasslands and summer pastures (Quétier et al. 2007). North-facing, steeper slopes are forested below 2200 m following cessation of timber production during the nineteenth century. Sparse vegetation, rocks and ice at higher altitude are located in the core area of the Ecrins National Park and in an offtrack skiing basin.

Methods

Our study included three stages: (i) preliminary analysis with secondary literature, databases and exploratory interviews, (ii) timeline construction from interviews and workshops, and (iii) timeline interpretation. The first stage included two steps in order to obtain an overview of the SES dynamics with the main social and ecological trends and events since 1900. First, we analysed the history of the valley from existing grey and scientific literature and databases on demographic and social data (INSEE 2016), agriculture (Agreste), climate (temperature and precipitations—Météo- France), risk (ONF-BD-RTM) and municipality archives (for details on data used see appendix 1). Second, the interviews of thirteen inhabitants were done in June 2018 (farmers, tourism professionals, elected officials, association representatives and multisector people) who had lived at the site for at least 20 years and knew its history well (details in appendix 2). These semi directed interviews elicited descriptions of the SES and its subsystems, the past social, political, economic, ecological changes and their impacts. These information and data fed the timeline construction, by the identification of relevant themes.

In the second stage, we applied a timeline analysis, which is a deductive qualitative method for the systemic and temporal analyses of the past trajectory of a SES (Bergeret et al. 2015; Spiegelberger et al. 2018). The chronosystemic timeline construction follows four steps. First, we defined the problem addressed with the associated spatial and temporal scales, which here is the past adaptation of the SES of Pays de la Meije from 1900 to 2015. Second, we identified main themes where change has occurred over this period. Based on our preliminary analysis, we selected eight themes: external policies, local governance, social dynamics, agriculture, tourism, landscape dynamics, ecosystem management and climate. Third, we set milestones which are moments or periods associated with key events (punctual, repeated) and trends (with gradual changes or possibly state changes). Fourth, we described how interactions among milestones (e.g., causality, feedback loops, succession, collaboration, inertia and conflicts) led to the changes revealed by the timeline. The last two steps were performed during two participatory workshops including respectively two and six local stakeholders (see appendix 2). Based on their experience, knowledge and perceptions, participants identified and discussed the milestones for each theme and analysed their interactions. Finally, participants also identified and dated the main historical periods of change revealed by the timeline. From these, we were able to select four periods that display different responses of the SES to changes linked to agriculture, tourism or the entire SES. The elements of the timeline identified by the participants were, as far as possible, compared with information obtained from the literature, public

information and databases available and were integrated into the narrative. The chronosystemic timeline obtained was presented to local stakeholders during a feedback event, allowing us to validate our construction, enrich and correct it where necessary.

In the third stage, for the four periods of change, we investigated the processes that led to adaptation by identifying (1) the drivers that induced changes in the SES, (2) the impacts of the drivers on capitals, NCP or quality of life and the resulting vulnerability or opportunities and (3) the adaptive responses of the SES in terms of reconfiguration of NCP co-production (Fig. 1a). Once these elements and their causal relationships were identified, we investigated their implication for the three steps of NCP co-production within the IPBES framework (Diaz et al. 2015) focusing on the change between "Nature", "Nature's contributions to people" and "Good quality of life" (Bruley et al. 2021) (Fig. 1b). Thus, NCP impacted by and involved in these adaptations were deduced qualitatively from the evolution of human activities based on IPBES classification (Díaz et al. 2018); only NCP related to agriculture was analysed based on previous work at the site (Lavorel et al. 2017). We also identified the reconfigurations of human, social, financial, manufactured and natural capitals involved in the three steps of NCP co-production.

Results

The analysis of past social–ecological dynamics through the lens of NCP co-production revealed four periods since 1900 with distinct adaptive responses to external drivers. These periods of change are related to agriculture (periods 1, 2 and 4) and tourism (period 3), with temporal overlaps between the last two periods: (1) 1900–1960: gradual transformation from subsistence agriculture to a dairy production system, (2) 1965–1975: shift in livestock production towards heifer and lamb breeding, (3) 1976–2000: social transformation following tourism development, and (4) 1990–2015: agricultural system resistance to change (Fig. 2). For each period, we analyse changes of NCP and their co-production (Table 1). To describe each period, we present indicators of the SES trajectory related to population, agriculture, tourism, natural disasters or climate emerging from a combination of our multiple sources of information Fig. 3).

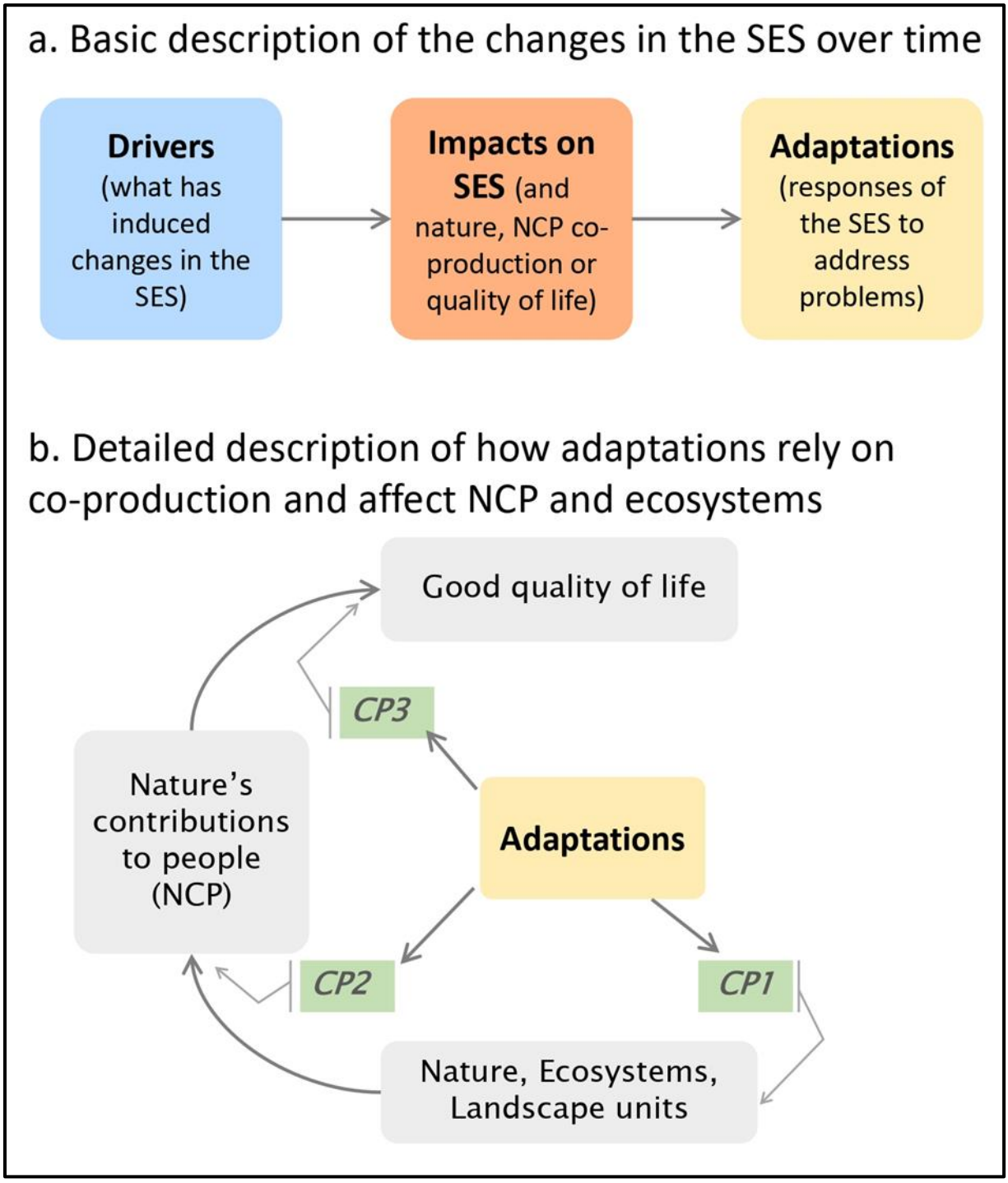


Fig. 1 Analytical framework to describe changes in the social-ecological system (SES) and their links to Nature's contributions to people (NCP) co-production. (a) Drivers-Impacts- Adaptive responses cascade; (b) Description of how adaptation occurs and affect NCP co-production steps (CP1: Ecosystem management, CP2: Mobilization, harvesting and physical access and CP3: Appropriation, appreciation and social access to benefits). Based on Bruley et al. 2021

Gradual transformation of the agricultural system (1900–1960)

In the nineteenth century, because of the steep topography and harsh winters in this high-altitude SES, people faced severe access restrictions and organised their activities to achieve food self-sufficiency through a system of family mixed farming and livestock rearing (cow and sheep for meat, dairy products and wool). These practises were essentially based on natural capital and widely available human workforce, skills, knowledge and collective organisation (Rousset 1992). These assets were central to the farming system, especially for building terraces that enabled crop production. The rural exodus caused by the new attractiveness of cities and industries led to a gradual population decline (INSEE) (Fig. 3, top row) and in particular the departure of youth (Girel et al. 2010). This trend persisted until the 1980s and made labour-intensive agriculture impossible to maintain; only summer transhumance of sheep and cattle persisted. As agricultural supply chains were getting more organised and market demand was growing at the national level (Marshall plan 1947), mountain agriculture turned partly into dairy production because of the high potential of alpine meadows for fodder production. As a result, a market was established in the Briançonnais region, with a cooperative and milk collection in the villages for dairy production (Girel et al. 2010). From 1900, supported by the development of milk transformation infrastructure, farming families gradually transformed their activity towards dairy farming and stopped cropping. Formerly ploughed terraces were transformed; the most accessible and least steep ones into hay meadows and the others into pasture (Girel et al. 2010). The lack of workforce was compensated by technical innovation that emerged in the 1950s (motorised mower). This process was facilitated by the improved accessibility, with the Lautaret pass opening to vehicle traffic during winter (1955). This especially supported food supply, which was less and less locally produced.

