Hautes-Alpes Department
Engineering and Services Division
Agricultural Water Systems Department

EVALUATION OF THE ECOLOGICAL EFFECTS OF HYDROMORPHOLOGICAL RESTORATION OF TWO RIVER SECTIONS, AND EVALUATION OF RELATED ECOSYSTEM SERVICES: CASE STUDY OF THE DRAC AND BUËCH RIVERS

QUALIFICATION, QUANTIFICATION (DRAC AND BUËCH) OF ECOSYSTEM SERVICES, AND MONETISATION (DRAC ONLY)

FINAL VERSION

MAY 2019

Hautes-Alpes Department
Engineering and Services Division
Agricultural Water Systems Department

Contract no.	**MA 17045**		
Version	**0**	**1**	**2**
Drafted by	***Name: Claire Bonnal*** ***Position: Economist*** ***Signature:*** ***Date*: 03/04/2019**		
Reviewed by	***Name:*** ***Position:*** ***Signature:*** ***Date*:**		

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Alpine Space HyMoCARES European research project focuses on the integration of ecosystem services (ES) in Alpine river restoration works. As part of this project, the Hautes-Alpes Department is seeking to qualify, quantify and measure the perception of the ES that rivers provide to humans, in particular among individuals and organisations responsible for managing the Drac and Buëch rivers.

The Hautes-Alpes Department has commissioned the Société du Canal de Provence to carry out this research as part of the European project.

The HyMoCARES project is co-financed by the European Union via the Interreg Alpine Space Programme. The project starts from the premise that river corridors (including the Drac and the Buëch) are one of the most used and modified landscape elements in the Alps. They provide key ES, but currently many of them are "at risk" or "significantly degraded".

In order to ensure their conservation or restoration, the effects of human uses on ES need to be understood and tackled.

This study therefore aims to better understand the ES that restored rivers, and the Drac and the Buëch in particular, provide.

The study is based on the following documents:

- the results of the previous parts of Work Package 3 (A.T3.1, A.T3.2 and A.T3.3)
- the work performed as part of HyMoCARES Work Package 1, "Ecosystem Services assessment framework", and the classification system for the 18 ES identified for Alpine river corridors
- the pre-existing ecological evaluation produced by previous missions
- the evaluation of the physical effects of restoration works provided by IRSTEA (WP3 A.T3.2)
- the HyMoCARES standard questionnaire circulated in the project's six partner countries (WP4 A.T4.2)
- the desire to include local stakeholders' perceptions (WP4 A.T4.3).

2 FOREWORD: WHAT IS AN ECOSYSTEM SERVICE?

According to the literature, ecosystem services (ES) can be classified in a number of ways. While there is no intention here to review these classifications in detail, it is important to touch on them briefly in order to determine the system used as part of the HyMoCARES project.

The first step is to arrive at a **precise definition of ecosystem services**. ES are services provided by ecosystems. The term refers to: *"human use of natural processes through products obtained from ecosystems, benefits obtained from regulation of ecological processes, and non-material benefits obtained from ecosystems (artistic activities, education, etc.). In other words, ecosystem services refer solely to the positive impacts of ecosystems on human well-being, through the provision of goods and services."* Source: *Etude exploratoire pour une évaluation des services rendus par les écosystèmes en France*, CREDOC, September 2009.

In most classification systems, ES are divided into three categories:

1. **provisioning services** (products obtained from ecosystems and consumed by humans)
2. **regulation and maintenance services** (environmental services with a positive impact on human well-being)
3. **cultural (social) services** (non-material benefits obtained by humans from ecosystems, including health, recreation, knowledge, aesthetic enjoyment, freedom and identity).

There are multiple definitions of ES, as well as a variety of different ES classification systems.

Figure 1 below shows the classification of ES according to the Millennium Ecosystem Assessment (MEA), which was called for by United Nations Secretary-General Kofi Annan. The classification, which dates from 2005, provides a global overview of interactions between economic, social and ecological issues.

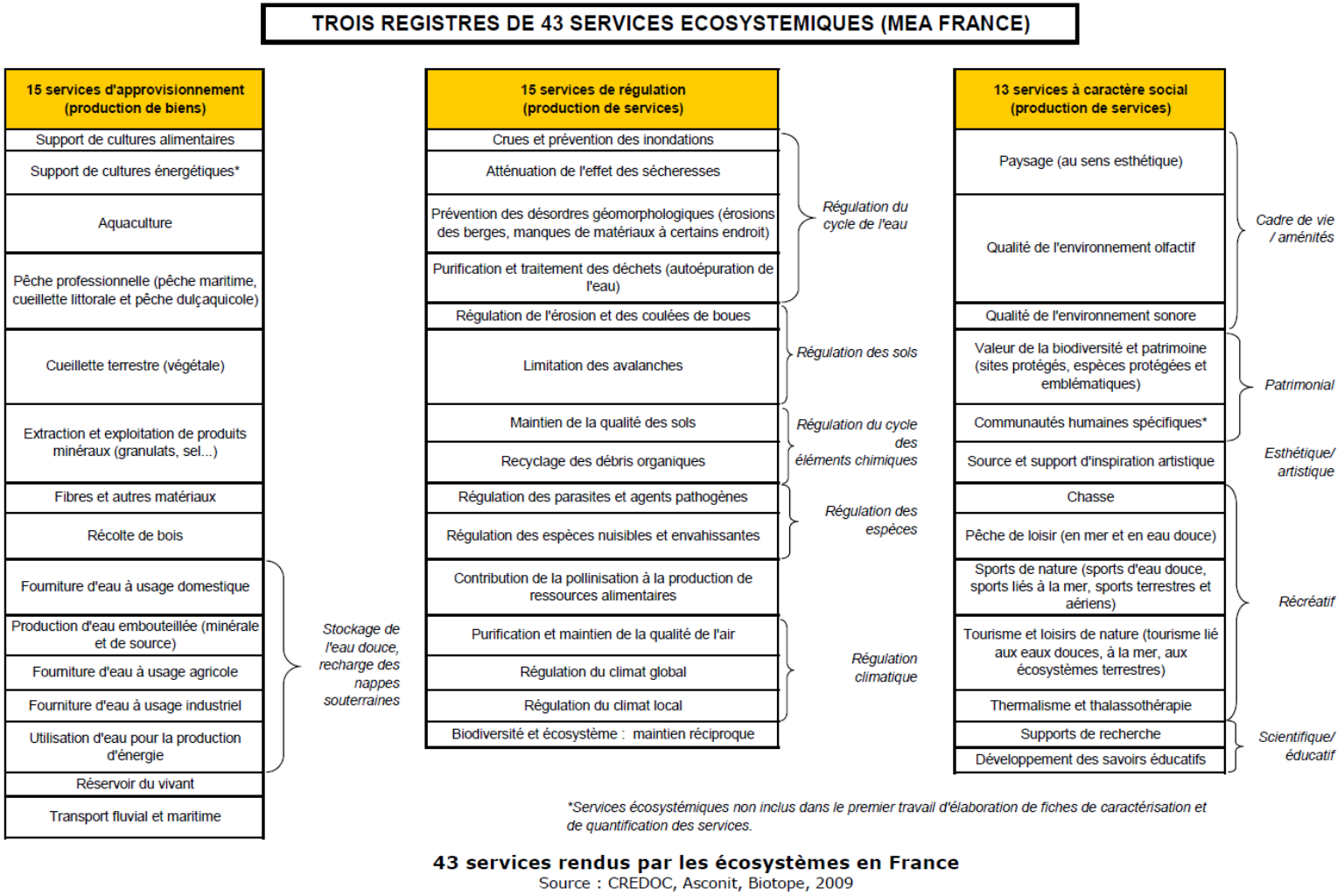


Figure 1: Global classification of ecosystem services by Millennium Ecosystem Assessment (United Nations)

The HyMoCARES project draws on the Common International Classification of Ecosystem Services (CICES), which is used as part of the River Ecosystem Service Index (RESI) project. The RESI quantifies the ES that rivers and floodplains provide to humans.

Table 1 below shows the 18 ES considered by the HyMoCARES project. The classification contains fewer ES than the RESI version because it has been adapted and adjusted to Alpine rivers and corridors.

Nevertheless, the RESI classification employed for the purposes of the HyMoCARES project has a similar four-level structure to the CICES:

- "provisioning" services in **purple**
- "regulation and maintenance" services in **green**
- "cultural" services in **blue**
- "usage of abiotic natural capital" services in **yellow**.

Main group	Subgroup	Ecosystem service
Provisioning	**Nutrition**	Cultivated crops
		Plant resources for agricultural use - Pasture
		Surface water for drinking purpose
		Ground water for drinking purpose
	Resources	Fibres and other resources from plants for direct use or for processing - Resources related to the riparian forests, wood
		Water for non-drinking purposes in industry and agriculture (surface water and ground water)
	Biomass-based energy resources	Plant-based resources from agriculture, short rotation coppice, forestry
Regulation & maintenance	**Retention (Self-purification)**	Retention of nutrients
	Global climate regulation	Reduction of greenhouse gas emission/carbon sequestration
	Extreme discharge mitigation	Flood risk mitigation (flooding and risk related to morphological dynamics of rivers)
		Drought risk mitigation
	Sediments (incl. suspended)	Soil formation in floodplains
	Micro and regional climate regulation	Regulating temperature/Cooling (water bodies and ground)
	Habitat-related services	Habitat-related services
Cultural	**Scenery**	Aesthetics of landscape
	Emotional and intellectual interactions	Natural and cultural heritage of the river and floodplain ecosystem
		Education, science
	Water-related activities	Water-related activities
Usage of abiotic natural capital		Hydropower
		Navigation
		Sediments for construction

Table 1: ES classification scheme of the HyMoCARES project; source: WPT1. Ecosystem Services (ES) assessment framework - D.T.1.1 Report on ES definition and systematics - EU HyMoCARES Project 30/06/2017

Methodological limitation:

Not all service categories are necessarily "adaptable and adapted" to the hydromorphological restoration of rivers. Consequently, some can only be qualified, not quantified, while others can only be quantified with certain caveats.

3 QUALIFICATION AND QUANTIFICATION OF ECOSYSTEM SERVICES

The ES qualification phase draws on the work performed under HyMoCARES Work Package 1 (WP1), "Ecosystem Services assessment framework", which resulted in a list of 18 ES provided by Alpine river corridors.

It also builds on the WP1 documents detailing the adaptation methodology for the CICES classification scheme, as well as on a second HyMoCARES deliverable that details linkages between river management works, ecological functions and impacts on relevant ES.

The purpose of this section is therefore to identify, qualify and quantify the 18 ES provided by the Drac and Buëch rivers, as identified beforehand by the HyMoCARES project. These ES may not necessarily be the same from one river to the next.

The overall aim of the study is to give a snapshot of water/ES uses and activities before and after the restoration works performed on the Drac and Buëch rivers, and to identify interactions – both positive and negative (conflicts, pressures, etc.) – between all uses.

In addition to qualitatively analysing the ES, the study also measures how stakeholders involved in managing the rivers in question (the Buëch and the Drac) perceive these ES.

Two participatory workshops were held (one on the Drac, the other on the Buëch) to gauge perceptions (deliverable of WP4 activity 4.3). The guidelines, methodology and photos of these workshops can be found in the annexes to this report.

The purpose of the workshops was to draw up an exhaustive overview of ES, as well as of water-related uses and activities. Participants were also asked to rank, in order of importance, those ES that, in their view, best represent the Drac or the Buëch.

The results of the workshops, along with direct quotes from participants, can be found in the relevant section of this report for each ES. Where possible, the most compelling answers from the HyMoCARES questionnaire (WP4 deliverable 4.2) are also highlighted.

Workshop results appear *in blue and in italics*, while questionnaire responses appear as insets.

3.1 ECOSYSTEM SERVICES: STUDY REACH

This ES study covers the two restored river sections as mentioned in the ecological evaluation (and elsewhere):

- The Drac upstream of Saint-Bonnet-en-Champsaur
- The Buëch downstream of the EDF dam of Saint-Sauveur.

The Drac restoration site measures 3.7 km long, directly upstream of Saint-Bonnet-en-Champsaur bridge. The general aim of the restoration project was to recreate a braided channel corridor. The complementary objective was to avoid the destabilisation of the right-side dyke protecting the artificial pond of Saint Bonnet, which is a major tourist attraction.

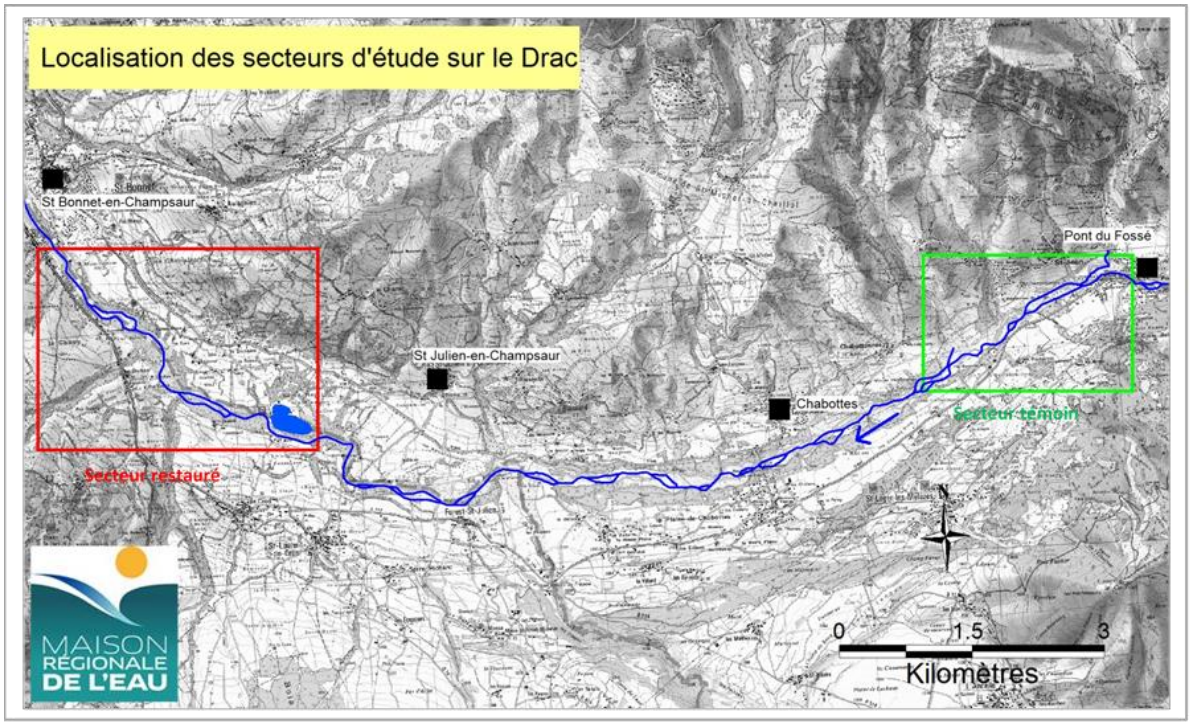


Figure 2: Location of the site where the protocol was applied on the Drac (source: MRE)

The Buëch restoration site is situated immediately downstream of Saint-Sauveur dam in the commune of Serres. The general objective of the restoration project was to improve the hydrogeomorphological conditions of the degraded reach by reinjecting 44,000 m3 of coarse sediment that had not passed downstream of the dam. A complementary objective was to reduce the flooding risk upstream of the dam by dredging the Serres floodplain.

