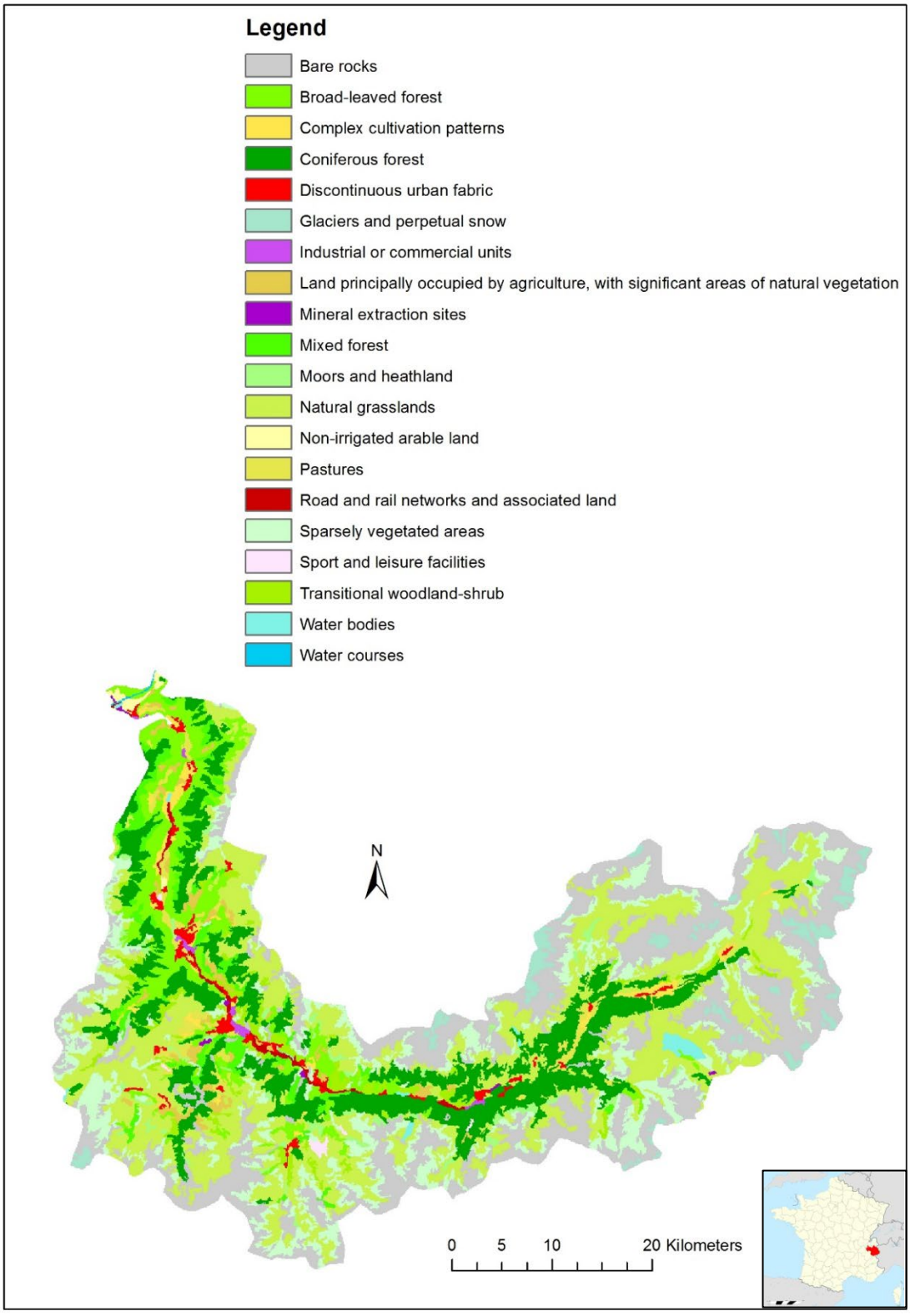
Supplemental material for

"Community-Based Institutions Shape Cheese Co-production in a French Alpine Valley", by Julia Grosinger, Karl Grigulis, Nicolas Elleaume, Nicolas Buclet, and Sandra Lavorel, published in *Mountain Research and Development* 42(3), 2022. (See https://bioone.org/toc/mred/42/3)

APPENDIX S1 Land use map of the area



Map at the right corner at the bottom of the land use map shows the department of the study area within France and Western Europe.