During this period, the main driver was the emigration and the associated loss of workforce, which affected food NCP coproduction at all steps. By taking advantage of the opportunity offered by dairy specialisation, farmers profoundly transformed the agricultural NCP co-production system. Agroecosystem management (CP1) shifted from ploughed terraces to fertilised grasslands. The mobilisation of production (CP2) was simplified from harvestingmultiple products (cereals, vegetables, fodder, pasture, etc.) to mowing and grazing, supported by mechanisation from the 1950s. Finally, the multiple forms of appropriation and transformation of benefits (CP3) were progressively abandoned, replaced by larger infrastructure (dairy cooperative) to support milk transformation and trade. There was a profound change in the capitals mobilised for the coproduction of these NCP with less labour,

less animals and more machinery. This transformation was accompanied not only by a loss of traditional knowledge and skills associated with subsistence agriculture but also by a shift in families and their lifestyle to a modern system, in which farming is a business. This adaptation also significantly impacted natural capital, through a transition from a cultivated to a grassland landscape, and a resulting increase in hay meadow biodiversity, fertility and soil stability (Lavorel et al. 2017).

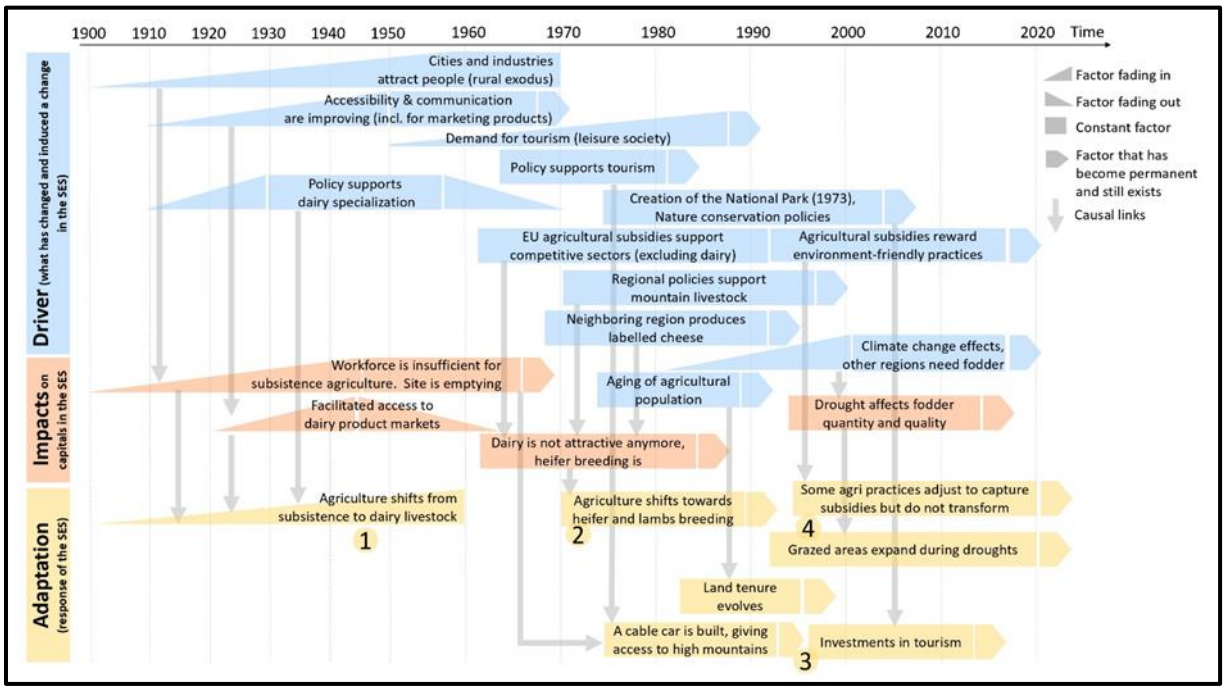


Fig. 2 Trajectories of drivers, impacts and adaptive responses of the social-ecological system (SES) of le Pays de la Meije, from 1900 to 2020. Grey arrows represent how drivers lead to adaptation. The four adaptation periods detailed in this paper are represented by numbers (1,2,3&4)

Agriculture shift toward heifer and lamb breeding (1965-1990)

With the establishment of the Common Agricultural Policy (CAP) in 1962, the search for food self-sufficiency at national and European levels gradually led to the prioritization of the most productive or efficient activities and the decline of others. Because milk production in Pays de la Meije had no comparative advantage (Girel et al. 2010), this activity declined, the cooperative closed, and milk collection ended shortly before 1970 (Martin-Noel 1962). The future of agriculture was once again jeopardized, leading to farmland area and farm number decline until the 1990s (Figure 3 – second row). Following a different trajectory, some neighbouring valleys (in Savoie and Haute-Savoie for cattle and South French Alps for lambs) maintained agriculture by value-adding to products through geographic indication labels, such as the European Protected Designation of Origin like the creation of the Beaufort cheese label in 1968 in nearby

valleys (Beaufort, Tarentaise and Maurienne). Farmers in these areas did not see value in raising non-productive heifers (juvenile and non-lactating cows) on high-quality grazing land. Meije farmers seized this opportunity to establish a trading link with breeding and selling heifers for these valleys. Livestock farming adapted to the new context by shifting herds toward heifer but also lambs breeding during the 1970s. This new production system was strengthened by growing mechanisation (tractors) and supported by subsidies from the CAP, in particular the compensatory allowances for permanent natural handicaps (ICHN) for disadvantaged regions from 1975 (Schermer et al. 2016). The agricultural economy was also supported by the concurrent development of tourism, which offered an opportunity for multi-activity.

During this period, the collapse of the milk supply chain in the region forced local farmers to reorient the appropriation of benefits (CP3) from the sale of milk to the sale of heifers and lambs. As the management of meadows and pastures (CP1) and mowing and grazing practices (CP2) remained nearly the same, this adaptation had little impact on ecosystems and NCP other than animal productions.

Phase # (in the figure 2.a)	Main adaptation	Years	Effects on NCP	Changes in CP1 (ecosystem management)	Changes in CP2 (NCP mobilization)	Changes in CP3 (NCP appropriation)	Effects on ecosystems
1	**Dairy agriculture:** Agriculture shifts from subsistence to dairy livestock	1900 - 1960 (progressive change)	Decrease of material NCP: ↘ food for self-consumption ↗ fodder for livestock ↕ identity link to agricultural practices	↘ cropping and terraces maintenance ↗ meadow fertilization	↘ harvesting crop production ↗ mowing and grazing on terraces	↘ local food consumption and transformation ↗ milk transformation and trading, loss of cultural identities	↘ crops ↗ meadow and pasture, ↗ soil fertility, soil maintenance and biodiversity
2	**Breeding**: Agriculture shifts towards heifer and lambs breeding	1965 – 1993	No changes	No or limited changes	No or limited changes (mostly linked to increased mechanization)	End of milk transformation (remain marginal) ↗ trading with Beaufort heifer market and Alpes lambs' market	No changes
3	**Tourism development**: A new cable car in 1976 opens access to high mountain	1976 – 2000	Increase of non-material NCP: recreational, leisure, physical and spiritual experience, ↕ sense of place/identity	↗ urbanization and infrastructure, ↗ Nature protection (no strong management)	↗ physical access to natural landscape (cable car, roads, paths, signage…)	↗↗ appropriation, appreciation and ↕ place attachment from rural to leisure	↗ urbanization and infrastructure, ↘ Protection of natural areas
4	**Resistance to change**: Some agricultural practices adjust for capturing subsidies but do not transform	1990 – 2015	No changes in agricultural NCP	↗ financial capital, Better land allocation, ↘ fertilization (Practices facilitated by mechanization, re-parceling, subsidies, local organization and management)	↘ mowed surface (↗ on drought years)/ ↗ grazed surfaces (↗↗ on drought years) ↗ livestock number (cattle and sheep by transhumance) (Practices facilitated by mechanization, re-parceling, subsidies, local organization and management)	No changes	↘ biodiversity in grazed grasslands

Table 1 Changes in nature's contributions to people (NCP) co-production steps (CP1,2&3), ecosystems and NCP during the four periods of adaptation of the social-ecological system (↗: increasing or gain; ↘: decreasing or loss; ↕: switch or transformation).

Social transformation following tourism development (1976-2000)

Benefiting from the first national development plan for mountain resorts (Snow Plan), the creation a small ski resort and a tourism office in the 1960s was a first attempt to develop tourism with the objective of reinvigorating the local economy heavily affected by rural exodus and a shrinking agriculture (Muscella 2004). However, as customers were attracted by larger skiing resorts, several tourism businesses closed in the 1970s (Girel et al. 2010). To address this challenge and respond to the growing demand for mountain outdoor activities, the municipality of La Grave intended to build a cable car to access the Meije high mountain massif, already well known for alpinism (Muscella 2004). This project took more than 10 years to be achieved, facing much resistance from public authorities, investors and the local population. Another key driver of change in this period was the creation of the Ecrins National Park, which conflicted with local tourism development objectives and associated ecological impacts of the cable car. Following tough negotiations, the Park decree was ratified by municipalities (1973), followed by the release of the authorization and funding for the cable car by regional authorities (1976-77) (Siniscalchi 2008). Once the cable car was in place, the local society transformed gradually from an agricultural to a leisure- and tourism-oriented economy mainly based on nature, as evidenced by the increase in accommodation during the 1990s (Figure 3 – third row). The transformation process peaked in the 1990s with the popularity of off-piste skiing at La Grave (Muscella 2004). The cable car infrastructure brought financial benefits for local businesses (e.g. accommodation, shops, tourism professionals). The composition of municipal councils, which are competent authorities in many land use decisions, mainly composed of farmers until the 1970s, diversified to include more tourism professionals (Figure 3 – second row). The entire local community and many newcomers attracted by nature proximity for outdoor sports turned their activities towards mountain tourism (Martin 2014). Summer and winter mountain sports gradually developed and shifted from elite (alpinism and off-piste skiing) to more popular activities. The cable car and the National Park thus contributed to making an array of nature activities (e.g., hiking, climbing, skiing, wildlife watching) widely accessible.