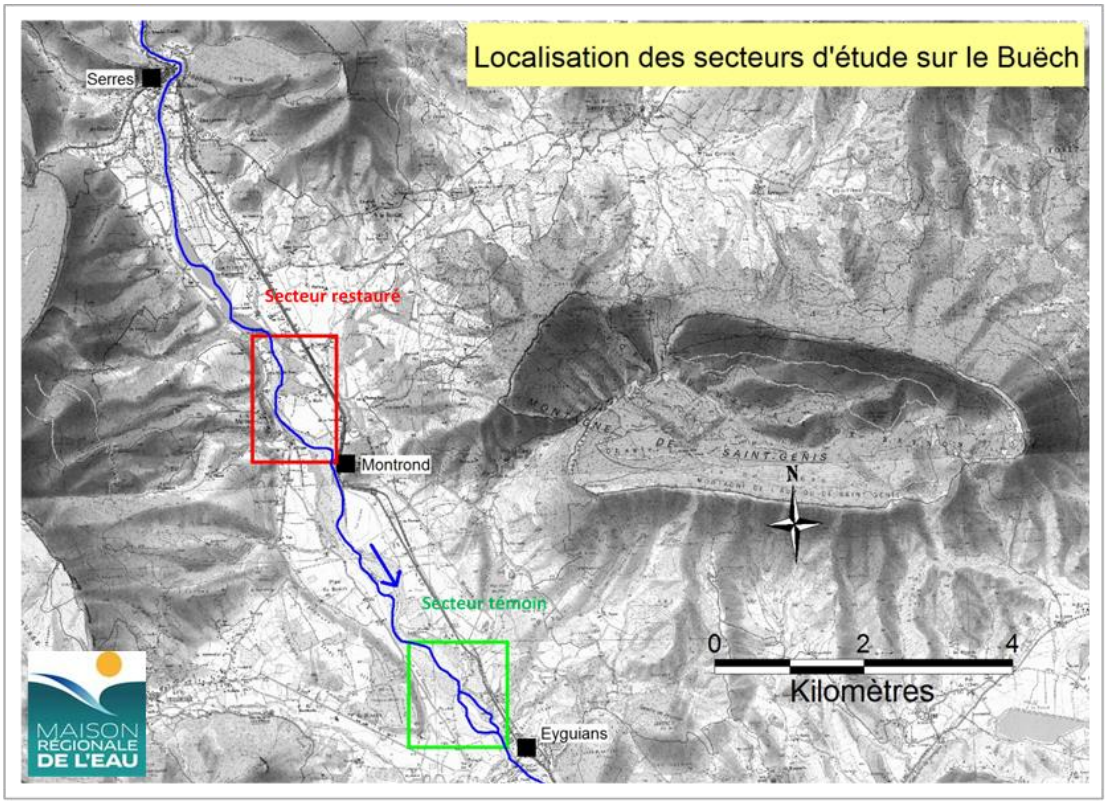


Figure 3: Location of the site where the protocol was applied on the Buëch – Source: MRE)

The study specifies the scale at which each ES was analysed:

- across an entire drainage basin, or
- within a particular community of communes or single commune, or
- at a specific measuring station on the restored section of the Drac or Buëch (the smallest scale of analysis).

At commune scale, the following communes were chosen for the Drac:

- Chauffayer
- Saint-Bonnet-en-Champsaur
- Saint-Julien-en-Champsaur
- Chabottes
- Saint-Jean-Saint-Nicolas.

And for the Buëch:

- Serres
- Méreuil
- Montrond
- Eyguians.

Methodology note:

Note on data: the communes of Eyguians, Lagrand and Saint-Genis have merged to form the commune of Garde-Colombe. For optimal GIS data division purposes, the former administrative division was retained (i.e. Eyguians only) rather than the new structure. The area covered by the new administrative division is too large when compared with the restoration site.

In the sections that follow, the ES are described and studied by main group and subgroup.

Precise definitions, data sources and analysis scales are given for each drainage basin and for each ES.

3.1.1 "PROVISIONING" SERVICES

"Provisioning" ES refer to products obtained from ecosystems and consumed by humans (such as food, water, fibre and wood).

These "provisioning" services are divided into three "subgroups":

- nutrition
- resource
- biomass-based energy resources.

3.1.1.1 NUTRITION

3.1.1.1.1 Cultivated crops

This ES is studied at the commune level.

Crops are foodstuffs produced by farmers for human consumption. The figures used here update those contained in the "crops" category of the 2010 *Recensement Général Agricole* (RGA), expressed in hectares, at 2010 levels, and by commune. The RGA is updated every 10 years, meaning the latest data sources from this database date back to 2010. In some cases, changes between 2000 and 2010 are also taken into account.

The relevant communes for the Drac and Buëch rivers are those mentioned in paragraph 3.1.

Superficie en hectare	Chauffayer		Saint-Bonnet-En-Champsaur		Saint-Julien-En-Champsaur		Chabottes		Saint-Jean-Saint-Nicolas	
	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010
Total SAU	**610**	**812**	**1 048**	**1 133**	**686**	**666**	**412**	**441**	**984**	**807**
- dont : Céréales et oléoprotéagineux (*)	69	93	115	86	91	61	83	64	71	50
- dont : Vignes	0	0	0	0	0	0	0	0	0	0
- dont : Arboriculture, y compris oléiculture	0	0	0	s	0	0	s	0	s	0
- dont : Légumes frais	0	0	0	0	0	0	0	0	0	0
- dont : PAPAM (**)	0	0	0	0	0	0	0	0	0	0
- dont : Horticulture	0	0	0	0	0	0	0	s	0	0
- dont : Prairies temporaires	45	361	452	397	261	291	0	31	0	0
- dont : Prairies artificielles	204	0	0	s	s	0	142	96	200	175
- dont : STH (***) productive	101	214	58	136	74	57	80	133	246	205
- dont : STH (***) peu-productive	174	132	341	426	255	232	107	109	455	375

(*) y compris Riz (**) Plantes à Parfum, Aromatiques et Médicinales (***) Surfaces Toujours en Herbe s : secret statistique

Table 2: Surface area (in hectares) per crop, per commune representing the Drac restoration site, in 2000 and 2010

According to the 2010 RGA, the total surface area (all crops combined) for the five Drac communes is 772 hectares on average. The data here covers 759 hectares, or 98% of that surface area.

The most common crops in the Drac territory are unproductive permanent grassland (34%), productive permanent grassland (20%), temporary grassland (20%), grain, oilseed and protein crops (9%), and artificial grassland (also 9%).

Overall, the figure remained largely unchanged between 2000 and 2010 (up 1%). The largest recorded decline (by surface area) over the period was for artificial grassland (down 50%), while temporary grassland was up 43%. Permanent grassland increased by 34%, and grain, oilseed and protein crops declined by 18%.

Superficie en hectare	Serres		Mereuil		Montrond		Eyguians	
	2000	2010	2000	2010	2000	2010	2000	2010
Total SAU	**318**	**341**	**342**	**411**	**73**	**47**	**420**	**368**
- dont : Céréales et oléoprotéagineu	66	50	63	44	s	s	52	s
- dont : Vignes	0	0	s	s	0	0	s	0
- dont : Arboriculture, y compris olé	17	12	s	s	s	s	s	s
- dont : Légumes frais	s	s	0	0	s	s	s	0
- dont : PAPAM (**)	0	0	0	0	0	0	0	0
- dont : Horticulture	s	0	0	0	0	0	0	0
- dont : Prairies temporaires	0	s	s	0	0	0	0	100
- dont : Prairies artificielles	47	63	30	79	s	s	118	s
- dont : STH (***) productive	59	80	49	51	s	0	33	20
- dont : STH (***) peu-productive	113	118	159	196	s	0	152	s

(*) y compris Riz (**) Plantes à Parfum, Aromatiques et Médicinales (***) Surfaces Toujours en Herbe s : secret statistique

Table 3: Surface area (in hectares) per crop, per commune representing the Buëch restoration site, in 2000 and 2010

In 2010, of the total farmland in the Buëch communes, 34% was unproductive permanent grassland, 23% was artificial grassland, 15% was grain, oilseed and protein crops, 12% was productive permanent grassland, and 11% was temporary grassland.

Overall, the figure declined by 8% between 2000 and 2010. The total area covered by tree crops (including olive trees) declined by 32%, while there was a 26% fall in unproductive permanent grassland by area. Other declines between 2000 and 2010 were in grain, oilseed and protein crops (down 22% by surface area) and productive permanent grassland (down 20%).

Only artificial grassland saw an increase, up 9% between 2000 and 2010.

In both the Drac and Buëch sites, permanent (productive or unproductive) grassland is the most common type of farmland by area. According to Agreste and the *Statistique agricole annuelle*, this type of land is used to grow perennial herbaceous forage plants.

Productive permanent grassland is either naturally occurring or seeded more than six years ago, while unproductive permanent grassland refers to paths, moorland and mountain pastures.

At the participatory workshops (especially the Drac workshop), the participants stressed that: "irrigated farming can affect the river if done intensively or inappropriately" (unfortunately irrigation received little or no coverage at the Buëch workshop, not least because the participants had little involvement with irrigation or prioritised/placed greater importance on other ES).

3.1.1.1.2 Plant resources for agricultural use - Pasture

This ES is studied at the commune level.

Plant resources for agricultural use and pasture are plants used as feed for animals reared for meat and dairy production. Unlike permanent grassland, temporary grassland is any grassland seeded within the past six years.

In the Drac drainage basin, utilised agricultural area (UAA) stands at approximately 20,000 ha, or 20% of the total basin by surface area. Livestock farming is the primary form of agriculture in the Drac drainage basin.

In the Buëch drainage basin, tree crops and mountain farming (combining livestock farming and fodder) dominate. There are 362 separate farms in the basin, totalling 32,418 ha UAA, or 89 ha UAA per farm on average (source: *Document d'objectifs Tome 1 - Diagnostic, enjeux et objectifs de conservation – 2010*).

The "temporary and artificial grassland" fields have been isolated from the "crop" fields in the 2010 RGA so as to retain only farmland used for animal feeding.

Superficie en hectare	Chauffayer		Saint-Bonnet-En-Champsaur		Saint-Julien-En-Champsaur		Chabottes		Saint-Jean-Saint-Nicolas	
	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010
Total SAU	**610**	**812**	**1 048**	**1 133**	**686**	**666**	**412**	**441**	**984**	**807**
- dont : Prairies temporaires	45	361	452	397	261	291	0	31	0	0
- dont : Prairies artificielles	204	0	0	s	s	0	142	96	200	175

Table 4: Surface area of grassland (temporary or artificial), per commune representing the Drac restoration site, in 2000 and 2010

By surface area, temporary and permanent grassland makes up a large share of crop rotation land in the Drac communes, totalling 284 ha (38%) of farmland in the area covered by the study. On average, permanent grassland declined by 50% between 2000 and 2010, while artificial grassland increased by 43% over the same period.

Superficie en hectare	Serres		Mereuil		Montrond		Eyguians	
	2000	2010	2000	2010	2000	2010	2000	2010
Total SAU	**318**	**341**	**342**	**411**	**73**	**47**	**420**	**368**
- dont : Prairies temporaires	0	s	s	0	0	0	0	100
- dont : Prairies artificielles	47	63	30	79	s	s	118	s

Table 5: Surface area of grassland (temporary or artificial), per commune representing the Buëch restoration site, in 2000 and 2010

In 2010, there were 104 ha of permanent and temporary grassland in the four communes around the Buëch restoration site (34% of total surface area). In 2000, there was no recorded temporary grassland in the area covered by the study. In contrast, there were 33 ha of reported temporary grassland in 2010. By surface area, permanent grassland increased by 9% over the 10-year period.

3.1.1.1.3 Surface water for drinking purpose

This ES is studied at the commune level.

The "surface water for drinking purpose" ES is qualified using two data sources:

1. the catalogue of technical data from the Agence de l'Eau Rhône Méditerranée Corse water charging processes (February 2015)
2. CEREMA data from the AlpES project.[1]

The data from the Agence de l'Eau Rhône Méditerranée Corse technical catalogue are data based on water charging and withdrawal calculation models, as defined by law.

The way these values are calculated can cause inherent bias in the data, meaning they are not an accurate representation of physical reality. Consequently, caution is required when using them in a different context, such as evaluating pressure on the natural environment from different activities.

The geographical area covered by the agency is based on a hydrographical division of France as a whole. As a result, the data that the agency manages covers certain regions or departments only partially.

The agency's data concerns surface water and ground water use and is supplied by commune and by water-withdrawing structure for the year 2016.

The data was therefore filtered for each commune in the area covered by the study, for water covered by two agency-specific categories: "continental surface water" and "drinking water supply".

- Applying these filters gives the volume of surface drinking water per commune, in cubic metres, for 2016.

The results are shown below:

- For the Drac: **2,060,800 m³** of water withdrawn between the Les Ricous gauging station on the Drac and the ASA du Canal de Gap (ground water accounted for the majority of identified volumes).
- For the Buëch: **no surface water withdrawal was identified in the Buëch communes** (here too, ground water accounted for the majority of water withdrawal).

The CEREMA data from the AlpES project was used for this ES. For the purpose of the project, the ES is defined as "Surface water for drinking with minor or no treatment". This refers to surface water for drinking for domestic consumption only (e.g. bathrooms and kitchens).

There are three indicators for this ES:

[1] http://www.alpes-webgis.eu/

- Supply: the supply of surface water for drinking for domestic consumption, expressed in m^3/hectare and /year. This ES is calculated across the entire Alpine space using the "INVEST water yield model"[2] tool, giving the average annual quantity of runoff and surface water.
- Flow: the consumption of drinking water (tap water) for any connection to the public drinking water supply network. This refers to the use of drinking water at a given supply point (expressed in m^3/hectare and /year).
- Demand: captured water resources to cater to public demand for drinking water (expressed in m^3/hectare and /year).

Here, a decision has been made to **focus on "ecosystem service production", where production corresponds to the quantity of an ES that an ecosystem can provide.**

The AlpES project data are available per-commune for each drainage basin. Consequently, surface water for drinking purpose figures are given per commune, expressed in m^3/hectare/year.

Surface water for drinking purpose (m^3/hectare and /year)	**Buëch**				**Drac**				
	Serres	**Méreuil**	**Montrond**	**Eyguians**	**Chauffayer**	**Saint-Bonnet-en-Champsaur**	**Saint-Julien-en-Champsaur**	**Chabottes**	**Saint-Jean-Saint-Nicolas**
Demand	84	10	16	32	44	70	38	94	33

Table 6: Demand for surface water for drinking purpose (in m^3/hectare and /year) for the communes in the areas covered by the study (Drac and Buëch) – Source: CEREMA

For the Buëch, demand is 35 m^3/hectare/year on average, with the highest figure recorded in the commune of Serres.

For the Drac, demand is 56 m^3/hectare/year on average, with the highest figure recorded in the commune of Chabottes (94 m^3/hectare/year).