APPENDIX S2 Profile of interview partners

Table 1: Overview of conducted interviews with the corresponding actors characteristics (BC: Beaufort cooperative, oBC: Outside Beaufort cooperative). We included seven stakeholders from the skiing resort in our sample to take into account the deep interlinkages of tourism and agriculture (e.g. by land use, employment, economic revenues, etc.) typical for the Alpine area. Due to the focus on the role of local actors we did not include seasonal actors, such as transhumant actors in our sample. Frequently actors of the oBC group also have roles in other local and regional institutions. 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). ***Age structure of the interview data set is as follows: 18-35 years: 9%; 36-45 years: 27%; 46-55 years: 18%; 56-62 years: 30%; >62 years: 16%. 75% of the interview partners was male, compared to 25% female.***

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

Int. 35	OBC	Actor 34	Skiing resort	managing	Employee
Int. 36	BC	Actor 35	Agricultural association	leading	Farmer
Int. 37	BC	Actor 36	Beaufort cooperative system	leading	Farmer
Int. 38	BC	Actor 37	Agricultural association	technical	Employee
Int. 39	BC	Actor 38	Beaufort cooperative system	managing	Employee
Int. 40	OBC	Actor 39	Regional authority	managing	State official
Int. 41	OBC	Actor 40	Farmer	leading	Farmer
Int. 42	OBC	Actor 41	National Park	technical	State official
Int. 43	OBC	Actor 42	Skiing resort	managing	Employee
Int. 44	OBC	Actor 43	Pastoral land association	leading	Retired

APPENDIX S3 Qualitative research and interview guide

Selection of interview partners

Stakeholder analysis supports the identification of actors and the analysis of their roles and relations in, to and within valley's agricultural system (Reed et al. 2009). We ultimately identified around 400 actors. We used an internet search of academic and grey sources and a brainstorming process with four academic experts of the region to select initial interview partners. The interviews aimed to get a comprehensive understanding of the functioning of the agricultural system. We then updated this list over the course of field research by purposive snowballing (Bryman 2016).

The questions focused on the role, background, perceptions on and relations to the agricultural sector (see Appendix S3). We transcribed the recorded interviews 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). This information served as the base for our reasoning and the definition of the initial conceptual model of cheese co-production. Selected translated citations into the Results section of this article support outcomes of the quantitative analysis.

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?
3. What is the main activity of your institution in relation to the agricultural sector in the Maurienne?
4. How many people are working in your institution?
5. How many members are affiliated/controlled by your institution?

Second part: interactions with other actors

6. Who are the other actors you are working with?
7. Do you have relations to …. (name of different institutions)
8. Who is in your mind the most powerful (in terms of decision-making) actor in the agricultural sector of the Maurienne?
9. Who is in your mind the most competent (knowledge) actor in the agricultural sector in the Maurienne?
10. With whom would you like to work more together?

Third part: Describing the agricultural sector in the Maurienne valley

11. How do you describe the agricultural sector in the Maurienne?
12. What are the challenges of the agricultural sector in the Maurienne?
13. How do you see agriculture in the Maurienne in 2050?
14. Do you think that climate change will have an impact on the agricultural sector?

Fourth part: Co-production activities

15. How to you intervene in the management of pasture land?
16. Can you describe the milking process in summer and in winter? How long does it take you?
17. How many hours are you working per week?
18. What is your motivations?
19. What would you improve if you could?
20. What do you think about the specification requirements of Beaufort cheese? [Only for actors of the Beaufort cooperative system]