The accessibility provided by the cable-car infrastructure, as well as the national park, facilitated the co-production of many non-material NCP. For example, nature experiences, leisure activities in the mountain landscape and a new supporting identity driven by a change in the values for nature as a playground. Simultaneously, structural adjustments of power relations occurred in local institutions with the decreasing representation of the agricultural sector in favour of tourism. There was significant capital involved in CP2 and CP3, but very

limited capital in CP1: physical access (CP2) became essential to support development through the construction of transport infrastructure, particularly the cable car. The professionalization and construction of tourist facilities, but also the creation of the imaginary around mountains increased social access, appreciation and appropriation of the benefits of nature (CP3). However, very limited changes in ecosystem management (CP1) apart from a low level of land take and soil sealing were necessary to allow this nature-based tourism development. Tourism was based on landscape beauty, which is partly the result of landscape management through agricultural activities (CP1). It can also be noted that a large part of the area was protected within the core area of the Park, which restricted the consequences of this transformation on landscapes and natural environments (CP1).

Agricultural system resistance to change (1990-2015)

Since 1990, multiple external drivers have pressured the farming system, which has been able to cope with small adjustments, without engaging in major transformation. Firstly, several changes in the CAP (in 1984, 1992, 2003 and 2015) to support rural development and the environment modified the requirements for obtaining subsidies (Schermer et al. 2016). The livestock breeding practices implemented in Pays de la Meije did not face restrictions to access subsidies, as they were already extensive enough to meet environmental requirements. Moreover, since 2003, with the help of the regional agricultural institutions and the Ecrins National Park, local farmers have been able to receive additional subsidies (agri-environment-climate measures) without modifying their practices, which has supported rural livelihoods and regional identity. Local land governance became more collective (creation of pastoral land associations) and land distribution changed (with fewer larger farms because of ageing population and the low rate of farm takeovers). The decrease in the number of farmers also caused a reduction in mown area and fertilization, in favour of grazed area (Lavorel et al. 2017). Since the 1980s, fodder availability as well as livestock breeding have been affected by recurrent droughts and increasing temperatures (Figure 3 – bottom row), which have led to increased mowing in less accessible grasslands or purchases of outside fodder (Lamarque et al. 2013). At the same time, the demand for transhumant grazing in high altitude grasslands has increased from pastoralists in the Southern Alps and Provence. Finally, tourism development has continued to support farming families through multi-activity.

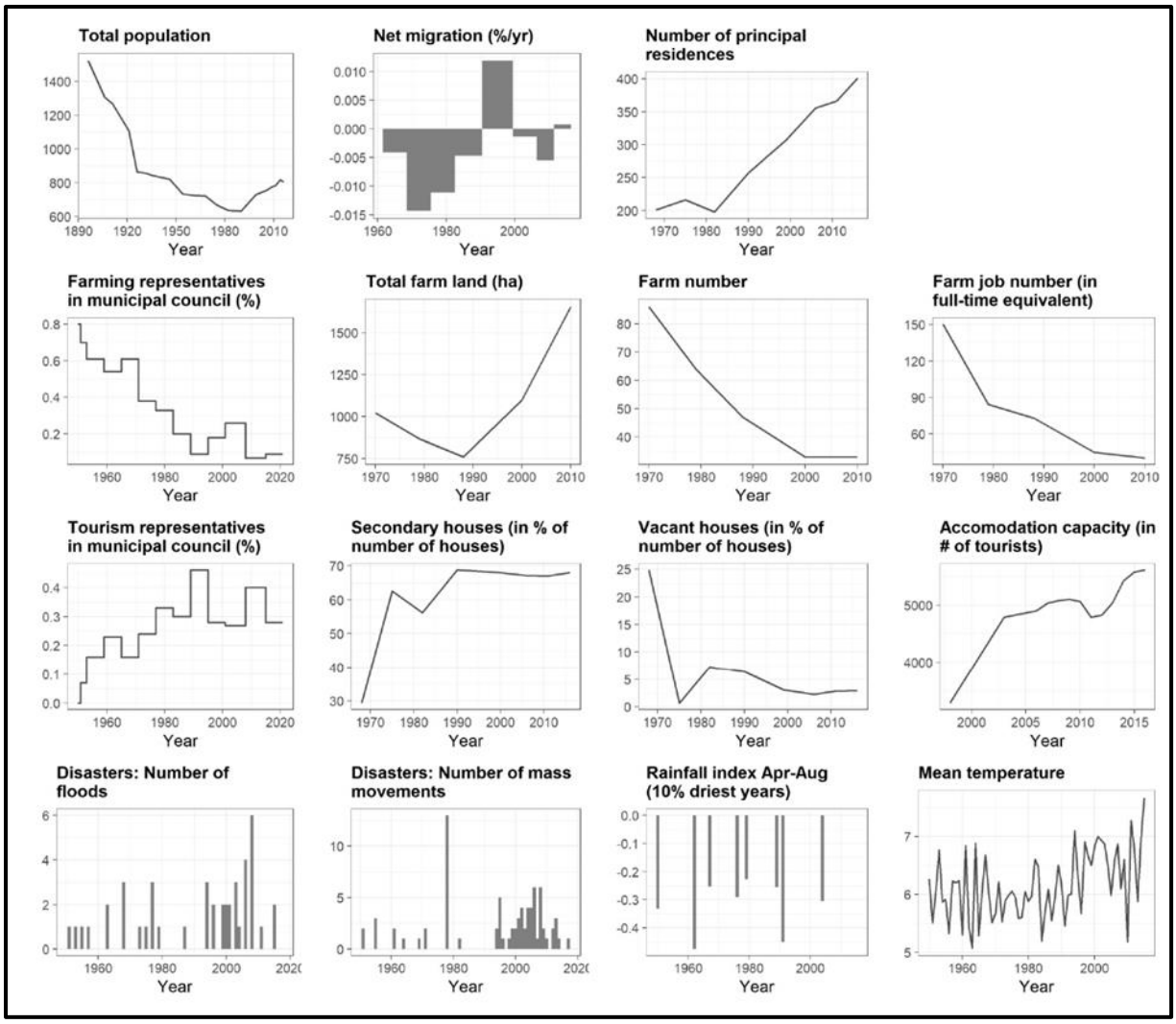


Fig. 3 Historical changes of indicators related to population (top row - INSEE), agriculture (second row - Agreste), tourism (third row- INSEE), and disaster or climate (bottom row – Météo-France; ONF-BD-RTM) in the study area. For drought, we used a rainfall index representing the mean value over the months of April to August of the Standardized Precipitation-Evapotranspiration Index (Vicente Serrano et al. 2010) and we highlighted remarkable drought years by displaying only the 10% years with the lowest values

During this period, there was a reconfiguration of capitals without change in the co-production of fodder. Financial capital from subsidies supporting CP1 and CP2 has evolved, power relations at municipal level did not change significantly, tourism representation remained strong, and the governance of land management (CP1) was reorganised by the establishment of bottom-up collective strategies. Because of droughts, the least accessible areas were remobilized for mowing and grazing (CP2), and the demand for transhumance (CP2) increased. Therefore, financial capital and rural identity, as along with the preservation of biodiversity as a condition for subsidies, became the main support for the co-production of fodder. These

reconfigurations of capital have not led to changes in the landscape, but to declining fertility in hay meadows and declining biodiversity in grasslands converted from mowing to grazing (Quétier et al. 2007; Grigulis et al. 2013). While non-material NCP (such as recreation, tourism, leisure and aesthetic enjoyment) have greatly increased since the 1970s because of tourism, material NCP have remained stable and linked to forage production.

Discussion

We studied the past trajectory of a social-ecological system to understand adaptive response mechanisms by analysing how human-nature interactions have changed over time through reconfiguration of NCP co-production. This systemic approach described adaptations through actors' agency in NCP co-production. In the following we discuss the drivers of change, their impacts on NCP co-production associated mechanisms of adaptive responses and the nature of adaptive responses.

Drivers of change and impacts on nature contributions to people co-production

We found that multiple external drivers affected directly or indirectly the Pays de la Meije SES through multi-scale interactions. In Europe, changes in regional, national and EU policies, markets or consumption patterns have strongly influenced agriculture and tourism (Levers et al. 2015; Plieninger et al. 2016). Changes also often stemmed from interactions with trajectories of others systems (region, national) at various spatial and temporal scales (Fazey et al. 2015). For example, as observed in many mountain regions, demographic fluctuations reflect regional trajectories, with rural exodus resulting from loss of local farm employment, new job opportunities in close industrializing cities of the region, and the national urbanization (Hinojosa et al. 2016). We observed that drivers may impact all the co-production steps through capital reconfigurations, by affecting NCP supply with ecosystem management or mobilization (CP1/CP2), and/or NCP demand through appreciation and appropriation (CP3). For example, changes in social demand for food combined to the development of new markets and agricultural policies affected all co-production steps, thus affecting both supply and demand of agricultural NCP. Social and environmental policies as well as changing leisure preferences and habits have led to the emergence of new tourism-related NCP demand and supply. These drivers have long been identified as having indirect effects on ecosystems (Nelson et al. 2006). However, here we highlight these drivers' impact through the co-production of NCP. Numerous capitals were thus reconfigured, such as access conditions to financial capital, modification of power and local agency affecting collective and individual decisions, new perception and

relation to nature, or shift in preferences and values of societies. These results reflect the prevalent role of external drivers, especially socio-economic and policies, in SES adaptation dynamics (Prokopová et al. 2018).