There appears to be a strong, positive correlation between drinking water consumption figures and the resident population of each commune.

For the Buëch, drinking water is sourced from ground water (springs and alluvial ground water wells). Most withdrawals come from surface water, especially for irrigation and hydropower production (source: *Etude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*).

For the Drac, and looking at a more macro scale, **total withdrawals across the drainage basin for drinking water stand at between 5 and 6.7 million m^3 per year**, distributed evenly between the communes in the basin and the town of Gap. Monthly flows for drinking water withdrawals are between 100 and 270 l/s (source: *Etudes d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012*).

[2] http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/reservoirhydropowerproduction.html#interpreting-results%3C/font

The stakeholders at the Buëch workshop were clear that the "surface water for drinking purpose" ES was both important and representative.

3.1.1.1.4 Ground water for drinking purpose

This ES is studied at commune level, referring to those communes identified in each area covered by the study (see 3.1), where data was available.

Ground water figures come from the catalogue of technical data from the Agence de l'Eau Rhône Méditerranée Corse water charging processes (February 2015)[3] and from "eaufrance" water withdrawal data.[4] The figures are shown in the table below:

Eau SOUTERRAINE pour l'eau potable (en m³/an)	Buech	Drac				
	Serres	Chauffayer	Saint-Bonnet -en-Champsaur	Saint-Julien- en-Champsaur	Chabottes	Saint-Jean- Saint-Nicolas
	185 339 m3	42 910 m3	191 624 m3	60 087 m3	186 813 m3	232 795 m3

Table 7: Withdrawals of ground water for drinking purpose (in m³/year) for the communes in the areas covered by the study (Drac and Buëch)

Ground water withdrawals, expressed in m³, come from the water agency charging data. There are given for each commune in which the withdrawal point is situated.

For the Buëch, only the commune of Serres has one or more ground water withdrawal structures. **185,339 m³ of ground water was withdrawn in the commune of Serres in 2016, for drinking water purposes.**

For the Drac, the available ground water withdrawal figures seem to be exhaustive, with data for each commune covered by the study.

Details are given for each commune below:

- For Saint-Bonnet-en-Champsaur, ground water comes from the Barboutane, Les Infournas and Le Vivier catchments, and from the Le Fontenil spring.
- For Saint-Julien-en-Champsaur, ground water comes from another commune (no further details are given in the databases).
- For Chauffayer, ground water comes from the Belle Carre spring (Chauffayer and La Pierre Reservoir), the Le Peyssier spring (Les Blachus Reservoir), the Les Casses spring (Beaurepaire Reservoir) and the Les Sagnes spring (Les Bannettes and Mandaty Reservoirs).

For the Drac communes, total ground water withdrawals were **142,846 m³ in 2016.**

*The stakeholders at the Drac workshop were clear that the "ground water for drinking purpose" ES was both **extremely important and representative**.*

[3] http://sierm.eaurmc.fr/telechargements/telechargement/bibliotheque.php?categorie=prelevements
[4] http://www.bnpe.eaufrance.fr/acces-donnees/codeCommune/05145/annee/2016

3.1.1.2 RESOURCES

3.1.1.2.1 Fibres and other resources from plants for direct use or for processing - Resources related to the riparian forests, wood

This ES is studied at the commune level.

This ES concerns the use of wood and biomass from agriculture and forests as a resource for power production.

This ES is best characterised using data from two sources:

- CRIGE PACA *occupation du sol* (land cover) data for 2016 at level 3 (the most granular level) per commune
- "Fuelwood" data from CEREMA, as part of the AlpES project, expressed in m^3/year per commune.

Resources **potentially** related to riparian forests, wood – *Occupation du sol 2016*, in hectares	Buëch				Drac				
	Serres	Méreuil	Montrond	Eyguians	Chauffayer	Saint-Bonnet-en-Champsaur	Saint-Julien-en-Champsaur	Chabottes	Saint-Jean-Saint-Nicolas
Transitional woodland-shrub	30	65	11	57	5	79	51	16	213
Coniferous forest	345	135	77	208	32	46	66	14	951
Broad-leaved forest	379	163	22	143	67	117	112	48	400
Mixed forest	366	424	72	189	316	94	179	230	327
TOTAL	**1120**	**787**	**182**	**597**	**421**	**336**	**408**	**308**	**1891**

Table 8: Characterisation of forest resource land cover in 2016 for the Drac and Buëch communes covered by the study

On average, forest resource land cover stands at 672 ha for the Buëch (all tree species combined) and 673 ha for the Drac. The two figures are almost identical, although there are major differences between the two areas in question (the Drac area includes one more commune than the Buëch).

The figures for the Buëch area are as follows: 39% mixed forest, 28% coniferous forest, 26% broad-leaved forest, and 6% transitional woodland-shrub.

For the Drac, mixed forest also holds the single biggest share, at 34%. The remaining figures are: 33% coniferous forest, 22% broad-leaved forest, and 11% transitional woodland-shrub.

Consequently, mixed and broad-leaved forests are representative of the Buëch and Drac areas.

Fuelwood (in m^3/hectare and /year)	Buëch				Drac				
	Serres	Méreuil	Montrond	Eyguians	Chauffayer	Saint-Bonnet-en-Champsaur	Saint-Julien-en-Champsaur	Chabottes	Saint-Jean-Saint-Nicolas

Demand	12,597	1,730	781	3,454	6,688	21,696	5,457	8,239	10,571
Supply	6	7	7	6	6	5	5	4	4
Flow	0	0	0	0	0	0	0	0	0

Table 9: Demand, supply and flow of fuelwood (in m^3/hectare and /year) for the Drac and Buëch communes covered by the study (Source: CEREMA)

In its work on the AlpES project, CEREMA divided data on resources related to riparian forests and wood into three indicators:

- **demand** for fuelwood (need for fuelwood)
- **supply** of fuelwood (equivalent to the increase in forest biomass)
- **flow** of fuelwood (how much wood is extracted).

According to the AlpES project, there is a close relationship between demand for fuelwood and the growth of forests (which is dependent on climate and altitude).

For the purpose of this study, the most comprehensive indicator has been chosen (see table below), namely demand for fuelwood, expressed in m^3/hectare and /year.

On average, demand for fuelwood for the Buëch stands at 4,641 m^3/hectare/year, with demand at its highest in the commune of Serres (not least because this commune has the largest population).

For the Drac, average demand for fuelwood across the five communes is 10,530 m^3/hectare/year. There is a positive correlation between demand for fuelwood and each commune's population.

3.1.1.2.2 Water for non-drinking purposes in industry and agriculture (surface water and ground water)

This ES relates to non-drinking water for use in industry and agriculture (surface and ground water). According to the HyMoCARES project, this water is used for either industrial cooling or irrigation in agriculture.

This ES is qualified from the following data sources:

- the study entitled *Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012*
- the study entitled *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*
- figures from the catalogue of technical data from the Agence de l'Eau Rhône Méditerranée Corse water charging processes (February 2015).

For both the Drac and the Buëch, much more of this water is used in agriculture than in industry, which barely exists, if at all, in the areas studied here.

3.1.1.2.2.1 Water for non-drinking purposes in industry

This ES is studied at the drainage basin level.

For both the Drac and the Buëch, the water agency charging data do not identify use for "industrial cooling".

a) <u>For the Drac:</u>

According to the study entitled *Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012*, water use in industry is limited within the drainage basin.

The same study, however, does identify withdrawals for artificial snow production and power generation. These withdrawals (relating to hydropower) can be included in this category. This section only covers withdrawals for artificial snow production. Withdrawals for hydropower generation are covered in 3.1.4 "Usage of abiotic natural capital services".

On the subject of artificial snow production, there are six ski resorts in the Drac drainage basin with snow cannons for making artificial snow:

- Superdévoluy
- Ancelle
- Orcières
- Saint-Léger-les-Mélèzes
- Laye
- Chaillol.

Water withdrawals for artificial snow production fall into two categories:

- withdrawals outside the winter season, stored in reservoirs
- real-time withdrawals to cater to demand during the winter season.

As the table below shows, **the six ski resorts do not withdraw water directly from the Drac or one of its tributaries**.

Station	Réserves	Période de remplissage	Lieu prélèvement	Débit	Débit réservé
Superdevoluy / La Joue du Loup	200 000 m^3	15/04 – 30/06 01/09 - 15/12	Vallon de Pelourenq + réseau AEP Agnières	10 l/s 45 m^3/h	
Ancelle	70 000 m^3	Automne	Source de la Rouane	50 l/s	
Chaillol	24 000 m^3	Automne	Torrent du Buissard Torrent du Renc	100 l/s 30 l/s	5 l/s 2 l/s
Saint Léger les Mélèzes	14 000 m^3	Automne	Trop plein captage Laye + drains autour réserve		
Laye	Captage en temps réel en torrents	30/11 au 21/01	Captage des Chanarettes	66 m^3/h	1 l/s
		30/11 au 28/02	Captage de Combe Robert	40 m^3/h	0,5 l/s
Orcières			Lac des Estaris	70 l/s	

Table 10: Characteristics of artificial snow production equipment (source: Etudes d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012)

b) <u>For the Buëch:</u>

According to the study entitled *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*, most water withdrawals for industrial use concern hydropower generation (especially the Saint-Sauveur dam).

Minimum flow rates downstream of the Saint-Sauveur dam are as follows:

- 900 l/s-1: 1 July to September
- 1,500 l/s-1: 16 to 30 June and 1 to 15 October
- 2,000 l/s-1: 16 October to 15 March
- 2,500 l/s-1: 16 March to 15 June.

There are, however, some gravel pits in the drainage basin, which withdraw water from drinking water supply networks or rivers for gravel washing. **There are no withdrawals for artificial snow production from the Buëch.**

3.1.1.2.2.2 Water for non-drinking purposes in agriculture

This ES **also relates to non-drinking water for use in agriculture. This ES is studied at the drainage basin level.**

<u>For the Drac:</u>

Within the Drac drainage basin, there are two main types of irrigation body: authorised syndicated associations (ASAs) and free syndicated associations (ASLs). In 2012, there were 39 ASAs or ASLs operating in the basin.

According to the study entitled *Etudes d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012*: "there are also some individual irrigators, mostly located outside areas of irrigated farmland. They source their water from springs, by diverting water from a river or mountain stream, or by installing pumps in the river."

Two types of irrigation are practised in the Upper Drac drainage basin:

- Gravity-fed irrigation, which is the most water-intensive but the least energy-intensive method. In 2000, this system accounted for 43% of irrigated farmland.
- Spray irrigation (using reels or sprinklers), which accounted for the remaining 57% of irrigated farmland in 2000.

Drip irrigation is not practised in the drainage basin.

Usage		Volume annuel (m^3)	Pourcentage / total	Débit moyen (m^3/s)
Alimentation en eau potable	Drac amont	3 110 000	0,8 %	0,099
	Gap	3 000 000	0,8 %	0,095
	Sous-total AEP (1)	6 110 000	1,7 %	0,2
Irrigation	Drac amont	25 700 000	7 %	0,81
	ASA du canal de Gap	19 000 000	5,2 %	0,6
	Sous-total irrigation (2)	44 700 000	12,2 %	1,41
Hydroélectricité	Drac amont	308 000 000	83,8 %	9,76
	Pont Sarrazin	8 000 000	2,2 %	0,25
	Sous-total hydroélectricité (3)	316 000 000	86 %	10,02
Neige de culture	(4)	520 000	0,1 %	0,016
Autres usages industriels	(5)	90 000	0,02 %	0,003
Total	(1) + (2) + (3) + (4) + (5)	367 400 000	100 %	11,6

Table 11: Average annual withdrawals per use in the Drac drainage basin, 2012

In 2012, 25,700,000 m^3 of water was used for agricultural irrigation in the Upper Drac basin.

For the Buëch:

As with the Drac, gravity-fed and spray irrigation are practised in two ways:

- collective withdrawals: farmers forming grouped structures (ASAs or ASLs)
- individual withdrawals: often sourced from pumps or wells, sometimes operating multiple withdrawal points under a single permit.

According to the study entitled *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*: "For the downstream Buëch, water is drawn from three withdrawal points on the canal leading from the river at the Saint-Sauveur dam. Water from these points feeds pressurised spraying networks operated by three ASA groupings: the Union des ASA du carrefour Céans Buëch, the ASA de Lazer, and the ASA de Laragne Montéglin et Châteauneuf-de-Chabre."

There are 35 syndicated irrigation associations operating in the Buëch drainage basin (source: SCP study and BD Hydra database):

- 13 practising pressurised irrigation
- 20 practising gravity-fed irrigation
- 2 practising mixed irrigation.

These associations either store water in small reservoirs or ponds on the hills at the head of the basin, or draw it directly from the river or the accompanying water table.

The map below shows 85 individual withdrawal points. There are very few in the identified communes around the restored site.

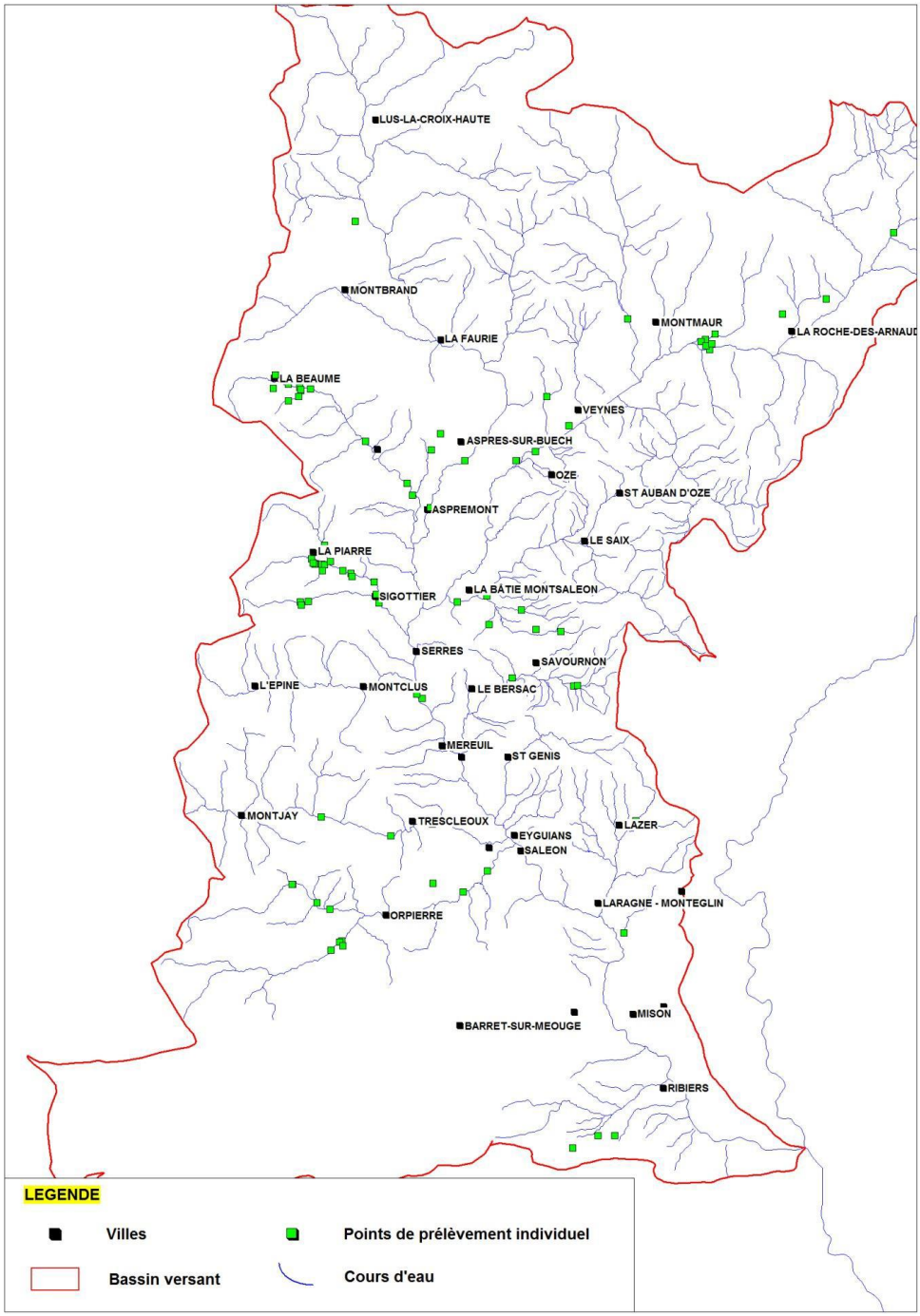


Figure 4: Individual withdrawal points in the Buëch drainage basin (source: Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011)

For both drainage basins:

The table below gives more detailed figures (in thousands of cubic metres) of the volume of ground water and surface water withdrawn per commune, per area studied (Drac and Buëch), for agricultural irrigation (gravity-fed and non-gravity fed), in 2016.