APPENDIX S4 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** [1]	**Unit**	**Explanation**	**Source**
Biophysical constraints	Geographic	Mean direct insolation	$Wh.m^{-2}.day^{-1}$	Shows exogenous, non modifiable conditions	(IGN-F 2021a Dec 18)
	Impact of solar power	**Altitude**[2]	Meters (m)	Mean altitude of municipality, shows exogenous, non modifiable conditions	(IGN-F 2021a Dec 18)
Context	Agricultural land availability	Pastoral land	%	Percentage of land to total area. Agricultural land is a crucial factor of production.	(SPM and SEA 2015)
	Agricultural land tenure fragmentation	Agricultural parcels	Number (nr)	Indicates agricultural management history and can impact the access to land	(IGN-F 2021b Dec 18)
	Landscape consolidation	Consolidated land	Hectare (ha)	Indicates former efforts to consolidate **historically** fragmented land	(SMB 2020 Dec 18)
	Agricultural Past	Agricultural holdings in 1988	Nr.	Indicates the amount of existing private infrastructure, but also the associated agricultural history of a local community at farm level	(AGRESTE 2010)

	Collective infrastructure	Production facilities in 1985-1990	Nr.	Indicates the amount of existing **collective** infrastructure, but also the associated common values of a local community at municipal level	(Lynch and Harvois 2016)
CP0 Organise	Power	Mayors who are farmers 2015-2020	Nr.	Indicates power in decision making over agricultural land use	www.mon-maire.fr (last access : 18/12/2020)
	Interest	Farmers active in the municipal council 2015-2020	Nr.	Indicates interest to participate in local governance processes	www.mon-maire.fr (last access : 18/12/2020)
	Legitimacy	Pastoral land management organisation	Nr.	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$	The sum of subsidies that farms in a municipality receive.	(MAA 2016 2017)
	Agricultural work force	**Agricultural work force**	Hours/week	Factor of production at farm level	(AGRESTE 2010)

	Irrigation	Irrigation	Nr.	Percentage of total agricultural area. Factor of production at farm level	(Clavel 2013)
	Type of agriculture	**Farm size**	Hectare (ha)	Type of management conditions at municipal level	(AGRESTE 2010)
		Number of farms	Nr.		(AGRESTE 2010)
		Parcels/farm	Nr.		(IGN-F 2021b Dec 18)
	Transhumance	**Transhumance**	% of total agriculturl area		(SMB 2020 Dec 18)
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)
	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 Dec 18)
CP3 Appreciation	Purchase access	Sale points in the valley	Nr.	Indicates how product serves as value construction	pers. communication with each cooperative
Outcomes	Activity attachment	Museums related to agriculture (nr.)	Nr.	Indicates if society considers agriculture as valuable to municipal identity	(SPM 2020)
	Activity maintenance	**Farmers > 50 years**	%	Percentage farmers over 50 years old of total agricultural work force. Indicates the medium durability of the system.	(INSEE 2017b)
		Agricultural population	%	Indicates the short term durability, % of agricultural population on total working population	

	Place attachment	Natura 2000 sites maintained by agricultural activities	%	Percentage of total municipal area. Protected sites which that require regular agricultural activities	(INPN 2020)
	Socioeconomic livelihood	**Production potential value/farm**	**US$**	Describes a farm's potential for economic production based on its land and/or livestock Indicates the economic viability of farms.	(INSEE 2017b)
Demand	Tourist demand	**Tourist beds**	**Nr.**	Indicates potential tourist demand	(INSEE 2017a)
	Local demand	**Median income**	**US$**	Indicates local potential purchase power of households	(INSEE 2019)
		Tertiary education of population	%	Percentage of total population with 15 or more years of education. Hypothesised as potential willingness of higher-level professionals to buy the product	(INSEE 2015)

Table 1: Overview and sources of indicators of NCP co-production steps, 1= if not otherwise indicated variables are calculated at municipal level; 2=bold writing shows variables with significant relationships(s);

APPENDIX S5 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 13 variables for further analysis (Table 2).

Biophysical	**Contextual variables**	**CP0**	**CP1**	**CP2**	**CP3**	**Outcome**	**Demand**
Altitude	-	% farmers in collective organisations	Farm size	Distance to cooperative	-	Production potential value per farm	Tourist beds
-	-	-	Parcels/farm	Hectares of agricultural land / cooperative employee	-	% agricultural population > 50 yrs	Median income
-	-	-	Agricultural workforce	-			-
-	-	-	Transhumance	-	-	-	-
-	-	-	Financial subsidies	-	-	-	-

Table 2: List of indicators for correlation analysis

Among contextual variables, 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 societal 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.

Production potential value per farm, % agricultural workers and proportion of agricultural workers > 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.

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