Commonly with many marginal systems, three drivers played a predominant role in Pays de la Meije's past socio-ecological trajectory. First, accessibility was a prerequisite for the local development, for supporting local livelihoods and tourism development (Geneletti and Dawa 2009; Schirpke et al. 2019). Second, external policies triggered local agency as Common Agricultural Policy subsidies, national regional development and tourism policies, national urban planning rules and nature protection imposed by national conservation policy (Briner et al. 2013; Gretter et al. 2018; Antoni et al. 2019). Finally, outgoing (farm) and incoming (tourism) migratory flows have determined population size and composition across time. These drivers are shared characteristics of mountain SES, and associated paradoxes of "Policies by outsider" and "in and out migration" (Klein et al. 2019), along with aging population (Ianni et al. 2015). While many mountain regions have experienced similar trajectories (Locatelli et al. 2017), other trajectories have been observed, particularly in terms of agricultural and tourism development (Spiegelberger et al. 2018). For example, as few regions have been able to maintain agricultural activity, land abandonment is widespread in the Alps causing significant landscape transformation (Hinojosa et al. 2019; Schirpke et al. 2019). Rural activity has often given way to intensive tourism which is still ongoing today (Morán-Ordóñez et al. 2013). Moreover, some regions have been able to develop other types of activities such as industry, or to take advantage of close proximity to large urban areas. While in their past trajectories each SES experiences variations in the NCP mobilized, archetypes of NCP bundles can be found depending on the local context and their adaptive responses (Renard et al. 2015).

We note that in this SES adaptation has occurred in response to socioeconomic changes that threatened livelihoods, mainly in relation to economic and employment security. This contrasts with many other places where changes in natural capital have been the force towards SES transformation (Colloff et al. 2020). However, climatic and environmental drivers were rarely perceived by participants as main drivers impacting their livelihoods, although they can play an important role on natural capital reconfiguration. When climatic drivers were perceived by stakeholders (particularly droughts), we observed a difference between perceptions and climatic data. Some droughts did not appear in precipitation records but were perceived as such by farmers for years of lower fodder yields due to specific events like cold springs or rainy harvests. This finding is consistent with previous studies suggesting that farmers' perceptions

are influenced by economic and psychological rather than purely biophysical impacts (Foguesatto et al. 2020). Despite actors perceiving recent signals of environmental changes, their discourses did not report past reconfiguration of NCP co-production due to change in natural capital. While climatic and environmental stressors are central to adaptation research, they are often not reported by actors as primary drivers of adaptation or of livelihood vulnerabilities (Mcdowell and Hess 2012; Räsänen et al. 2016). This may reflect their diffuse nature, along with intrinsic adaptation to harsh environments of SES subject to floods, drought, naturals hazards or high climate variations like in mountains regions (Boissière et al. 2013; Klein et al. 2019). This may also be due to the interactions between multiple types of drivers, which blur the specific roles of individual drivers.

Mechanisms of adaptive responses

Changes in the availability or accessibility of capital created vulnerabilities or opportunities triggering local communities' decisions. We observed two types of adaptive responses to these changes. First, during periods 1 and 2, farmers were forced to adapt their practices in order to avoid the collapse of the agricultural system and livelihoods creating a trade-off between the loss of traditional knowledge and skills, and the gain in economic and social conditions. In contrast, during period 3, local communities seized the opportunity to improve their livelihoods by developing tourism. This observation relates to a distinction often made to explain decisions (e.g., entrepreneurship and migration decisions), between push motivation (the need to avoid an undesirable situation) and pull motivation (the willingness to reach a desirable situation) (Zimmermann 1996; Dawson and Henley 2012). Moreover, types of responses will strongly depend on the local context. Indeed, under the influence of the same large-scale drivers, other SES will take different trajectories due to local specificities and depending on the role of the affected NCP in local livelihoods (Jaligot et al. 2019). Collective or individual agency triggering adaptive responses is then facilitated or limited depending on threats or opportunities generated by changes among capitals involved in NCP co-production.

We observed multiple responses to drivers involving reconfiguration of NCP co-production and cascading effects on other co-production steps leading sometimes to systemic change. Drivers can directly affect one or several capitals involved in NCP co-production. All co-production steps may be impacted though cascading effects, as when loss of human capital (workforce) due to rural exodus reconfigured the entire food production system (period 1) and crop production ceased (CP1). Cascading effects can also be avoided when only one step of co-production is impacted, such as when change in dairy products markets (period 2) impacted

value creation (CP3) and threatened the whole co-production of dairy farming (CP1/CP2/CP3). Systemic change was avoided during this period when local farmers seized the opportunity of a new market for heifer breeding (CP3) without changing the management or mobilization of fodder production (CP1&CP2). This was also observed in period 3 when increased demand from tourists for mountains activities (CP3) led locals and newcomers to co-produce new recreation NCP by increasing access, infrastructure and technical skills (CP2&CP3) without requiring dedicated ecosystem management (CP1). Lastly, part of the capital may reconfigure without impacting co-production actions as described in the maintenance of the farming system from 1990 (period 4). Mechanisms of adaptive responses can then be characterized by the degree of reconfiguration of the capitals they induce. These mechanisms, and thus adaptive capacity, therefore depend on the access to different capitals that is facilitated or hindered by the drivers of change (Freduah et al. 2019).

Nature of adaptive responses

This study has identified adaptive responses of different natures, ranging from incremental to transformational based on degree of reconfiguration of NCP and their co-production steps, and the amount of capital required for adaptation. We highlighted the role of agency in these adaptive responses and how path-dependency and resistance to change have emerged. Our analyses showed that the SES has undergone two major transformations since 1900 (periods 1 and 3), considering that responses are transformative when a SES fundamentally shifts its social and/or ecological properties and functions (Feola 2015; Colloff et al. 2017; Fedele et al. 2019). We observed that transformative responses required reconfigurations of multiple NCP co-productions, which were accompanied by important changes in human derived capitals but not always in natural capitals (i.e. change in ecosystem types, structures and functions).

The reconfiguration of NCP co-production leading to transformation can take two forms. First, existing NCP can be intensified, as shown by the transformative responses in period 1, when people shifted from subsistence agriculture to a market-oriented activity for few families (i.e. livestock rearing), creating significant social change and shift in values (Carrer et al. 2020). Moreover, transformation of farming practices, here to fodder and dairy production, required the reconfiguration of all co-production steps using new capitals, such as skills, knowledge, tools and governance (Krausmann 2004) causing change in mountains landscape (Egarter Vigl et al. 2016). Second, new NCP whose social or economic value has increased can appear, as shown by the transformative responses in period 3, when arrival of new populations in the Alps (workers and tourists) attracted by nature and leisure activities caused a social transformation;

also called “amenity migrants” (Perlik 2006; Martin 2014). This transformation resulted from the massive mobilization of new human-derived capital to co-produce new recreational NCP, for example rules, skills, knowledge and funds needed for tourism businesses or building of trails and infrastructure (Kariel and Kariel 1982). Thus, the development of a tourism-oriented population as well as the transformation of the local economy was generated by reconfigurations in values by putting leisure at the centre of local society, knowledge systems and in power relations with the growing importance of the tourism sector in decision making (Corneloup et al. 2004). The amount of human capital required for NCP co-production appears as a characteristic of transformation (Chhetri et al. 2019). Indeed, both transformations were accompanied by change in the values, rules and knowledge systems shaping the decisional context. This shift in decisional context, influencing community’s agency and adaptive capacity, was necessary for a paradigm change leading to social transformation (Gorddard et al. 2016; Colloff et al. 2017).

Transformative adaptation often requires changes in ecological processes and relies on latent, sustained or novel NCP (Lavorel et al. 2020). The reported social transformation in period 3 required only few changes in the ecological system. First, due to the low intensity of ecosystem management and the ecosystem protection thanks to limited infrastructure development and landscape conservation resulting from national rules and local willingness to preserve the landscape. Second, due to the type of NCP, indeed, non-material NCP often required less direct ecosystem management and more appropriation and appreciation actions (Bruley et al. 2021). Moreover, other NCP co-productions, e.g. food and fodder production management, contribute greatly to the development of new non-material NCP, like scenic beauty, by shaping the landscape. Also, synergies among different NCP co-production steps were required in transformative responses to allow new NCP co-production, such as the combination of natural landscape conservation (CP1), creation of access to nature (CP2) and practice of tourism professionals (CP3) for many non-material NCP developed.

We also observed incremental responses characterized by adjustment of the current system functioning while maintaining its fundamental characteristics (Chhetri et al. 2019; Fedele et al. 2019) when adjustments in NCP co-production allowed tourism and agricultural activities to persist (period 2 & 4). First, adjustments occurred in the capital involved in NCP co-production without changing the nature of co-production. For example, we observed adjustments of farmers collective governance, land allocation and farming practices in response to twenty years of changing institutional, financial and climatic conditions to maintain local livelihoods (period

4) (Schermer et al. 2016). Secondly, some incremental responses modified only one NCP co-production step to ensure that other co-production steps could be maintained. During period 2, farmers adjusted the transformation and valorisation of livestock products (CP3) while maintaining the other practices of livestock farming and fodder production (CP1 and CP2). While this is not a systemic transformation for the SES, this transition from dairy to heifer production resulted in a significant change in the identity of farmers. Indeed, this adaptation led to the dependence of their activity on external actors, but also to a loss of added value and local valorisation through the relocation of part of the activity (CP3). Thus, a significant change in the identity of a sub-system linked to a co-production step was not enough to trigger the transformation of the system. In these two examples, farmers maintained "business as usual" and avoided the costs and risks of developing new NCP co-production.