The figures, in mass of water per commune, come from the Agence de l'Eau Rhône Méditerranée Corse.

DRAC	Ground water	Surface water
CHABOTTES		
Drac, from the Drac de Champoléon to upstream of Saint-Bonnet-en-Champsaur		**1,213**
Non-gravity-fed irrigation		1,213
SAINT-JEAN-SAINT-NICOLAS		
Upper Drac alluvial beds and Séveraisse	**5**	
Non-gravity-fed irrigation	5	
Romanche and Drac drainage basin folding zone	**10**	
Non-gravity-fed irrigation	10	
Drac, from the Drac de Champoléon to upstream of Saint-Bonnet-en-Champsaur		**9,340**
Gravity-fed irrigation		6,270
Non-gravity-fed irrigation		3,070
SAINT-JULIEN-EN-CHAMPSAUR		
Romanche and Drac drainage basin folding zone	**48**	
Non-gravity-fed irrigation	48	
BUËCH	**Ground water**	**Surface water**
SERRES		
Upstream Buëch		**1,022**
Non-gravity-fed irrigation		1,022
Downstream Buëch		**36**
Non-gravity-fed irrigation		36
GARDE-COLOMBE		
Downstream Buëch		**2,579**
Non-gravity-fed irrigation		2,579

Annual volume drawn per use per withdrawal point, expressed in thousands of cubic metres

Table 12: Annual volume drawn (in thousands of m³) for agriculture by commune, by mass of water, in 2016 (source: Agence de l'Eau Rhône Méditerranée Corse)

The tale above provides more accurate information about total mass for each commune. For the Drac, most water is drawn from the Les Ricous gauging station. Les Ricous, which feeds into the Canal de Gap, is located on the Drac immediately downstream of the confluence of the Drac Blanc and the Drac Noir. The point is situated in the commune of Saint-Jean Saint-Nicolas. Total annual withdrawals stand at around 9 million m³.

For the Buëch, water for agricultural use is drawn solely for non-gravity-fed irrigation. Some 71% of withdrawals come from the downstream Buëch. However, the figures in the table may be inherently biased because the commune of Garde-Colombe was formed through the merger of three former communes including Eyguians, which is included in the restoration site for the purpose of this study. It is therefore difficult to identify exactly where the withdrawals took place to any greater degree of accuracy.

3.1.1.3 BIOMASS-BASED ENERGY RESOURCES

This subgroup of the "provisioning" category contains just one ES. It refers to the potential use of plant-based resources from agriculture and forestry for energy production.

3.1.1.3.1 Plant-based resources from agriculture, short rotation coppice, forestry

This ES is studied at the commune level.

For effective qualification and quantification of this ES, and **plant-based resources from agriculture** in particular, the "diversification" category of the RGA was used (which is defined as "Agricultural or other contract work, forestry, timber processing, accommodation, catering, leisure activities, handicrafts, renewable energy production").

For each of the identified communes in the restoration site, the tables below show farms that could potentially be involved in forestry work and that could produce renewable energy (such as short rotation coppice).

Number of farms involved in "Diversification"	2000	2010
Chauffayer	s	0
Saint-Bonnet-en-Champsaur	9	s
Saint-Julien-en-Champsaur	4	3
Chabottes	3	5
Saint-Jean-Saint-Nicolas	4	s

Table 13: Number of farms in the Drac communes potentially involved in "diversification" (as per the RGA definition)

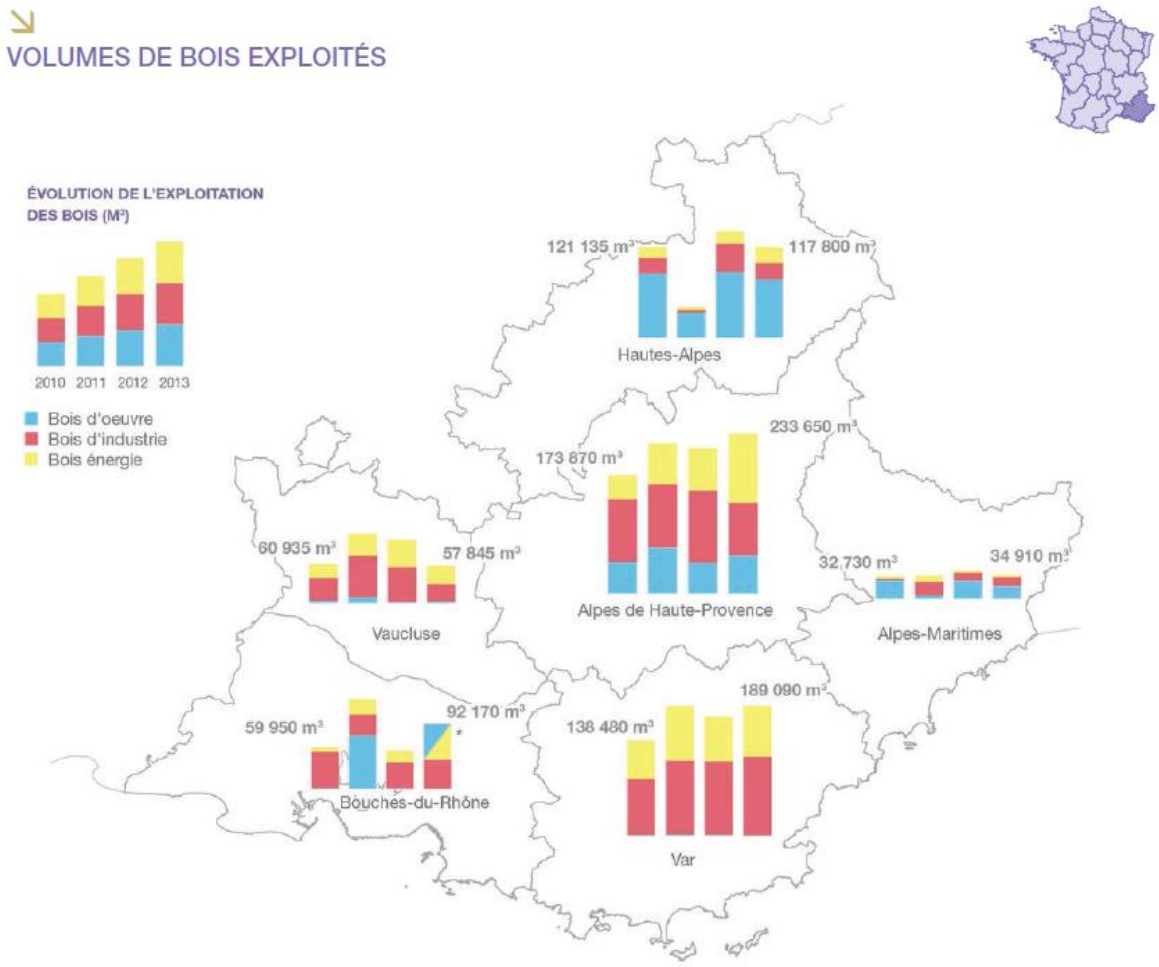
Number of farms involved in "Diversification"	2000	2010
Serres	s	0
Méreuil	3	0
Montrond	s	0
Eyguians	3	0

Table 14: Number of farms in the Buëch communes potentially involved in "diversification" (as per the RGA definition)

There is a downward trend in the number of farms involved in diversification in both the Drac and Buëch communes, although this ES cannot be analysed in detail because some of the information is classified as secret ("*s*").

Forest charter data is used to better qualify and quantify this ES, and plant-based resources from forestry in particular.

On a macro level, and according to the Observatoire de la Forêt Méditerranéenne (*Données & chiffres-clés 2014*), 117,800 m³ of forest was exploited in 2013, largely for lumber.



On a more micro level, **the vast majority of the Buëch communes are situated in the Baronnies Provençales Regional Nature Park**. Data from the Baronnies Provençales Forest Charter (February 2012) is used here.

Major tree populations in Baronnies Provençales are as follows:

- downy oak coppices and protective coppices (43%) on south-facing slopes and/or on poor-quality, thin soils
- Scots pine woodland (19%), growing abundantly throughout the area, especially in the high Eygues basin
- other coniferous woodland (5%), mostly Aleppo pine, mainly around Buis-les-Baronnies and Nyons, in the most Mediterranean part of the area
- beech coppices (5%) on high-altitude, north-facing slopes, especially in and around Séderon and on all north-facing slopes of the Buëch tributaries
- Austrian pine woodland (5%) dispersed throughout the area
- moorland and wooded moorland (22%) throughout the area, on most slopes and particularly to the east along a line between Montagne d'Angèle and Col de Fontaube.

Logs are the traditional fuelwood resource in the Buëch drainage basin. There are several large-scale producers in the area, many of which have diversified into trading pellets and making woodchips, using specialist equipment (storage platform, loader, blower truck, etc.).

For the Drac, data from the document entitled *Evaluation de la Charte forestière de territoire du Champsaur Valgaudemar – Rapport d'étape* (November 2013) will be examined here to characterise energy resources from forestry by month.

Objective no.2 of the charter is to improve operating conditions in challenging areas within the territory of Champsaur Valgaudemar. The table below shows that, in 2013, an additional 21,616 m³ of wood could have been exploited had operating conditions been less challenging. In Saint-Jean-Saint-Nicolas, the resurfacing of the Autane forest road has made it easier to transport and market wood.

	Linéaire de piste ou route créé (km)	*Volume Mobilisable (m³)*	*Surface impactée (ha)*	*Montant global du projet*
Terminée	8,84	21616	464	200 051,00 €
En cours	1,555	0	0	20 900,00 €
En projet	3,135	1000	15	16 500,00 €
Abandonnée	2,5	367	10	59 000,00 €
Total général	16,03	22983	489	296 451,00 €

Table 15: Summary of data on improvements to operating conditions in challenging areas (source: CC Champsaur).

The table below gives the total forest area for each commune covered by the Pan European Forest Certification (PEFC, now Programme for the Endorsement of Forest Certification) scheme – an ecolabel and forest management certification mark that aims to contribute to sustainable forest management.

Commune	Surface de Forêt totale	Part forêt communales PEFC	Part de forêt privée certifié	Part forêt domaniale certifiée	Surface totale certifées	Part totale de forêt certifiée
ANCELLE	1390 ha	0%	0%	100%	184 ha	13%
ASPRES-LES-CORPS	830 ha	0%	0%	100%	147 ha	18%
BUISSARD	70 ha		0%			0%
CHABOTTES	330 ha	0%	0%			0%
CHAMPOLEON	1570 ha	100%	0%	100%	1501 ha	96%
CHAUFFAYER	360 ha	0%	0%		5 ha	1%
LES COSTES	260 ha	0%	0%	100%	4 ha	1%
LA FARE-EN-CHAMPSAUR	400 ha	0%	0%	100%	206 ha	52%
FOREST-SAINT-JULIEN	110 ha	0%	0%			0%
LE GLAIZIL	1080 ha	0%	0%			0%
LA CHAPELLE-EN-VALGAUDEMAR	960 ha	0%	0%	100%	116 ha	12%
LAYE	460 ha		0%	100%	317 ha	69%
LA MOTTE-EN-CHAMPSAUR	1710 ha	100%	0%	100%	1437 ha	84%
LE NOYER	1030 ha	0%	0%	100%	102 ha	10%
ORCIERES	1940 ha	0%	0%	100%	440 ha	23%
POLIGNY	670 ha	0%	0%	100%	1 ha	0%
SAINT BONNET-EN-CHAMPSAUR 1	1050 ha	84%	0%	100%	358 ha	34%
SAINT-EUSEBE-EN-CHAMPSAUR	340 ha		0%			0%
SAINT-FIRMIN	1120 ha	0%	0%	100%	267 ha	24%
SAINT-JACQUES-EN-VALGAUDEMAR	1000 ha	0%	0%			0%
SAINT-JEAN-SAINT-NICOLAS	1640 ha	100%	4,53%	100%	640 ha	39%
SAINT-JULIEN-EN-CHAMPSAUR	290 ha	0%	0%	100%	1 ha	0%
SAINT-LAURENT-DU-CROS	220 ha		0%			0%
SAINT-LEGER-LES-MELEZES	320 ha	100%	0%	100%	235 ha	74%
SAINT-MAURICE-EN-VALGAUDEMAR	1320 ha	0%	0%			0%
SAINT-MICHEL-DE-CHAILLOL	740 ha	0%	0%	100%	346 ha	47%
VILLAR-LOUBIERE	530 ha	0%	0%	100%	69 ha	13%
TOTAL	21740 ha	30%	0,37%	100%	6375 ha	29%

Table 16: PEFC surface area by owner type and by commune (data source: OFME)

Focus on HyMoCARES questionnaire:

The questionnaire asked the following question: *"In your view, which ecosystem services are affected by hydromorphological changes such as the construction of weirs or dams, flow rate regulation, bank reinforcement, sediment extraction, etc.?"* More than half of the 57 respondents said that such changes had a moderate to high impact on provisioning ES (30% and 21% respectively). For the seven ES included in the "provisioning" category, 11% said they did not know which ones were affected by hydromorphological changes, and a further 20% expressed no opinion at all.

3.1.2 "REGULATION AND MAINTENANCE" SERVICES

The following "regulation and maintenance" service subgroups are studied in this section:

- retention (self-purification)
- global climate regulation

- extreme discharge mitigation
- sediments (incl. suspended)
- micro and regional climate regulation
- habitat-related services.