The entire trajectory of the Pays de la Meije SES reveals how path dependency and resistance of the system have increased over time, partly because of the dependence of agriculture and tourism on external drivers. After their transformation, farmers became dependent on heifer and lamb external markets, on European subsidies (more than 60% of farm incomes), and on tourism (providing off-farm jobs). The local tourism sector became dependent on the consumption patterns or preferences of tourists, on accessibility, and on climatic conditions (snow for winter sports). Agricultural subsidies and winter sports constitute powerful economic attractors that encourage communities to maintain their activities and resist change (Bussey et al. 2012). Local communities have developed resistance to change and the SES is in a phase of accumulation of capitals. Using the metaphor of the adaptive cycle defined by Gunderson et al. (2002), we can consider that the SES is in a conservation phase, characterized by stabilization and accumulation (period 3 & 4). In the adaptive cycle, a conservation phase follows phases of reorganisation and growth (which could be our periods 1 & 2) but leads to a progressive loss of flexibility and is followed by a phase of collapse or release (Antoni et al. 2019). We believe that period 4 and its increased climate change vulnerability illustrates such a conservation phase in spite of small adjustments, for example in farmers practices (Lamarque et al. 2014; Nettier et al. 2017) and in the subsidy system (Darnhofer et al. 2017). Actors will need to imagine new attractors in order to overcome dependencies that weaken the systems resilience over the long term.

The main capitals underpinning these dependencies are social and human capital related to institutions (e.g. external policies), formal and informal rules, power relations (e.g. farmers vs tourism professionals), values (e.g. leisure society) and preferences (e.g. consumption patterns).

Social capital has been shown to play a key role in adaptive capacity, particularly in interactions with natural capital (Adger 2010; Barnett et al. 2015). As an example, the Pays de la Meije SES experienced a major crisis in 2015, when its main road access kept closed during 9 months after a large landslide. Although livelihoods were threatened by this road closure and had to adjust temporally, there was not enough coordination among actors to seize the opportunities of this crisis, engage in transformative responses, and reduce structural vulnerabilities (Bally et al. 2020). Resistance mechanisms constitute a barrier to future adaptation if communities cannot adjust to ongoing changes, including facing climate change (Chhetri et al. 2019) and fall into social-ecological traps (Boonstra and De Boer 2014). There is indeed a risk of entering an unwanted future trajectory, linked to the high level of specialisation, the rigidity of the agricultural and tourism systems, the lack of local actor's influence, and marginality of this SES facing increasing signals of biodiversity loss and climate change that could alter supporting ecosystems (Cumming 2018).

Conclusion

The last decade of sustainability research has strongly focused on adaptation of social-ecological systems, promoting a better understanding of mechanisms underpinning social-ecological adaptation. Empirical studies of historical trajectories have been suggested as a way to evaluate the adaptive capacity of social-ecological systems. In this study, we identified several mechanisms, from resistance to transformation, that influence ecosystem-based adaptation. We characterize them by the nature of associated changes in natural and anthropogenic capitals, the level of reconfiguration of NCP co-production for adapting, and by the degree of change in agency, mainly associated with changes in human and social capitals.

This study highlights the need for scientists to engage with local stakeholders and decision makers to co-produce knowledge based on past trajectories for informing future adaptation pathways. Along with improving our understanding of transformative adaptation, such engagement can help local actors identify their strengths (mechanisms and capitals that supported past adaptation) and weaknesses (vulnerability and dependence on certain capitals, often external) in facing global changes. Importantly, nature appeared as an important capital supporting adaptive responses and on which actors can act. In addition, identifying dependencies on capitals on which actors cannot act could be an important step for increasing adaptive capacity. This was the case here with subsidies for agriculture: they are indispensable but the dependence of farmers on them could be reduced by developing direct sales and moving to higher value-added production. Also, the local economic dependence on tourism could be

reduced by diversifying winter activities to ensure income despite the impacts of climate change on snow cover or by developing activities in other sectors.

We encourage more numerous historical studies in other socio-ecological contexts for exploring adaptation mechanisms. Additional place-based research is needed to better understand how future adaptation plans can be informed by the analysis of past trajectories of human and nature interactions. Our results also suggest that a more in depth understanding of agency in adaptive responses would be required, informing heterogeneity and inequalities in adaptive capacity across actors, their power relations and access to capitals for NCP co-production.

Acknowledgements

This paper is a contribution from the Transformative Adaptation Research Alliance (TARA, https//research.csiro.au/tara/), an international network of researchers and practitioners dedicated to the development and implementation of novel approaches to transformative adaptation to global change. We warmly thank inhabitants of Villar d'Arène and La Grave for participation in workshops and interviews. We warmly thank the young researchers' group from CDP Trajectories for their investigations on the historical data and the trajectory of the Pays de la Meije. We also thank Jardin du Lautaret for hosting the research team (UMS 3370 Univ. Grenoble Alpes–CNRS) a member of the Zone Atelier Alpes and eLTER network and of AnaEE-France (ANR-11- INBS-0001AnaEE-Services, Investissements d'Avenir frame). This research was carried out within the Long-Term Socio-Ecological Research (LTSER) platform Lautaret-Oisans, a site of the European Research Infrastructure eLTER.. This research was funded through French Agence Nationale pour la Recherche projects MtnPaths (ANR-16-CE93-0008-01), Investissements d'Avenir CDP Trajectories (ANR-15-IDEX-02) and TRASSE (ANR- 17-CE32-0012-01), and the CGIAR Research Program on Forests, Trees and Agroforestry (CRP-FTA) with financial support from the CGIAR Fund.

REFERENCES

Adamson GCD, Hannaford MJ, Rohland EJ (2018) Re-thinking the present: The role of a historical focus in climate change adaptation research. Global Environmental Change 48:195–205 . https://doi.org/10.1016/j.gloenvcha.2017.12.003

Adger WN (2010) Social Capital, Collective Action, and Adaptation to Climate Change. In: Voss M. (eds) Der Klimawandel. VS Verlag für Sozialwissenschaften. pp 327–345

Agreste La statistique agricole : Recensements agricoles. www.agreste.agriculture.gouv.fr

Antoni C, Huber-Sannwald E, Reyes Hernández H, van't Hooft A, Schoon M (2019) Socio-ecological dynamics of a tropical agricultural region: Historical analysis of system change and opportunities. Land Use Policy 81:346–359 . https://doi.org/10.1016/j.landusepol.2018.10.028

Bally F, Gabillet M, Laforgue D, Lavorel S, Peyrache-Gadeau V (2020) L'étude de la « Crise du Chambon » pour penser les rapports entre territoire, institutions, populations et sciences. Nature, Sciences et Sociétés 28:24–34 . https://doi.org/https://doi.org/10.1051/nss/2020019

Barnett J, Evans LS, Gross C, Kiem AS, Kingsford RT, Palutikof JP, Pickering CM, Smithers SG (2015) From barriers to limits to climate change adaptation: Path dependency and the speed of change. Ecology and Society 20: . https://doi.org/10.5751/ES-07698-200305

Bergeret A, George-Marcelpoil E, Delannoy J, Piazza-morel D (2015) L'outil-frise : une expérimentation interdisciplinaire - Comment représenter des processus de changements en territoires de montagne ? Les Carnets du Labex ITEM <hal- 01230027>

Boissière M, Locatelli B, Sheil D, Padmanaba, Michael Sadjudin E (2013) Local Perceptions of Climate Variability and Change in Tropical Forests of Papua , Indonesia. Ecology and Society 18: . https://doi.org/http://dx.doi.org/10.5751/ES-05822-180413

Boonstra WJ, De Boer FW (2014) The historical dynamics of social-ecological traps. Ambio 43:260–274 . https://doi.org/https://doi.org/10.1007/s13280-013-0419-1

Briner S, Elkin C, Huber R (2013) Evaluating the relative impact of climate and economic changes on forest and agricultural ecosystem services in mountain regions. Journal of Environmental Management 129:414–422 . https://doi.org/10.1016/j.jenvman.2013.07.018

Bruley E, Locatelli B, Lavorel S (2021) Nature's contributions to people: Co-producing quality of life from multifunctional landscapes. Ecology and Society 26:12 . https://doi.org/https://doi.org/10.5751/ES-12031-260112

Bürgi M, Silbernagel J, Wu J, Kienast F (2015) Linking ecosystem services with landscape history. Landscape Ecology 30:11–20 . https://doi.org/10.1007/s10980-014-0102-3

Bussey M, Carter RW (Bill., Keys N, Carter J, Mangoyana R, Matthews J, Nash D, Oliver J, Richards R, Roiko A, Sano M, Thomsen DC, Weber E, Smith TF (2012) Framing adaptive capacity through a history-futures lens: Lessons from the South East Queensland Climate Adaptation Research Initiative. Futures 44:385–397 . https://doi.org/10.1016/j.futures.2011.12.002

Carrer F, Walsh K, Mocci F (2020) Ecology, Economy, and Upland Landscapes: Socio-Ecological Dynamics in the Alps during the Transition to Modernity. Human Ecology 48:69–84 . https://doi.org/10.1007/s10745-020-00130-y

Chhetri N, Stuhlmacher M, Ishtiaque A (2019) Nested pathways to adaptation. Environmental Research Communications 1:015001 . https://doi.org/10.1088/2515-7620/aaf9f9

Colloff MJ, Martín-López B, Lavorel S, Locatelli B, Gorddard R, Longaretti PY, Walters G, van Kerkhoff L, Wyborn C, Coreau A, Wise RM, Dunlop M, Degeorges P, Grantham H, Overton IC, Williams RD, Doherty MD, Capon T, Sanderson T, Murphy HT (2017) An integrative research framework for enabling transformative adaptation. Environmental Science and Policy 68:87–96 . https://doi.org/10.1016/j.envsci.2016.11.007

Colloff MJ, Wise RM, Palomo I, Lavorel S, Pascual U (2020) Nature's contribution to adaptation: insights from examples of the transformation of social-ecological systems. Ecosystems and People 16:137–150 . https://doi.org/10.1080/26395916.2020.1754919