These ES are mainly characterised using data from the following study: *Evaluation des effets écologiques de la restauration hydromorphologique de deux tronçons de cours d'eau et évaluation des services écosystémiques associées - cas d'étude du Drac et du Buëch – Maison Régionale de l'Eau* (referred to hereafter as "MRE" for data source purposes).

These ES are studied at different levels, but the measuring station scale is used in the majority of cases. Otherwise, the level is specified on a case by case basis.

3.1.2.1.1 Retention (Self-purification)

This ES relates mainly to the ability of rivers to self-purify and retain organic or chemical compounds (carbon, nitrogen, phosphorous), or to the microbial degradation of organic pollutants.

Studies conducted on the two rivers show that, overall, the water in both is of generally very good physical-chemical quality. Among other things, this property is an indicator of self-purification capability.

Classes d'état	très bon	bon	passable	médiocre	mauvaise
Bilan de l'oxygène					
O_2 dissous ($mg.l^{-1}$)	8	6	4	3	
DBO5 ($mg.l^{-1}$ O_2)	3	6	10	25	
Température					
Eaux salmonicoles	20	21.5	25	28	
Eaux cyprinicoles	24	25,5	27	28	
Nutriments					
PO_4^{3-} ($mg.l^{-1}$)	0,1	0,5	1	2	
NH_4^+ ($mg.l^{-1}$)	0,1	0,5	2	5	

Table 17: Status categories for physical-chemical parameters (source: MRE)

Results for the Drac

Prior to the restoration (2014), winter surveys found that the water contained high concentrations of ammonium, attributed to poorly treated water discharged into the river from the ski resorts upstream.
According to monitoring data from the Agence de l'Eau and water quality measurements taken by the Department at Chauffayer, there was a pollution peak in February 2015 but, otherwise, water quality improved overall downstream of the restoration site once the work was complete. This improvement is linked to the fact that sanitation systems in the Upper Drac worked better during the period in question.

These observations suggest, therefore, that water quality improvements can be attributed not so much to the effects of the restoration work, but rather to better-functioning sanitation systems in the Upper Drac between 2013 and 2015.

No major differences in other parameters (oxygen and phosphate concentrations) were found before and after the restoration work.

At the Drac workshop, participants focused on purification and water quality aspects. The following benefits of the restoration were raised during the session:

- *"water quality and standard of living" and*
- *"drinking water".*

Results for the Buëch

Ammonium and phosphate measures in 2017 showed that the environment is of very good quality. Concentrations were not at levels indicating pollution from wastewater discharge.

All 2017 measurements found a well-oxygenated environment, both upstream and downstream of the Saint-Sauveur dam.

An analysis of all data acquired at these two points throughout 2017 (after the restoration) reveals no disruption. Data for all water quality descriptors (COD5, suspended solids, nitrogen and phosphorous compounds, etc.) indicate that the environment is of good or very good quality.

Physical-chemical quality was identical before and after the restoration work ("very good"), meaning the restoration had no impact on this parameter.

SUMMARY: For the Drac, physical-chemical data plus monitoring measurements by the Agence de l'Eau at Chauffayer indicate that the water is of very good quality, suggesting that the environment had high self-purification capability both before and after the restoration. In addition, suspended solid concentrations are routinely higher downstream than upstream of the restored site (influence of deepened sections not filled in during the work).

Restoration of the Buëch downstream of the Saint-Sauveur dam has had no impact on water quality.

While sampling results suggest that the restoration work has had no discernible effect on the physical-chemical quality of the water in both rivers, it is possible to conclude that better overall functioning of the rivers post-restoration has resulted in improved filtration capacity, with the appearance of an alluvial bed with underflow and the presence of several branches when compared with the former clay-sediment bed.

3.1.2.1.2 Global climate regulation

This ES is characterised by the presence of organic-matter-rich soils in the area studied, as well as by the presence of peatbogs, plus plant growth indicators. These measurements/indicators point, among other things, to a reduction in greenhouse gas emissions, and carbon sequestration by different soil and resource types.

This ES is studied at the commune level.

The table below, which shows land cover data, details plant-covered soils by category (mostly natural plant-covered areas).

Resources **potentially** related to global climate regulation – *Occupation du sol 2016*, in hectares	Buëch				Drac				
	Serres	Méreuil	Montrond	Eyguians	Chauffayer	Saint-Bonnet-en-Champsaur	Saint-Julien-en-Champsaur	Chabottes	Saint-Jean-Saint-Nicolas
Transitional woodland-shrub	30	65	11	57	5	79	51	16	213
Coniferous forest	345	135	77	208	32	46	66	14	951
Broad-leaved forest	379	163	22	143	67	117	112	48	400
Mixed forest	366	424	72	189	316	94	179	230	327
Tree crops other than olive groves	32	3	0	22	0	0	0	3	12
Moors and heathland	231	93	26	67	17	122	53	21	432
Pastures	11	7	16	21	2	29	44	8	370
Natural grassland	65	99	49	114	432	520	395	322	372
Peatbogs	0	0	0	0	5	69	1		5
Sparsely vegetated areas	17	2	6	11	0	33	0	0	318
TOTAL	**1475**	**991**	**279**	**833**	**877**	**1108**	**901**	**662**	**3400**

Table 18: Characterisation of organic-matter-rich soil cover (potentially related to global climate regulation) in 2016 for the Drac and Buëch communes covered by the study

The following ecosystems are notably present in the area covered by the study: organic-matter-rich soils and peatbogs, which help to reduce greenhouse gas emissions and support carbon sequestration.

For both the Drac **AND** the Buëch, organic-matter-rich soils account for 80% of all soils.

Only the commune of Saint-Bonnet-en-Champsaur has a large area of peatbogs (69 ha). The other communes have much smaller areas of peatbogs (5 ha in Chauffayer and Saint-Jean-Saint-Nicolas, 1 ha in Saint-Julien-en-Champsaur). There are no peatbogs in any of the Buëch communes.

Peatbogs **have a functional ecological value**. They help to purify the air and water, **capture carbon, and regulate local climate conditions** (via evapotranspiration, which reduces periods of drought and warming). They are connected to neighbouring ecosystems through trophic chains, as well as through animal migration and hydrology.

3.1.2.1.3 Extreme discharge mitigation

Extreme discharge mitigation is manifested through the presence, with a given area, of floodplains (created under the European Floods Directive), artificial ponds and reservoirs.

This ES is studied at the drainage basin level.

The study also looks at flood risk mitigation (flooding and risk related to morphological dynamics of rivers).

For the Drac, the IRSTEA document *Technical note about the monitoring of hydromorphological restoration of the Upper Drac River (Hautes-Alpes, France)* outlines the protocol used to evaluate the physical and ecological effects of the restoration, as well as flood risk and discharge mitigation.

The reach covered by the IRSTEA study extends from Champsaur lake to the commune of Saint-Bonnet-en-Champsaur, 3.7 km away. The channel morphology is an artificial wide and shallow channel created by the restoration project. The restoration work was expected to transform the channel into a braided channel.

The dominant substrate is composed of gravel-sided sediments of between 40 and 80 mm in diameter.

Well-preserved patches of alluvial forest are marginally observed along the channel. Most of the floodplain is occupied by cultivated lands.

The Drac water regime is characterised by major snowmelt peak during May and June. The mean daily discharge is 5.46 m^3/s, and the 2 and 10-year daily flood discharges are 41 and 61 m^3/s respectively.

At the Drac workshop, participants talked about the highly positive impact of the restoration on the "extreme discharge mitigation" ES: "flood protection" was mentioned directly on several occasions and the service emerged as the most important and representative among the participants (see Drac workshop annex).

For the Buëch, the IRSTEA document *Technical note about the monitoring of hydromorphological restoration of the Buëch River (Hautes-Alpes, France)* outlines the protocol used to evaluate the physical and ecological effects of the restoration, as well as flood risk and discharge mitigation.

Although the reach is included in a ~1 km wide alluvial floodplain, the lateral confinement related to roads or bedrock outcrops is important.

Well-preserved patches of alluvial forest are observed in the right-side of the channel immediately downstream from the Saint-Sauveur dam and in the left-side downstream of the confluence with the Torrent de Channe.

Most of the floodplain is occupied by cultivated lands.

The hydrological regime of the reach is impacted by the Saint-Sauveur dam, which diverts more than 75% of the natural flow. The flow downstream from the dam does not exceed 2.5 m^3/s. The water regime is characterised by a peak during spring, and a second peak during autumn. The

mean daily discharge is around 14.10 m^3/s, and the 2, 10 and 50-year daily flood discharges are estimated at 140, 250 and 350 m^3/s respectively.

To recap, minimum flow rates downstream of the Saint-Sauveur dam are as follows:

- 900 l/s-1: 1 July to September
- 1,500 l/s-1: 16 to 30 June and 1 to 15 October
- 2,000 l/s-1: 16 October to 15 March
- 2,500 l/s-1: 16 March to 15 June.

At the Buëch workshop, the "extreme discharge mitigation" ES was viewed positively. Some participants were uncertain about the positive impact in terms of "flooding", but others were more convinced that the restoration had provided "Better protection against flooding" and "Less flooding".

3.1.2.1.4 Sediments (incl. suspended)

This ES corresponds to two parameters:

- sediment recharge of the bed and control of meander and channel erosion
- soil formation in floodplains.

On the first point, the following elements are worth highlighting:

- **For the Drac:**

➢ The Drac was impacted by intensive gravel mining between 1960 and 2008. Massive extraction at the Les Ricous gauging station significantly modified solid-matter transport and damming of the Chabottes plain.

➢ The restoration of the degraded reach upstream of Saint-Bonnet-en-Champsaur (2013-2014) involved widening the active strip of the channel by injecting more than 450,000 m^3 of coarse sediment, mainly from the adjacent alluvial terraces. The widening operation involved a 100-metre-wide rectangular cross-section, associated with a general rise of the bed level, plus the construction of a 1.65-metre weir with a fish and canoe/kayak pass. The immediate surroundings of the river were also redeveloped.

➢ Post-restoration changes in channel morphology revealed a positive impact, with the creation of a braided bed that is still present and active in 2018. The channel is still adjusting, with the accretion of sediment berms and the deepening of low-flow channels.

➢ Deepened sections have been observed downstream of the lake and downstream of the Brutinel alluvial fan. These sections are caused by the configuration of the site: narrowing of the active strip of the channel, concentration of flow in a single channel, local break in slope and a temporary break in sediment transport downstream of the reach. At present, sediment carried from upstream is stored in braided zones and does not appear to be reaching the part downstream of the reach.

➢ The work has prompted the diversification of functional units, as pioneer and herbaceous plant species colonised the bare alluvial berms. There is clear evidence of strong spatial dynamics in hydrological functional units: erosion processes (bare alluvial berms to water) are partially offset by deposit processes (water to bare alluvial berms). There remains a functional break between the river's edge and the external wooded strip. The intermediate strata (herbaceous plants and shrubs) are (not yet?) completing the succession process.

➢ The observed changes are linked with 2-year floods. It will be important to monitor how the reach evolves following a more substantial flood.

Restoration of the Drac a montré un impact positif avec la création d'un tressage. However, areas of deepening are visible both upstream and downstream of Saint-Bonnet lake. The injected sediments do not yet appear to have reached the downstream part of the reach. It will be vital to observe changes after a more substantial flood than those that occurred during the study period.

At the Drac workshop, the participants spoke extremely positively about channel morphology and the Drac as a whole, calling it a "support function, the backbone of the valley".

- **For the Buëch:**

➢ A major sediment replenishment exercise was carried out in September 2016 to stop deepening of the channel and to reduce the associated silting of the Saint-Sauveur reservoir. Some 44,000 m^3 of gravel was extracted from the Saint-Sauveur reservoir and deposited along a 400-metre stretch immediately downstream of the dam, creating two gravel berms. To facilitate the remobilisation of the left-side berm, a trench was cut into the deposit.

➢ Morphological changes to the Buëch two years on from the restoration showed a functional sediment replenishment with erosion of 46% of the initially deposited gravel (central and right-side berms) following the 10-year flood in November 2016. The right-side berm had to be reworked in 2018 because it was eroding more slowly. Morphological changes have been observed along a 2.5-km stretch downstream of the injection site, with raising of the river bed and the active strip and repopulation of the vegetation along the river's edge, as well as the reactivation of bio-geomorphological processes at the restoration site and further downstream.

➢ There is still a marked functional break between the river's edge and the external strip. The intermediate strata (herbaceous plants and shrubs) are not yet completing the succession process – a process typical of a riparian forest that is dynamically balanced with its environment.

➢ The sedimentary tracers revealed that the increased transparency of the Saint-Sauveur dam was allowing sediment in the reservoir to pass through during flood events, but that sediment from further upstream was being held in the reservoir.

➢ Two years on from the replenishment, positive effects have therefore been observed immediately downstream of the injection site (2.5 km). The effectiveness of the injection, coupled with the increased transparency of the dam, should be analysed over a longer term to determine the relevant timescales.

Half of the deposited sediment was reclaimed by the river in November 2016. This led to morphological changes along a 6-km reach of the Buëch downstream of the injection suite, with the most notable changes occurring 2.5 km immediately downstream, where the river bed rose by as much as 76 cm. As regards riverside vegetation, the active strip has been revitalised but there is still a marked functional break between the river's edge and the external strip. The sedimentary tracers also showed that, during a flood, sediment from upstream was held back by the Saint-Sauveur dam, despite it being made more transparent.

On the issue of sol formation in floodplains, the coarse sediments in the river channels are not yet suited to soil formation.

At the Buëch workshop, participants took a negative view of sediment transport caused by the restoration work, mentioning "blockage of materials" and "retention of materials".

However, they were positive about post-restoration braiding of the river, stating that "increased braiding causes an increase in the amount of productive land", and mentioning an "improved braiding index", "preservation of land, stabilisation of banks" and good "channel management".

3.1.2.1.5 Micro and regional climate regulation

This ES refers primarily to local temperature regulation and the cooling of bodies of water and the soil. The corresponding indicator is estimated biomass of natural ecosystems, which allows for improved regulation of surrounding temperatures, for instance through evapotranspiration. This ES is studied at the commune level.

- An initial analysis of land cover data gives an indication of plant-covered and natural non-plant-covered soils, along with bodies of water, all of which can contribute to local climate regulation.

These elements are detailed in the table below:

Resources **potentially** related to micro and regional climate regulation – *Occupation du sol 2016*, in hectares	Buëch				Drac				
	Serres	Méreuil	Montrond	Eyguians	Chauffayer	Saint-Bonnet-en-Champsaur	Saint-Julien-en-Champsaur	Chabottes	Saint-Jean-Saint-Nicolas
Transitional woodland-shrub	30	65	11	57	5	79	51	16	213
Coniferous forest	345	135	77	208	32	46	66	14	951

Broad-leaved forest	379	163	22	143	67	117	112	48	400
Mixed forest	366	424	72	189	316	94	179	230	327
Tree crops other than olive groves	32	3	0	22	0	0	0	3	12
Moors and heathland	231	93	26	67	17	122	53	21	432
Pastures	11	7	16	21	2	29	44	8	370
Natural grassland	65	99	49	114	432	520	395	322	372
Peatbogs	0	0	0	0	5	69	1		5
Sparsely vegetated areas	17	2	6	11	0	33	0	0	318
Inland marshes				1					2
Water courses	55	24	44	33	61	65	15	132	138
Water bodies	7			4		4	12		
Bare rock				17		0			53
TOTAL	1537	**1015**	**323**	**888**	**939**	**1178**	**928**	**794**	**3593**

Table 19: Characterisation of land cover potentially related to micro and regional climate regulation for the Drac and Buëch communes covered by the study

The presence of these ecosystems in the area covered by the study contributes to local climate regulation.

In the area covered by the study, forest environments are the most common type of terrestrial ecosystem by surface area (2,523 ha for the Buëch and 2,999 ha for the Drac). These are followed by open environments (418 ha for the Buëch and 2,919 ha for the Drac) and semi-open environments (637 ha for the Buëch and 1,014 ha for the Drac).[5]

Conversely, there are very few bare rock habitats (17 ha for the Buëch and 53 ha for the Drac).

Water courses are by far the dominant type of aquatic ecosystem in the studied areas for both rivers (156 ha for the Buëch and 411 ha for the Drac). Water bodies and inland marshes are roughly equivalent in both cases (between 5 and 6 ha).

Natural environments therefore play an important role in local climate regulation. Land clearing may form a necessary part of restoration work, but should be carried out with caution and kept to an absolute minimum, especially in dense or functional areas of riparian forest.

- The second indicator used here concerns temperature trends for the Drac and Buëch. These are detailed below. ***This indicator is studied at the measuring station level.***

Results for the Drac

[5] Land cover categories for forest environments: mixed forest, broad-leaved forest, and coniferous forest; land cover categories for semi-open environments: moors and heathland, tree crops other than olive groves, and transitional woodland-scrub; Land cover categories for open environments: pastures, natural grassland, peatbogs, and sparsely vegetated areas.

The water temperature at the three stations was measured at full sunlight. The results indicate that water at the restored site (DRAC0080) was 7.5°C higher than at the control sites. Other measurements should be taken (especially continuous recording) to confirm whether or not the water has actually become warmer, and to understand the Drac's thermal regime at the restored site. In all likelihood, the widening of the channel has caused the water to become more sensitive to changes in air temperature.

Températures (°C)	DRAC0030	DRAC0060	DRAC0070	DRAC0080	DRAC0090
févr.-15	4.1	7	6.0	4.3	3.9
mai-15	7.2		9.0		11.6
août-15	11.9	14.9	19.2	26.7	25.5
oct.-15	6.2		7		6.6
févr.-16	4.1		4		5.1
mai-16	6.3		5.9		8.4
août-16	11.8		19.2		13.8
oct.-16	6		9		7.9
févr.-17	3.5		5.1		3.7
mai-17	7.3		5		10.5
juil.-17	11.2		13.3		15.7
oct.-17	5.6		7.5		9.5

Table 20: Temperature measurements at the Drac stations monitored by the Hautes-Alpes Department, 2015-2017 (source: MRE)

An analysis of airborne thermal data (IRT) reveals the inherent difficulties of comparing the control site (Chabottes plain) with the restored site (upstream of Saint-Bonnet) post-restoration because of hydroecological and hydromorphological differences between them. The study indicates that the sediment injected into the restored section does not, at present, support the existence of a sufficiently large accompanying water table to influence surface water temperature in the Drac (see figure 5 below).

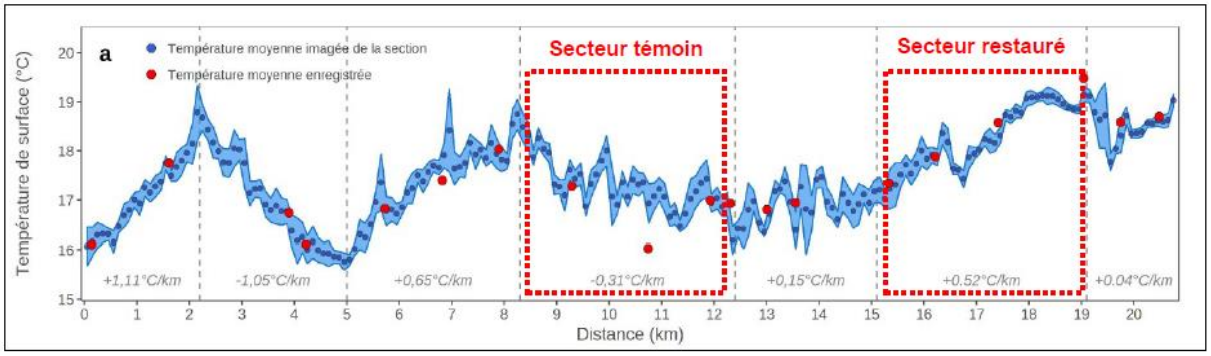


Figure 5: Longitudinal profile of Drac surface temperature and thermal gradients calculated by uniform section (from the Baptiste Marteau report, CNRS, December 2018) showing that the water is warming at the restored site and cooling at the control site under the effect of ground water (source: MRE)

The thermal analysis shows that the Drac is warming at a faster rate at the restored site than at the control site (Chabottes plain). This comparison is not especially useful because of the distinctive hydroecological features of these two sites. It does, however, reveal the limited influence of alluvial ground water flowing into the main channel of the river. Another possible factor is the fact that the surface of the river is wider in the restored section. The

absence of historical temperature records means that it is not possible to compare the Drac's thermal regime before and after the restoration work.

Results for the Buëch

Overall, the figures reveal a higher temperature upstream than downstream of the dam. These piecemeal records should be supplemented with continuous temperature measurements. All 2017 measurements show a well-oxygenated environment, both upstream (station BUEC0700) and downstream (station BUEC0800) of the Saint-Sauveur dam.

Underflow, where it exists, is insufficient in the restored reach to limit rapid warming of the water downstream of the dam in summer.

Températures (°C)	BUEC0700	BUEC0800
févr.-17	5.2	7.5
mai-17	15.8	19
juil.-17	22.2	21
oct.-17	9.1	15.1

Table 21: Temperature measurements at the Buëch stations monitored by the Hautes-Alpes Department post-restoration (2017) (source: MRE)

As regards temperature variations, the Saint-Sauveur dam influences the entire section of river by delivering buffered water that is less sensitive to variations in air temperature.

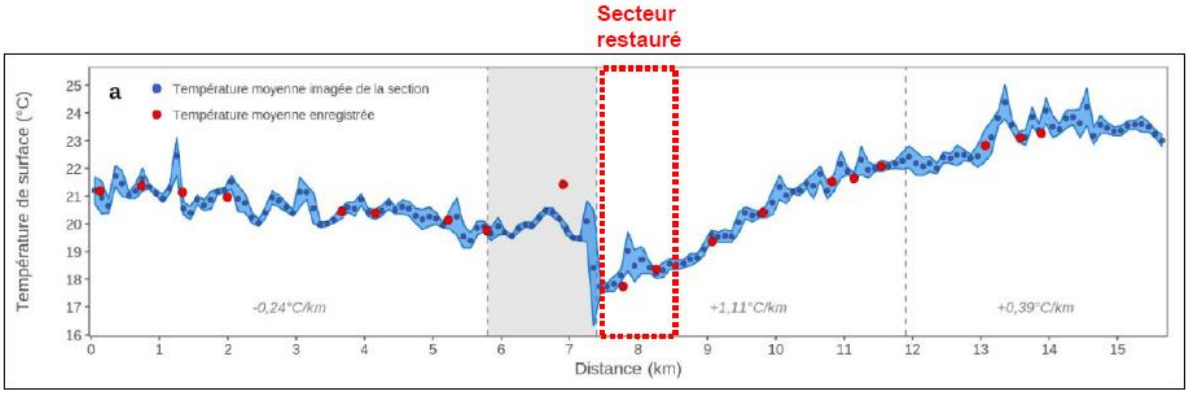


Figure 6: Longitudinal profile of Buëch surface temperature and thermal gradients calculated by uniform section (from the Baptiste Marteau report, CNRS, December 2018 (source: MRE)

Restoration of the Buëch downstream of the Saint-Sauveur dam has had no impact on water quality. The dam has a greater influence on water temperature. At present, the sediment re-injected upstream of the dam is not sufficient to cause underflow that could limit warming of the water.

At the Buëch workshops, the participants spoke in negative terms about the morphological restoration, claiming it had caused the "water temperature to increase" in the river. Attendees

including representatives of the fishing federation and a wildlife conservation charity assumed that the potential temperature increase was not conducive to fish health and development.

3.1.2.1.6 Habitat-related services

This service is characterised by the presence of areas of special environmental status, such as Natura 2000 sites (and their conservation statuses), biotope protection orders, national parks, listed wetlands, Natural Areas of Ecological, Fauna and Flora Interest, etc. It is also characterised by habitat quality and functionality, and by habitats' ability to host typical river and alluvial floodplain flora and fauna that can be partially exploited by humans.

This ES is studied at the drainage basin and measuring station levels.

<u>Areas of special environmental status</u>

The study reach includes several areas of special environmental status, a brief overview of which is given in the tables and maps below.

- <u>Legally protected areas:</u>

Area	Buëch	Drac
Écrins National Park	-	Chauffayer, Saint-Jean-Saint-Nicolas

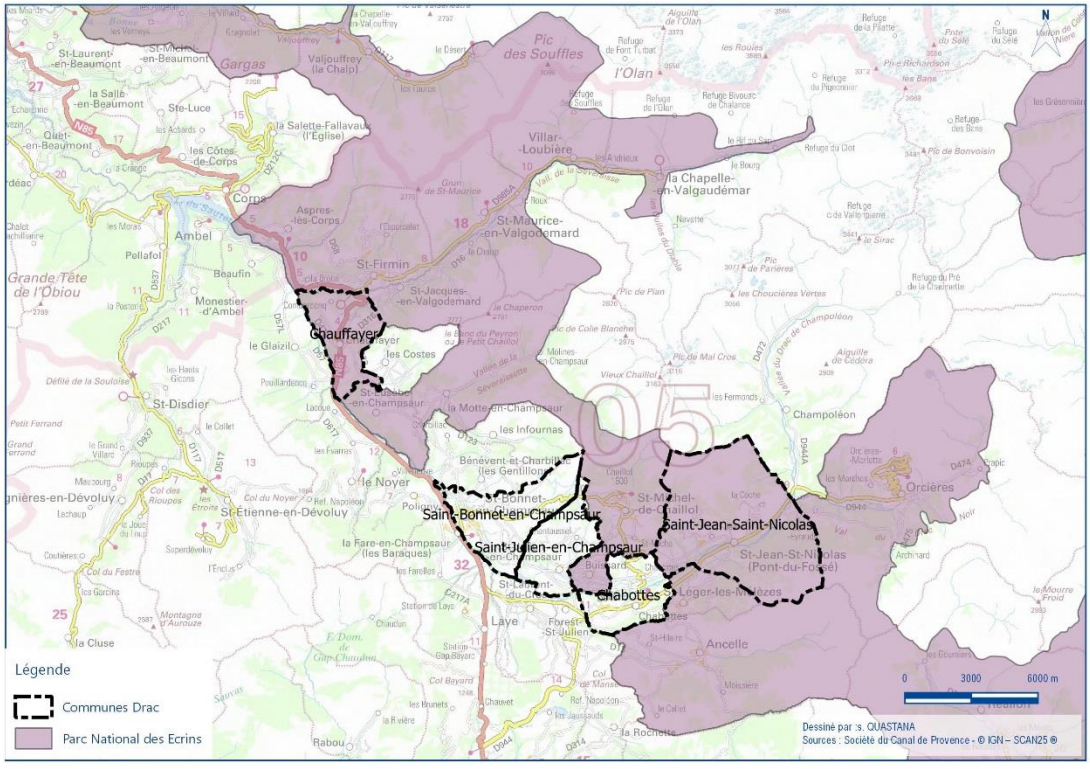


Figure 7: Legally protected areas: Drac

- Contractually protected areas:

Area	Buëch	Drac
Regional Nature Park	Baronnies Provençales Regional Nature Park	-
Natura 2000 sites (special area of conservation)	Céüse – Montagne d'Aujour – Pic de Crigne – Montagne de Saint-Genis (Eyguians) The Buëch (Eyguians, Montrond, Méreuil, Serres)	-

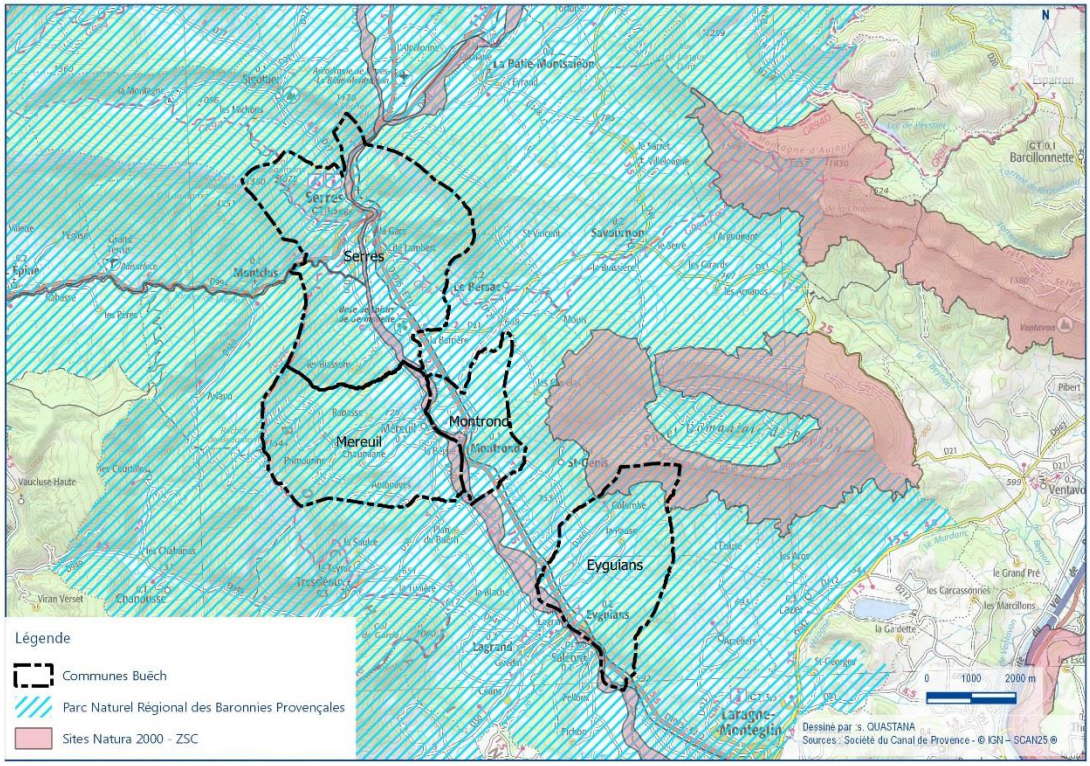


Figure 8: Contractually protected areas: Buëch

- Listed areas:

Area	Buëch	Drac
Departmental wetlands list	Wetlands linked to the Buëch (Eyguians, Montrond, Méreuil, Serres) Wetlands linked to the Torrent d'Aiguebelle and the Blème (Serres) Wetlands linked to the Torrent de Channe and the Adoux/the Raoux spring (Montrond) Wetlands linked to the Riou (Eyguians)	Wetlands linked to the Drac (Chauffayer, Saint-Bonnet-en-Champsaur, Saint-Julien-en-Champsaur, Chabottes, Saint-Jean-Saint-Nicolas) Wetlands linked to the Severaisse, the Les Blachus spring, the Cros low marsh (Chauffayer) Wetlands linked to the Blache, the

Area	Buëch	Drac
		Champs, Ponteillard, the Coquette wetland, the Adrechs, the Périères and the Roulières (Saint-Bonnet-en-Champsaur) Wetlands linked to the Agoulanciers, the Claves, the Laus, Villard Mouren, the Peyrouse reservoir (Saint-Julien-en-Champsaur) Wetlands linked to the Torrent d'Ancelle, the Adous of the Chabottes plain, the Thomas, the Cloutas, the Fiarèse (Chabottes) Wetlands linked to the Aupette pond, lower and upper St-Nicolas, the Pierre Drue, the Torrent des Aries, the Cloutas, Serre Mouret, Coste Mouraise, Champs la Peyre, the upper and lower Vernet, the Chaillol (Saint-Jean-Saint-Nicolas)
Natural Areas of Ecological, Fauna and Flora Interest (type I)	Rocher d'Agnielle – Crête Saint-Michel – Chabespan (Serres) The Grand Buëch, its islands and its riparian forests downstream of the Saint-Sauveur dam at Eyguians (Méreuil, Montrond, Eyguians) Wooded hills of Piénault and Les Plantiers (Eyguians) Montagne de l'Aup/Montagne de Saint-Genis – Le Revuaire (Eyguians)	Valleys of Molines-en-Champsaur (valleys of the Peyron and the Muande) – south-east-facing slopes of Le Vieux Chaillol and north-facing slopes of Pic Queyrel (very small portion in Saint-Jean-Saint-Nicolas and Saint-Bonnet-en-Champsaur) Plateau and wetlands of the Champ du Serre and Les Tresserres (very small portion in Chabottes)
Natural Areas of Ecological, Fauna and Flora Interest (type II)	The Grand Buëch and the Petit Buëch downstream of Veynes to the confluence with the Durance and their major tributaries: the Céans, the Blème and the Blaisance (Méreuil, Montrond, Eyguians, Serres) Rocher de Beaumont – Crête de l'Eyglière and Crête d'Aumage (Méreuil, Serres) Uplands of Montagne de l'Aup, Serre de la Bouisse and Crête de Saumane (Serres) Uplands of the Delphino-Provençal Alpine foothills of Céüse, Crigne-Aujour and l'Aup Saint-Genis (Eyguians)	Bocage du Champsaur from Saint-Michel-de-Chaillol to Saint-Jacques-en-Valgodemard (Chauffayer, St-Bonnet-en-Champsaur, St-Julien-en-Champsaur, Chabottes) South-western section of the Ecrins National Park and uplands - entrance to the Valgaudemar valley - Grun de Saint-Maurice - Séveraissette valley - Le Cuchon - Pic Queyrel - west-facing slope of Le Vieux Chaillol (Saint-Bonnet-en-Champsaur, Saint-Julien-en-Champsaur, Saint-Jean-Saint-Nicolas) Uplands of the Grande Autane and the Petite Autane (very small portion in Saint-Jean-Saint-Nicolas) The Drac, the Séveraisse and their confluence, downstream of Saint-Firmin and Saint-Eusèbe-en-Champsaur (Serres)

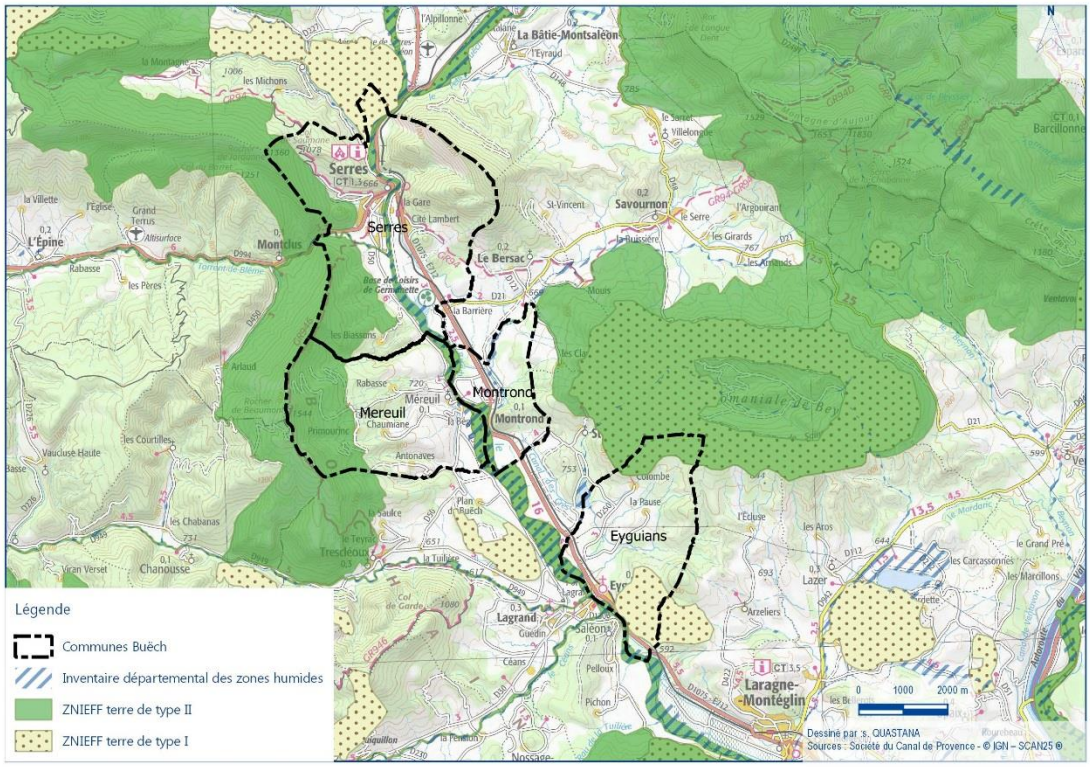


Figure 9: Listed areas: Buëch

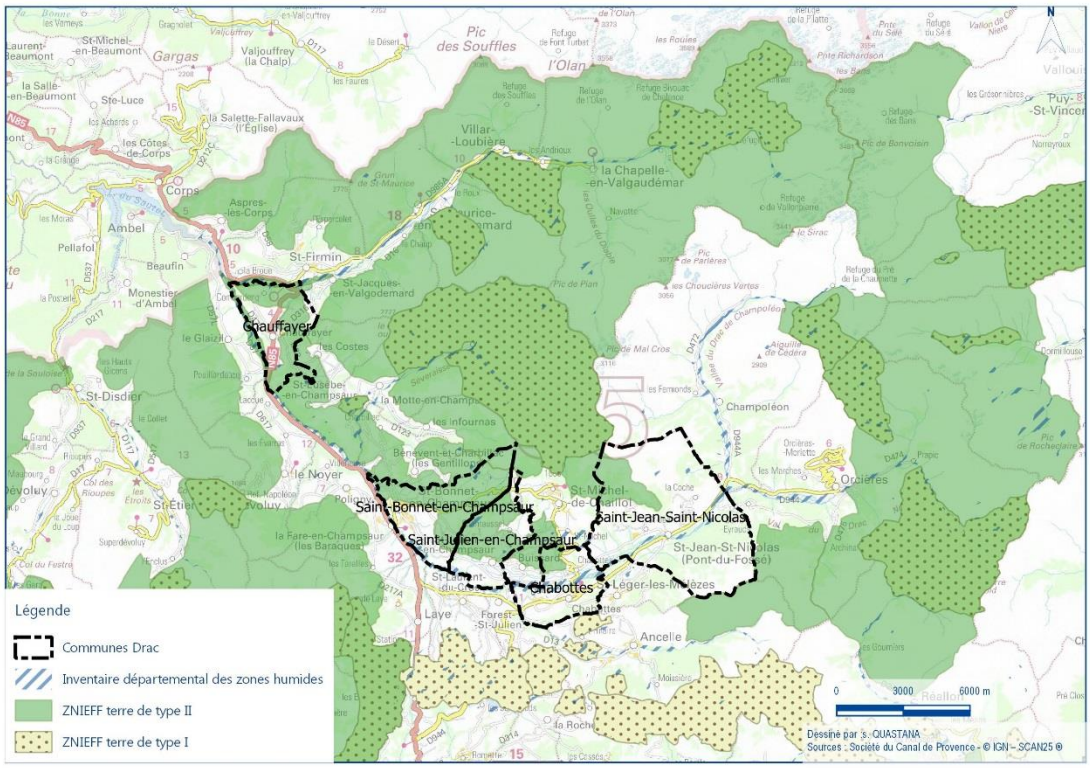


Figure 10: Listed areas: Drac

Aquatic habitat and biodiversity:

- **Aquatic invertebrates**

Drac: High population densities across the area covered by the study indicate that the river is highly productive because the upper basin is generally rich in organic matter.

Comparing the pre- and post-restoration situations, there has been a notable improvement in biological quality across the entire area due to better treatment of wastewater in the Upper Drac (construction or improvement of treatment plants).
This improvement is reflected in the composition of the population, and in particular in the reduction of the relatively abundant population of taxa that consume fine organic matter (Simuliidae and Chironomidae).

The post-restoration improvement in biological quality is significantly more marked at the restored site because of increased hosting capacity of the restored channel.

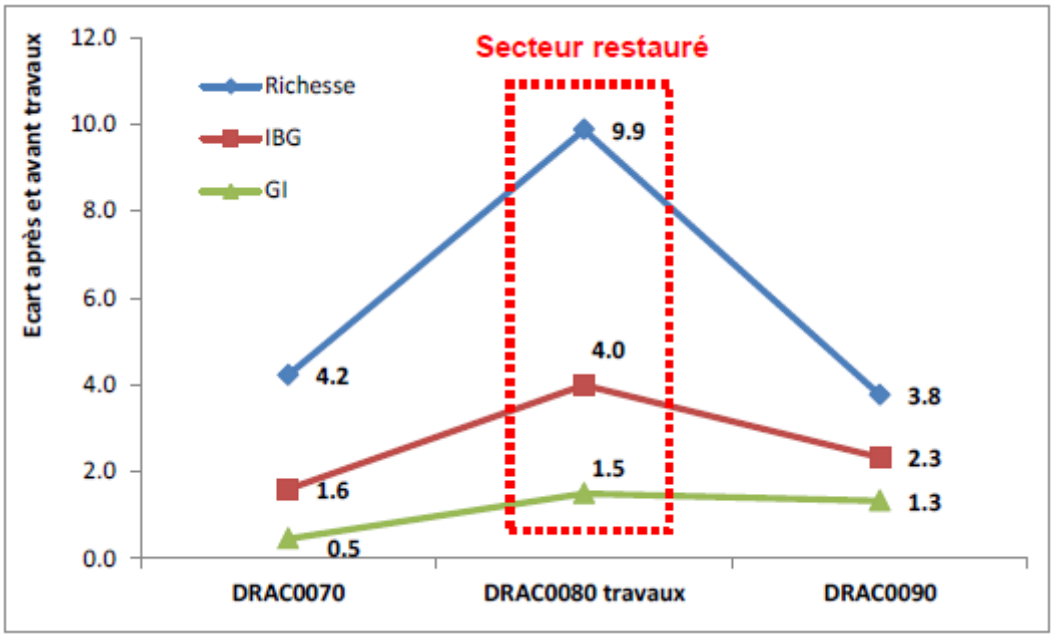


Figure 7: Differences between averages calculated pre- and post-restoration at the three monitored stations on the Drac (taxon richness, biological quality score and indicator group (IG))

- **High population density across the entire area covered by the study, indicating that the river is highly productive.**
- **Improvement in biological quality across the entire area due to better treatment of wastewater in the Upper Drac.**
- **Visible improvement in the composition of the population: reduction of the relatively abundant population of taxa that consume fine organic matter.**
- **Improvement in biological quality significantly more marked at the restored site: increased hosting capacity leading to greater taxon richness.**

- **Improvement in biological quality significantly more marked at the restored site: increased hosting capacity leading to greater taxon richness.**
- **Typology of the area covered by the study according to aquatic invertebrates: transitional zone between mountain stream and piedmont plain river.**

Buëch: In September 2017, calculations put the number of taxa at 29, a figure 11 fewer than observed in September 2016. Population density is also low at 1,042 individuals per m^2, three times lower than observed in September 2016. It would appear that the population was affected by an event occurring between the two measurement campaigns.

The hydrological regime, and the frequency and intensity of floods between September 2016 and September 2017, may well have impacted taxon richness and population density. Post-2017 monitoring results should give a better indication of the effects of the restoration work on the population.

Changes in wildlife populations have been observed upstream and downstream of the Saint-Sauveur dam, apparently due in large part to hydrological and temperature changes caused by the dam in this area.

It is difficult to draw conclusions about "habitat quality" in a hydrologically and thermally altered context, which appears to have a substantial influence on population structure.

More time is needed before any firm conclusions can be drawn about population impacts of the morphological restoration of the Buëch downstream of the Saint-Sauveur dam.

- **Measurements by Gay Environnement (EDF monitoring) and Hautes-Alpes quality monitoring data give different results, pointing to high population variability downstream of the Saint-Sauveur dam.**
- **In 2017 (one year post-restoration), fauna richness and population density were high and similar upstream and downstream of the Saint-Sauveur dam.**
- **In 2017, biological quality was good upstream of the restored site.**
- **More time is needed before any firm conclusions can be drawn about population impacts of the morphological restoration of the Buëch downstream of the Saint-Sauveur dam.**
- **It is difficult to determine how the Buëch restoration work has affected aquatic invertebrate populations because the Saint-Sauveur dam, which causes profound temperature and hydrological changes, appears to have a substantial influence. These observations, which were made one year post-restoration, will need to be confirmed through ongoing monitoring.**

- **Fish**

Drac: ONEMA conducted two electric fishing campaigns, in 2013 and 2017, to measure the effects of the restoration work on the aquatic environment. Four fish species were observed post-restoration (souffia, minnow, brown trout and bullhead), compared with two in 2013 (bullhead and brown trout). This change in fish population may be caused by environmental changes (habitat, temperature, hydrology) and the installation of a fish pass in the downstream section of the reach (Saint-Bonnet-en-Champsaur bridge).

Post-restoration, the brown trout population was found to have increased sharply (now abundant), whereas the bullhead population had declined.