Corneloup J, Bourdeau P, Mao P (2004) Le marquage culturel des territoires touristiques de nature. Revue de géographie alpine 92:11–20 . https://doi.org/10.3406/rga.2004.2317

Costanza R, Kubiszewski I, Heckbert S, Hibbard KA, Costanza R, Kubiszewski I, Heckbert S, Hibbard KA, Leeuw S Van Der, Jackson ST, Sinclair P, Sörlin S, Steffen WL, Folke C, Dearing JA (2012) Scholar Developing an Integrated History and future of People on Earth (IHOPE). 4:106–114 . https://doi.org/10.1016/j.cosust.2012.01.010.This

Cumming GS (2018) A Review of Social Dilemmas and Social-Ecological Traps in Conservation and Natural Resource Management. 11:1–15 . https://doi.org/10.1111/conl.12376

Darnhofer I, Schermer M, Steinbacher M, Gabillet M, Daugstad K (2017) Land Use Policy Preserving permanent mountain grasslands in Western Europe : Why are promising approaches not implemented more widely ? Land Use Policy 68:306–315 . https://doi.org/10.1016/j.landusepol.2017.08.005

Davidson DJ (2010) The applicability of the concept of resilience to social systems: Some sources of optimism and nagging doubts. Society and Natural Resources 23:1135–1149 . https://doi.org/10.1080/08941921003652940

Dawson C, Henley A (2012) “Push” versus “pull” entrepreneurship: An ambiguous distinction? International Journal of Entrepreneurial Behaviour and Research 18:697–719 . https://doi.org/10.1108/13552551211268139

Dearing JA, Acma B, Bub S, Chambers FM, Chen X, Cooper J, Crook D, Dong XH, Dotterweich M, Edwards ME, Foster TH, Mclean CE, Nunes LH, Raman S (2015) Social-ecological systems in the Anthropocene : The need for integrating social and biophysical records at regional scales. https://doi.org/10.1177/2053019615579128

Diaz S, Demissew S, Carabias J, Dı S, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Bartuska A, Baste IA, Bilgin A, Brondizio E, Chan KMA, Figueroa VE, Duraiappah A, Fischer M, Hill R, Koetz T, Leadley P, Lyver P, Mace GM, Martin-lopez B, Okumura M, Pacheco D, Reyers B, Pascual U, Pe ES, Roth E, Saito O, Scholes RJ, Sharma N, Tallis H, Thaman R, Watson R, Yahara T, Hamid ZA, Akosim C, Al-hafedh Y, Amankwah E, Asah ST, Asfaw Z, Bartus G, Brooks LA, Caillaux J, Dalle G, Darnaedi D, Driver A, Erpul G, Escobar-eyzaguirre P, Failler P, Moustafa A, Fouda M, Fu B, Gundimeda H, Hashimoto S, Homer F, Lavorel S, Lichtenstein G, Mala WA, Mandivenyi W, Matczak P, Mbizvo C, Mehrdadi M, Metzger JP, Mikissa JB, Moller H, Mooney HA, Mumby P, Nagendra H, Nesshover C, Oteng-yeboah AA, Rubis J, Schultz M, Smith P, Sumaila R, Takeuchi K, Thomas S (2015) The IPBES Conceptual Framework — connecting nature and people. 1–16 . https://doi.org/10.1016/j.cosust.2014.11.002

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, Polasky S, Church A, Lonsdale M, Larigauderie A, Leadley PW, van Oudenhoven APE, van der Plaat F, Schröter M, Lavorel S, Aumeeruddy-Thomas Y, Bukvareva E, Davies K, Demissew S, Erpul G, Failler P, Guerra CA, Hewitt CL, Keune H, Lindley S, Shirayama Y (2018) Assessing nature’s contributions to people. Science 359:270–272 . https://doi.org/10.1126/science.aap8826

Dittrich A, Seppelt R, Václavík T, Cord AF (2017) Integrating ecosystem service bundles and socio-environmental conditions – A national scale analysis from Germany. Ecosystem Services 28:273–282 . https://doi.org/10.1016/j.ecoser.2017.08.007

Egan PA, Price MF (2017) Mountain Ecosystem Services and Climate Change. A global overview of potential threats and strategies for adaptation, UNESCO. Paris

Egarter Vigl L, Schirpke U, Tasser E, Tappeiner U (2016) Linking long-term landscape dynamics to the multiple interactions among ecosystem services in the European Alps. Landscape Ecology 31:1903–1918 . https://doi.org/10.1007/s10980-016-0389-3

Egarter Vigl L, Tasser E, Schirpke U, Tappeiner U (2017) Using land use/land cover trajectories to uncover ecosystem service patterns across the Alps. Regional Environmental Change 17:2237–2250 . https://doi.org/10.1007/s10113-017-1132-6

Fazey I, Wise RM, Lyon C, Câmpeanu C, Moug P, Davies TE (2015) Past and future adaptation pathways. Climate and Development 8:26–44 . https://doi.org/10.1080/17565529.2014.989192

Fedele G, Donatti CI, Harvey CA, Hannah L, Hole DG (2019) Transformative adaptation to climate change for sustainable social-ecological systems. Environmental Science and Policy 101:116–125 . https://doi.org/10.1016/j.envsci.2019.07.001

Fedele G, Locatelli B, Djoudi H (2017) Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosystem Services 28:43–54 . https://doi.org/10.1016/j.ecoser.2017.09.011

Feola G (2015) Social transformation in response to global environmental change: A review of emerging concepts. Ambio 44:376–390 . https://doi.org/10.1007/s13280-014-0582-z

Foguesatto CR, Artuzo FD, Talamini E, Machado JAD (2020) Understanding the divergences between farmer's perception and meteorological records regarding climate change: a review. Environment, Development and Sustainability 22:1–16 . https://doi.org/10.1007/s10668-018-0193-0

Freduah G, Fidelman P, Smith TF (2019) A framework for assessing adaptive capacity to multiple climatic and non-climatic stressors in small-scale fisheries. Environmental Science and Policy 101:87–93 . https://doi.org/10.1016/j.envsci.2019.07.016

Geels FW, Schot J (2007) Typology of sociotechnical transition pathways. Research Policy 36:399–417 . https://doi.org/10.1016/j.respol.2007.01.003

Geneletti D, Dawa D (2009) Environmental impact assessment of mountain tourism in developing regions: A study in Ladakh, Indian Himalaya. Environmental Impact Assessment Review 29:229–242 . https://doi.org/10.1016/j.eiar.2009.01.003

Girel J, Quetier F, Bignon A, Aubert S (2010) Histoire de l'agriculture en Oisans, Hautes Romanche et pays Faranchin - Villar d'Arène, Hautes Alpes

Gorddard R, Colloff MJ, Wise RM, Ware D, Dunlop M (2016) Values, rules and knowledge: Adaptation as change in the decision context. Environmental Science and Policy 57:60–69 . https://doi.org/10.1016/j.envsci.2015.12.004

Grêt-Regamey A, Brunner SH, Kienast F (2012) Mountain Ecosystem Services: Who Cares? Mountain Research and Development 32:S23–S34 . https://doi.org/10.1659/MRD-JOURNAL-D-10-00115.S1

Gretter A, Ciolli M, Scolozzi R (2018) Governing mountain landscapes collectively: local responses to emerging challenges within a systems thinking perspective. Landscape Research 43:1117–1130 . https://doi.org/10.1080/01426397.2018.1503239

Grier C, Alessa L, Kliskey A (2017) Looking to the past to shape the future: addressing social-ecological change and adaptive trade-offs. Regional Environmental Change 17:1205–1215 . https://doi.org/10.1007/s10113-016-1096-y

Grigulis K, Lavorel S, Krainer U, Legay N, Baxendale C, Dumont M, Kastl E, Arnoldi C, Bardgett RD, Poly F, Pommier T, Schloter M, Tappeiner U, Bahn M, Clément JC (2013) Relative contributions of plant traits and soil microbial properties to mountain grassland ecosystem services. Journal of Ecology 101:47–57 . https://doi.org/10.1111/1365-2745.12014

Gunderson LH, Holling CS, (Eds.) (2002) Panarchy: Understanding Trans- formations in Human and Natural Systems., Island Pre. Washington, DC

Hinojosa L, Napoléone C, Moulery M, Lambin EF (2016) The “mountain effect” in the abandonment of grasslands: Insights from the French Southern Alps. Agriculture, Ecosystems and Environment 221:115–124 . https://doi.org/10.1016/j.agee.2016.01.032

Hinojosa L, Tasser E, Rüdisser J, Leitinger G, Schermer M, Lambin EF, Tappeiner U (2019) Geographical heterogeneity in mountain grasslands dynamics in the Austrian-Italian Tyrol region. Applied Geography 106:50–59 . https://doi.org/10.1016/j.apgeog.2019.03.006

Ianni E, Geneletti D, Ciolli M (2015) Revitalizing Traditional Ecological Knowledge: A Study in an Alpine Rural Community. Environmental Management 56:144–156 . https://doi.org/10.1007/s00267-015-0479-z

INSEE (2016) Institut national de la statistique et des études économiques (INSEE). https://www.insee.fr/fr/accueil

IPBES (2018) The regional assessment report on biodiversity and ecosystem services for Africa of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. ISBN No: 978-3-947851-05-8

Jaligot R, Chenal J, Bosch M, Hasler S (2019) Historical dynamics of ecosystem services and land management policies in Switzerland. Ecological Indicators 101:81–90 . https://doi.org/10.1016/j.ecolind.2019.01.007

Jepsen MR, Kuemmerle T, Müller D, Erb K, Verburg PH, Haberl H, Vesterager JP, Andrič M, Antrop M, Austrheim G, Björn I, Bondeau A, Bürgi M, Bryson J, Caspar G, Cassar LF, Conrad E, Chromý P, Daugirdas V, Van Eetvelde V, Elena-Rosselló R, Gimmi U, Izakovicova Z, Jančák V, Jansson U, Kladnik D, Kozak J, Konkoly-Gyuró E, Krausmann F, Mander Ü, McDonagh J, Pärn J, Niedertscheider M, Nikodemus O, Ostapowicz K, Pérez-Soba M, Pinto-Correia T, Ribokas G, Rounsevell M, Schistou D, Schmit C, Terkenli TS, Tretvik AM, Trzepacz P, Vadineanu A, Walz A, Zhllima E, Reenberg A (2015) Transitions in European land-management regimes between 1800 and 2010. Land Use Policy 49:53–64 . https://doi.org/10.1016/j.landusepol.2015.07.003

Kariel H., Kariel P. (1982) Socio-Cultural Impacts of Tourism: An Example from the Austrian Alps. Swedish Society for Anthropology and Geography Wiley 64:1–16

Klein JA, Tucker CM, Nolin AW, Hopping KA, Reid RS, Steger C, Grêt-Regamey A, Lavorel S, Müller B, Yeh ET, Boone RB, Bourgeron P, Butsic V, Castellanos E, Chen X, Dong SK, Greenwood G, Keiler M, Marchant R, Seidl R, Spies T, Thorn J, Yager K (2019) Catalyzing Transformations to Sustainability in the World's Mountains. Earth's Future 547–557 . https://doi.org/10.1029/2018EF001024

Körner C, Ohsawa M, Spehn E (2005) Mountain systems. In: Island press WD (ed) In: Millennium ecosystem assessment. Current state and trends: findings of the condition and trends working group. pp 681–716

Krausmann F (2004) Milk, manure, and muscle power. Livestock and the transformation of preindustrial agriculture in Central Europe. Human Ecology 32:735–772 . https://doi.org/10.1007/s10745-004-6834-y

Lamarque P, Artaux A, Barnaud C, Dobremez L, Nettier B, Lavorel S (2013) Taking into account farmers' decision making to map fine-scale land management adaptation to climate and

socio-economic scenarios. Landscape and Urban Planning 119:147–157 . https://doi.org/10.1016/j.landurbplan.2013.07.012

Lamarque P, Meyfroidt P, Nettier B, Lavorel S (2014) How ecosystem services knowledge and values influence farmers' decision-making. PLoS ONE 9: . https://doi.org/10.1371/journal.pone.0107572

Lavorel S, Colloff MJ, Locatelli B, Gorddard R, Prober SM, Gabillet M, Devaux C, Laforgue D, Peyrache-Gadeau V (2019) Mustering the power of ecosystems for adaptation to climate change. Environmental Science and Policy 92:87–97 . https://doi.org/10.1016/j.envsci.2018.11.010

Lavorel S, Grigulis K, Leitinger G, Kohler M, Schirpke U, Tappeiner U (2017) Historical trajectories in land use pattern and grassland ecosystem services in two European alpine landscapes. Regional Environmental Change 17:2251–2264 . https://doi.org/10.1007/s10113-017-1207-4

Lavorel S, Locatelli B, Colloff MJ, Bruley E (2020) Co-producing ecosystem services for adapting to climate change. Philosophical Transactions of the Royal Society 375: . https://doi.org/10.1098/rstb.2019.0119

Levers C, Erb K, Haberl H, Mu D, Rudbeck M, Marc J, Patrick JM, Mu D (2015) Archetypical patterns and trajectories of land systems in Europe. Regional Environmental Change 18:715–732 . https://doi.org/10.1007/s10113-015-0907-x

Locatelli B, Lavorel S, Sloan S, Tappeiner U, Geneletti D (2017) Characteristic trajectories of ecosystem services in mountains. Frontiers in Ecology and the Environment 15:150–159 . https://doi.org/10.1002/fee.1470

Martín-López B, Leister I, Cruz PL, Palomo I, Grêt-Regamey A, Harrison PA, Lavorel S, Locatelli B, Luque S, Walz A (2019) Nature's contributions to people in mountains: A review. PLoS ONE 14:1–24 . https://doi.org/10.1371/journal.pone.0217847

Martin-Noel J (1962) Une grande Coopérative laitière alpine : « Dauphilait ». Revue de géographie alpine 50:659–664 . https://doi.org/https://doi.org/10.3406/rga.1962.1008

Martin N (2014) Les migrations d ' agrément , marqueur d ' une dynamique d ' après tourisme dans les territoires de montagne

Mcdowell JZ, Hess JJ (2012) Accessing adaptation : Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. Global Environmental Change 22:342–352 . https://doi.org/10.1016/j.gloenvcha.2011.11.002

Météo-France Météo-France stations of Monêtier-Les-Bains (1950-2018). https://donneespubliques.meteofrance.fr/

Meyfroidt P, Chowdhury RR, Bremond A De, Ellis EC, Erb K, Filatova T, Garrett RD, Grove JM, Heinimann A, Kuemmerle T, Kull CA, Lambin EF, Landon Y, Polain Y, Waroux D, Messerli P, Müller D, Nielsen JØ, Peterson GD, García VR, Schlüter M, Ii BLT, Verburg PH (2018) Middle-range theories of land system change. Global Environmental Change 53:52–67 . https://doi.org/10.1016/j.gloenvcha.2018.08.006

Morán-Ordóñez A, Bugter R, Suárez-Seoane S, de Luis E, Calvo L (2013) Temporal Changes in Socio-Ecological Systems and Their Impact on Ecosystem Services at Different Governance Scales: A Case Study of Heathlands. Ecosystems 16:765–782 . https://doi.org/10.1007/s10021-013-9649-0

Munteanu C, Kuemmerle T, Boltiziar M, Butsic V, Gimmi U, Lúboš Halada, Kaim D, Király G, Konkoly-Gyuró É, Kozak J, Lieskovský J, Mojses M, Müller D, Ostafin K, Ostapowicz K, Shandra O, Štych P, Walker S, Radeloff VC (2014) Forest and agricultural land change in the Carpathian region-A meta-analysis of long-term patterns and drivers of change. Land Use Policy 38:685–697 . https://doi.org/10.1016/j.landusepol.2014.01.012

Muscella C (2004) Les enjeux de la construction d'un territoire de Haute Montagne : Etude du canton de la Grave (Hautes Alpes). Faculté d'Anthropologie et de Sociologie, Université Lumières Lyon II

Nelson DR, de Souza Filho F d. A, Finan TJ, Ferreira S (2014) Trajectories of adaptation: A retrospectus for future dynamics. Social-Ecological Systems in Transition 121–136 . https://doi.org/10.1007/978-4-431-54910-9_7

Nelson GC, Bennett E, Berhe AA, Cassman K, DeFries R, Dietz T, Dobermann A, Dobson A, Janetos A, Levy M, Marco D, Nakicenovic N, O'Neill B, Norgaard R, Petschel-Held G, Ojima D, Pingali P, Watson R, Zurek M (2006) Anthropogenic drivers of ecosystem change: An overview. Ecology and Society 11: . https://doi.org/10.5751/ES-01826-110229

Nettier B, Dobremez L, Lavorel S, Brunschwig G (2017) Resilience as a framework for analyzing the adaptation of mountain summer. Ecology a 22: . https://doi.org/https://doi.org/10.5751/ES-09625-220425

ONF-BD-RTM Office National des Forêts –Base de Donnée - Restauration des Terrains de Montagne Evènements. https://rtm-onf.ign.fr/. Accessed 20 Aug 2005

Palomo I (2017) Climate Change Impacts on Ecosystem Services in High Mountain Areas: A Literature Review. Mountain Research and Development 37:179–187 . https://doi.org/10.1659/MRD-JOURNAL-D-16-00110.1

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U (2016) Disentangling the Pathways and Effects of Ecosystem Service Co-Production. Advances in Ecological Research 54:245–283 . https://doi.org/10.1016/bs.aecr.2015.09.003

Perlik M (2006) The Specifics of Amenity Migration in the European Alps. In: Moss L (ed) The Amenity Migrants: Seeking and Sustaining Mountains and Their Cultures, CABI Publi. Cambridge, pp 215–231

Plieninger T, Draux H, Fagerholm N, Bieling C, Bürgi M, Kizos T, Kuemmerle T, Primdahl J, Verburg PH (2016) The driving forces of landscape change in Europe: A systematic review of the evidence. Land Use Policy 57:204–214 . https://doi.org/10.1016/j.landusepol.2016.04.040

Plieninger T, Kizos T, Bieling C, Dû-Blayo L Le, Budniok MA, Bürgi M, Crumley CL, Girod G, Howard P, Kolen J, Kuemmerle T, Milcinski G, Palang H, Trommler K, Verburg PH (2015) Exploring ecosystem-change and society through a landscape lens: Recent progress in european landscape research. Ecology and Society 20: . https://doi.org/10.5751/ES-07443-200205

Prokopová M, Cudlín O, Včeláková R, Lengyel S, Salvati L, Cudlín P (2018) Latent drivers of landscape transformation in eastern Europe: Past, present and future. Sustainability (Switzerland) 10:1–17 . https://doi.org/10.3390/su10082918

Quétier F, Rivoal F, Marty P, de Chazal J, Thuiller W, Lavorel S (2010) Social representations of an alpine grassland landscape and socio-political discourses on rural development. Regional Environmental Change 10:119–130 . https://doi.org/10.1007/s10113-009-0099-3

Quétier F, Thébault A, Lavorel S (2007) Plant traits in a state and transition framework as markers of ecosystem response to land-use change. Ecological Monographs 77:33–52 . https://doi.org/10.1890/06-0054

Räsänen A, Sirkku J, Nygren A, Käkönen M, Kallio M, Monge AM, Kanninen M (2016) Climate change , multiple stressors and human vulnerability : a systematic review. Regional Environmental Change 16:2291–2302 . https://doi.org/10.1007/s10113-016-0974-7

Rau AL, von Wehrden H, Abson DJ (2018) Temporal Dynamics of Ecosystem Services. Ecological Economics 151:122–130 . https://doi.org/10.1016/j.ecolecon.2018.05.009

Renard D, Rhemtull JM, Bennett EM (2015) Historical dynamics in ecosystem service bundles. Proceedings of the National Academy of Sciences of the United States of America 112:13411–13416 . https://doi.org/10.1073/pnas.1502565112

Rousset PL (1992) Au pays de la Meije 3ème édition, Curandera

Schermer M, Darnhofer I, Daugstad K, Gabillet M, Lavorel S, Steinbacher M (2016) Institutional impacts on the resilience of mountain grasslands: An analysis based on three European case studies. Land Use Policy 52:382–391 . https://doi.org/10.1016/j.landusepol.2015.12.009

Schirpke U, Altzinger A, Leitinger G, Tasser E (2019) Change from agricultural to touristic use: Effects on the aesthetic value of landscapes over the last 150 years. Landscape and Urban Planning 187:23–35 . https://doi.org/10.1016/j.landurbplan.2019.03.004

Siniscalchi V (2008) Économie Et Pouvoir Au Sein Du Parc National Des Écrins. Techniques & culture 40–59 . https://doi.org/10.4000/tc.3941

Spiegelberger T, Bergeret A, Crouzat É, Tschanz L, Piazza-Morel D, Brun J-J, Baud D, Lavorel S (2018) Interdisciplinary Construction of a Socio-ecological Vulnerability Trajectory Based on the Quatre Montagnes (Isère, France) Area from 1950 to 2016. Revue de géographie alpine 0–16 . https://doi.org/10.4000/rga.5046

Stürck J, Schulp CJE, Verburg PH (2015) Spatio-temporal dynamics of regulating ecosystem services in Europe- The role of past and future land use change. Applied Geography 63:121–135 . https://doi.org/10.1016/j.apgeog.2015.06.009

Tomscha SA, Gergel SE (2016) Ecosystem service trade-offs and synergies misunderstood without landscape history. Ecology and Society 21: . https://doi.org/10.5751/ES-08345-210143

Vicente Serrano SM;, Beguería S;, López-Moreno JI (2010) A Multiscalar Drought Index Sensitive to Global Warming : The Standardized Precipitation Evapotranspiration Index. Journal of Climate 23:1696–1718 . https://doi.org/10.1175/2009JCLI2909.1

Zimmermann KF (1996) European Migration : Push and Pull. International Regional Science Review 128:95–128 . https://doi.org/https://doi.org/10.1177/016001769601900211

Electronic supplementary materials

Appendix 1. Data and references mobilized to construct chronosystemic timeline and results narratives.

TYPE OF DATA	DATA SOURCES
Grey and scientific literature	**Agriculture history:** Girel J, Quetier F, Bignon A, Aubert S, 2010 - Histoire de l'agriculture en Oisans, Hautes Romanche et pays Faranchin - Villar d'Arène, Hautes Alpes C. Gardelle, 1965 - La transhumance ovine entre les régions méditerranéennes et les Alpes en 1964 . In: Revue de géographie alpine, tome 53, n°3, pp. 449-477 L. Lazaro, 2015 - Estives en partage : une approche relationnelle des externalités du pastoralisme collectif pyrénéen. Manuscrit de thèse, Université de Toulouse Une grande Coopérative laitière alpine : « Dauphilait ». In: Revue de géographie alpine, tome 50, n°4, 1962. pp. 659-664. J. Ancteau, 2003 - L'évolution paysagère des dépôts détritiques de la vallée de la Haute Romanche. Rôles respectifs des pratiques agro-sylvo-pastorales et du réchauffement climatique, Mémoire de DEA – IGA F. Quétier , F. Rivoal, P. Marty, et al, 2010 - Social representations of an alpine grassland landscape and socio-political discourses on rural development. Reg Environ Chang 10:119–130. https://doi.org/10.1007/s10113-009-0099-3 S. Lavorel , K. Grigulis, G. Leitinger, et al., 2017 - Historical trajectories in land use pattern and grassland ecosystem services in two European alpine landscapes. Reg Environ Chang 17:2251–2264. https://doi.org/10.1007/s10113-017-1207-4 B, Locatelli, S. Lavorel, S. Sloan, et al., 2017 - Characteristic trajectories of ecosystem services in mountains. Front Ecol Environ 15:150–159. https://doi.org/10.1002/fee.1470 P. Lamarque, 2012 - Une approche socio-écologique des services écosystémiques. Cas d' étude des prairies subalpines du Lautaret. 248. Manuscrit de thèse, Université Grenoble Alpes. **Tourism history:** C. Muscella, 2004 - Les enjeux de la construction d'un territoire de Haute Montagne : Etude du canton de La Grave (Hautes-Alpes). Manuscrit de thèse, Université Lyon II Aubert S., Bignon A.. 2013. 150 ans de tourisme au col du Lautaret. Le rôle de la Compagnie de chemin de fer Paris-Lyon-Méditerranée et du touring Club de France dans les Alpes. Les cahiers illustrés du Lautaret. N°4 George-Marcelpoil E., Hugues F., 2012. Vallée de la Tarentaise : de l'invention du Plan Neige à la constitution 'un milieu innovateur dans le domaine du tourisme d'hiver. In : Histoire des Alpes, Vol. 17. ed: Association Internationale pour l'Histoire des Alpes. **Broad history of the region:** R. Canac, et B. Boyer, 1997 - Vivre ici en Oisans. Éd. Glénat S. Blaise, 1983 - Les mutations d'une société montagnarde à travers l'Histoire : l'exemple de la Haute Romanche. Mémoire de DEA – IGA C. Broggio, 1997- Montagne et développement territorial: de l'auto-développement au développement durable. L'Information géographique, 61-4 pp. 160-174 **Nature conservation history:** A. Selmi, 2006 - Administrer la nature : Parc national de la vanoise. Paris, Eds. de la MSH / Eds. Quae, 487 p. J Peltier, 2008 - Plaines alluviales Alpines de Haute Romanche et du Vénéon. Analyse diachronique des paysages et tentative de proposition de gestion. Mémoire fin d'étude **Cultural and heritage history:** A. Mercan, I. Girard & S. Aubert. 2014. Ces bonnes choses que l on mange et savoure en Haut-Oisans Ethnographie de l alimentation en Haute-Romanche (La Grave et Villar d Arène) Avec recettes incluses. Les cahiers illustrés du Lautaret. n°6 M. Maget, 1989 - Le Pain anniversaire à Villar-d'Arêne en Oisans, Éd. des Archives contemporaines, 237 p ; **National and local policies:** M. Berriet-Solliec, C. Déprés, et A. Trouvé, 2005 - « La territorialisation de la politique agricole en France ». Vers un renouvellement de l'intervention publique en agriculture ; P. Muller, 2000 - « La politique agricole française: l'État et les organisations professionnelles ». Économie rurale 255, no 1: 33 39. https://doi.org/10.3406/ecoru.2000.5153. Le technocrate et le paysan les lois d'orientation agricole de 1960-1962 et la modernisation de l'agriculture française 1945-1984-1945-1984. Paris: L'Harmattan, 2015. http://www.harmatheque.com/ebook/9782343050409.
Databases	**Agriculture:** Total farm land area (ha)/ Farm number/ Farm job number from 1970, 1979, 1988, 200 & 2010 from Recensement Agricole of La Grave and Villar d'Arène: Agreste - la statistique agricole : Recensements agricoles. www.agreste.agriculture.gouv.fr Link to database: https://agreste.agriculture.gouv.fr/agreste-saiku/?plugin=true&query=query/open/G_2003#query/open/G_2003 **Climate:** Temperature and precipitation from 1950 of Monetier Les Bains metrological station - Météo-France stations of Monêtier-Les-Bains (1950-2018). https://donneespubliques.meteofrance.fr/ **Risks:** Count of avalanche, rockfall, torrential flood, landslide, flood, erosion events between 1950 and 2017. Disaster database: ONF-BD-RTM Office National des Forêts –Base de Donnée - Restauration des Terrains de Montagne Evènements. https://rtm-onf.ign.fr/ **Demographic and social**: Population index (from 1890 to 2017), migratory index, Residence, accommodation capacity (from 1970 to 2010) for La Grave and Villar d'Arène municipalities: INSEE Institut national de la statistique et des études économiques (INSEE). https://www.insee.fr/fr/accueil
Municipal Archives	Municipal council composition since 1950 Livestock registration since 1977 Other non-exploitable information

Appendix 2 Participants description and participation to interviews and workshops

N°	Function	Sector	Gender	Time spent in the region	Participation to interviews	Participation to workshops
1	Mountain guide Local councillor	Tourism Decision making	M	40 years	X	X
2	Farmer Ex-Local councillor	Agriculture Decision making	M	15 years	X	
3	Farmer (retired) Local councillor	Agriculture Decision making	M	Since birth	X	
4	Mountain guide Truck farmer Carpenter	Tourism Agriculture Artisan	M	15 years	X	
5	Gite holder	Tourism	F	10 years	X	
6	Hotel owners Former director of the pastoral land association (AFP)	Tourism Agriculture	M/F	Since birth	X	
7+8	Gite holder Local councillor	Tourism Decision making	M	40 years	X	
9	President of a cultural association	Culture	M	20 years	X	
10	President of a hunting association	Leisure	M	Lives outside the area	X	
11+12	Former public service employee Local councillor	Public services Decision making	M/F	Since birth	X	X (+F)
13	Researcher (retired) Former member of the pastoral land association (AFP)	Academic Agriculture	M	60 years	X	X
14	Former Mayor Former public service employee	Public services Decision making	M	Since birth	X	X
15+16	Ski resort employee Secretary	Tourism Administration	M/F	Since birth		X
17	Municipal employee	Public services	F	30 years		X