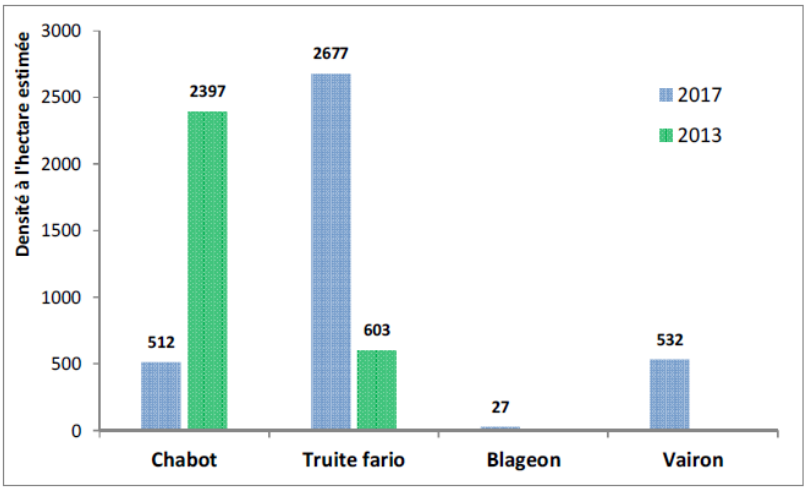


Figure 8: Composition of the fish population in 2013 (pre-restoration) and in 2017 (post-restoration) at the Drac station affected by the restoration

Distribution by size class shows a thriving trout population with a high reproduction rate post-restoration, reflecting the influence of changes in habitat quality.

- **Four species were observed post-restoration compared with two in 2013 (arrival of souffia following the construction of fish passes and improvements in habitat quality).**
- **The brown trout population has increased sharply (now abundant), whereas the bullhead population has declined.**
- **Distribution by size class shows a thriving trout population with a high reproduction rate post-restoration: influence of changes in habitat quality.**
- **Further monitoring is required to supplement these observations.**
- **The restoration of the Drac, coupled with the installation of a fish pass downstream of the restored reach, has had an impact on the fish population. The number of species has increased, as has the brown trout population. Post-restoration improvements to habitat quality seem to favour brown trout reproduction.**

Buëch: Some 12 species were caught in 2017, indicating that the fish population in the restored reach of the Buëch (station 02, BUEC0800) is similar to that observed in 2014 and 2015. Souffia is the dominant species, followed by common barbel, common nase, minnow and chub.

There is a small trout population. While reports of a bullhead population are anecdotal, the species was observed in the three monitoring years.

Espèces piscicoles
Ablette
Barbeau fluviatile
Blageon
Chabot
Chevaine
Goujon
Hotu
Loche franche
Toxostome
Truite fario
Vairon

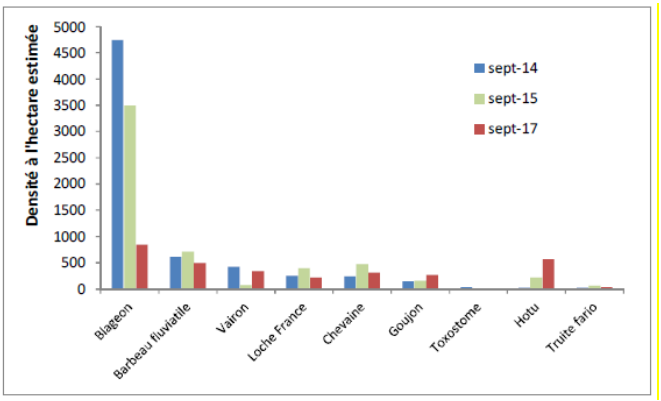


Figure 9: Species observed in 2017 (left) and population density per hectare of the main species between 2014 and 2017 (right)

Fishing campaigns in 2018 should supplement these observations and enable firmer conclusions to be drawn about the link with habitat quality.

- **A total of 12 species were observed following the restoration work.**
- **Freshwater Cyprinidae dominate the population.**
- **The populations were found to be extremely similar, in qualitative terms, pre- and post-restoration.**
- **Post-restoration, souffia population density declined and common nase population density increased.**
- **Populations of stenothermic freshwater species such as brown trout and bullhead remain small: influence of warming waters downstream of the Saint-Sauveur dam.**
- **Studies of the fish population reveal little qualitative change pre- and post-restoration. Freshwater Cyprinidae still dominate the population, while stenothermic species remain under-represented.**

Terrestrial habitat and biodiversity:

This section is based on the plant compartment spatial structure and temporal dynamics characterisation work carried out by Sorbonne University, UMR 8185 CNRS "Espace, Nature & Culture" (ENEC).
This study aimed to answer the following two key questions:
- How are vegetation units reorganising within the hydrological corridor following the restoration work?
- What ecological succession processes have the sediment replenishment operations activated (or re-activated)?

The study used remote sensing (satellite imaging analysis) combined with a field campaign in July 2018. SPOT satellite images were analysed diachronically between 2014 and 2017 (the 2018 image was not available at the time).
The various functional units were mapped (water, bare alluvial berms, pioneer species, herbaceous species, bushy species, forest species, exploited riparian forest, occupied riparian forest).

Drac: In order to characterise the response of plant species in the restored reach, a non-restored reach was also studied in parallel (braided section of the Chabottes plain).

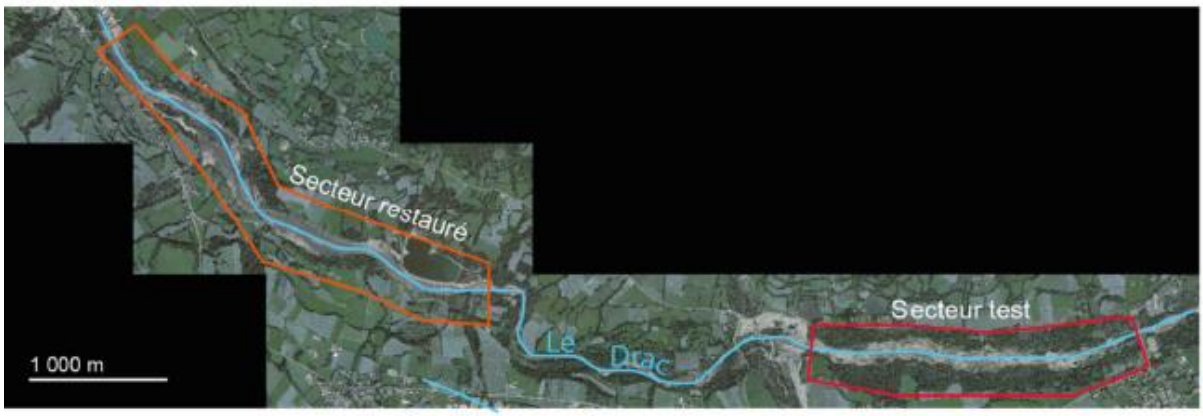


Figure 10: Location of the studied reaches of the Drac: test reach (upstream) and restored reach (downstream) (Sorbonne University, 2018)

The following conclusions can be drawn about post-restoration changes to the functional units:

- There are strong spatial dynamics in hydrological functional units (water class), with erosion processes (bare alluvial berms to water) partially offset by deposit processes (water to bare alluvial berms).
- The functional units in the active strip became more uniform between 2014 and 2017 (reduction in bare alluvial berms, increase in herbaceous and bushy plant populations).
- Progressive dynamic processes have been re-activated (especially bio-geomorphological phases, i.e. population by herbaceous and bushy species): reduction in bare alluvial berms through colonisation by pioneer plant species, or gradual stabilisation by herbaceous groups (vegetation shown to be resilient to sedimentary changes caused by the restoration work).
- There remains a functional break between the river's edge and the external strip.
- Vegetation has colonised rapidly from the outer edges of the bank. The banks have stabilised through the combined effect of geotextiles and planting of pioneers herbaceous species, rapidly activating the colonisation of the pre-bank alluvial berms.
- The absence of major floods during the period appears to have resulted in relatively efficient resilience within the active strip.

Figure 11: Left bank of the Drac in the restored reach. In the foreground: pioneer species; in the background: herbaceous species (Sorbonne University, 2018)

Buëch: The non-restored section used for comparison purposes is situated downstream of the restored reach.

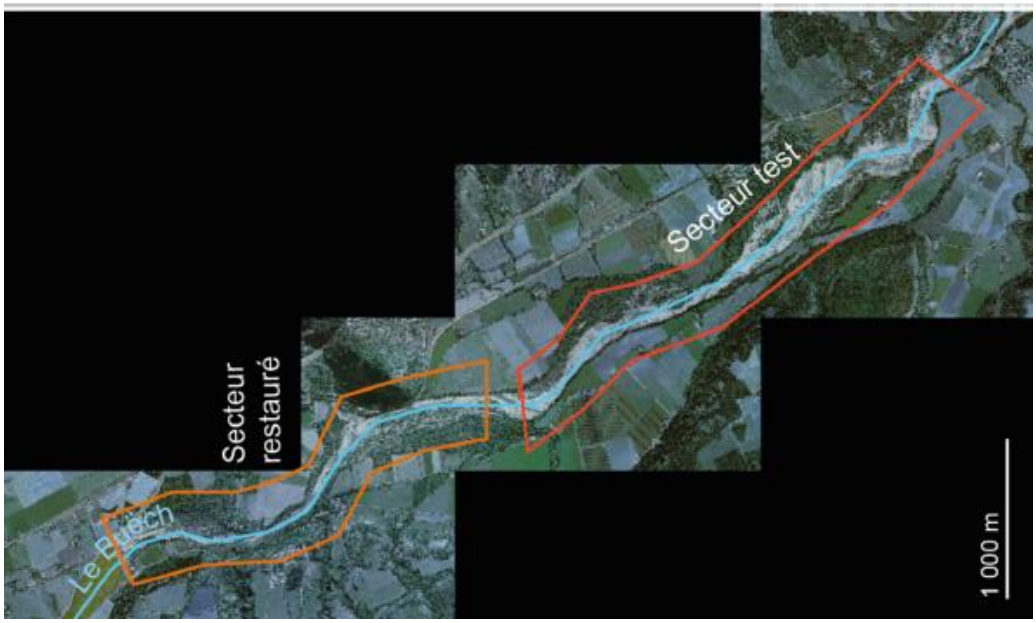


Figure 12: Left bank of the Drac in the restored reach. In the foreground: pioneer species; in the background: herbaceous species (Sorbonne University, 2018)

The results revealed that the active strip has been revitalised and that bio-geomorphological processes have been (re-)activated at the restoration site and further downstream. There is still a marked functional break between the river's edge and the external strip. The intermediate strata (herbaceous plants and shrubs) are not (yet?) completing the succession process – a process typical of a riparian forest that is dynamically balanced with its environment. The non-restored section (located 2,000 to 3,000 m downstream) remains unaffected by the restoration work, with less stable riverside vegetation than in the restored section and evidence of regressive dynamic processes.

The restoration work has therefore supported successful plant recolonisation and stabilised riverside vegetation, re-activating ecological succession processes.
This recolonisation and stabilisation could be linked to potential raising of the accompanying water table.

Index of the supply of representative and symbolic Alpine plants and animals

Habitat-related ES can also be characterised using an index of the supply of representative and symbolic Alpine plants and animals. The corresponding index has been developed by CEREMA.

The index is as follows:

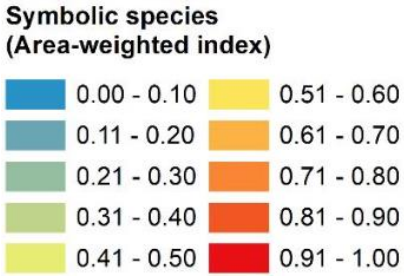


Figure 5: Index of symbolic Alpine species (source: AlpES project, CEREMA)

Supply of typical and symbolic Alpine plants and animals is measured on a scale between 0 (low) and 1 (high).

CEREMA considered the following symbolic Alpine species in the AlpES study:

Symbolic Alpine animals:

- ⇨ Alpine ibex (*Capra ibex*)
- ⇨ Brown bear (*Ursus arctos*)
- ⇨ Chamois (*Rupicapra rupicapra*)
- ⇨ Golden eagle (*Aquila chrysaetos*)
- ⇨ Alpine marmot (*Marmota marmota*)

Symbolic Alpine plants:

- ⇨ Rhododendrons (*Rhododendron hirsutum, Rhododendron ferrugineum*)
- ⇨ Edelweiss (*Leontopodium alpinum*)
- ⇨ Gentians (*Gentiana acaulis, Gentiana clusii*)
- ⇨ European larch (*Larix decidua*)
- ⇨ Swiss pine, Aleppo pine, Turkish pine, Mountain pine, Austrian pine, Maritime pine, Italian stone pine and Scots pine (*Pinus cembra, Pinus halepensis, Pinus brutia, Pinus mugo, Pinus nigra, Pinus pinaster, Pinus pinea, Pinus sylvestris*)

There are three possible indicators:

- Supply of symbolic species habitats (index)
- Flow: occurrence of species names in hotel names
- Demand expressed in "desired scenery and symbolic species"

Demand (in the form of an index) is used here, since this is the indicator for which the most data is available (see table 29).

Typical/characteristic Alpine plants, animals and scenery	Buëch				Drac				
	Serres	Méreuil	Montrond	Eyguians	Chauffayer	Saint-Bonnet-en-Champsaur	Saint-Julien-en-Champsaur	Chabottes	Saint-Jean-Saint-Nicolas
Demand									
Supply	0.22	0.00	0.23	0.01	0.28	0.35	0.31	0.26	0.44

Table 22: Index of supply of, and demand for, symbolic Alpine plants and animals (source: AlpES project, CEREMA)

The index (and, therefore, demand for symbolic Alpine species) is higher in the Drac communes than in the Buëch communes. The index is nevertheless low, at between 0.26 and 0.44, with the lowest overall demand in the Buëch communes (zero for Eyguians and Méreuil).

*At the **Buëch** workshop, the participants spoke in positive terms about the effects of the restoration on habitats: "improvement of habitats", "greater variety of sediments supporting wildlife/habitats", "more habitats", "habitats/functionality/braiding" and "more local plants". However, the overall picture was mixed, with some participants calling the restoration an "obstacle to migration - no fish pass". The participants recognised this as being one of the most important services.*

At the Drac workshop, the participants also spoke positively about the impact on habitats, indicating that "fish can now pass through the transverse structures again" and that this supported a return to a "favourable floodplain ecosystem".

Focus on HyMoCARES questionnaire:

The questionnaire asked the following question: *"In your view, which ecosystem services are affected by hydromorphological changes such as the construction of weirs or dams, flow rate regulation, bank reinforcement, sediment extraction, etc.?"* Of the 57 respondents, **42% said that hydromorphological changes had affected regulation and maintenance ES,** while 23% said the impact was moderate and 10% said it was low.

3.1.3 "CULTURAL" SERVICES

This section examines three subgroups of "cultural" ES:

- scenery
- emotional and intellectual interactions (natural and cultural heritage of the river and floodplain ecosystem, as well as education and science)

- water-related activities. Since relevant data was available, water-related activities were further subdivided into fishing, bathing and canoeing/kayaking.

3.1.3.1.1 Scenery

This ES is studied at the drainage basin level.

This ES concerns the aesthetic aspect of the landscape, and can be characterised in terms of diversity, uniqueness and naturalness. According to the CICES RESI classification scheme (adapted for the HyMoCARES project), this ES can be qualified using indicators such as nature and scenery protection zones, number of viewpoints, density of footpaths, absence of noise, etc.

There are approximately 6,800 km of footpaths in the Hautes Alpes, including 1,800 km of well-known long-distance footpaths.

The landscapes of the Drac are varied, as the figure below shows:

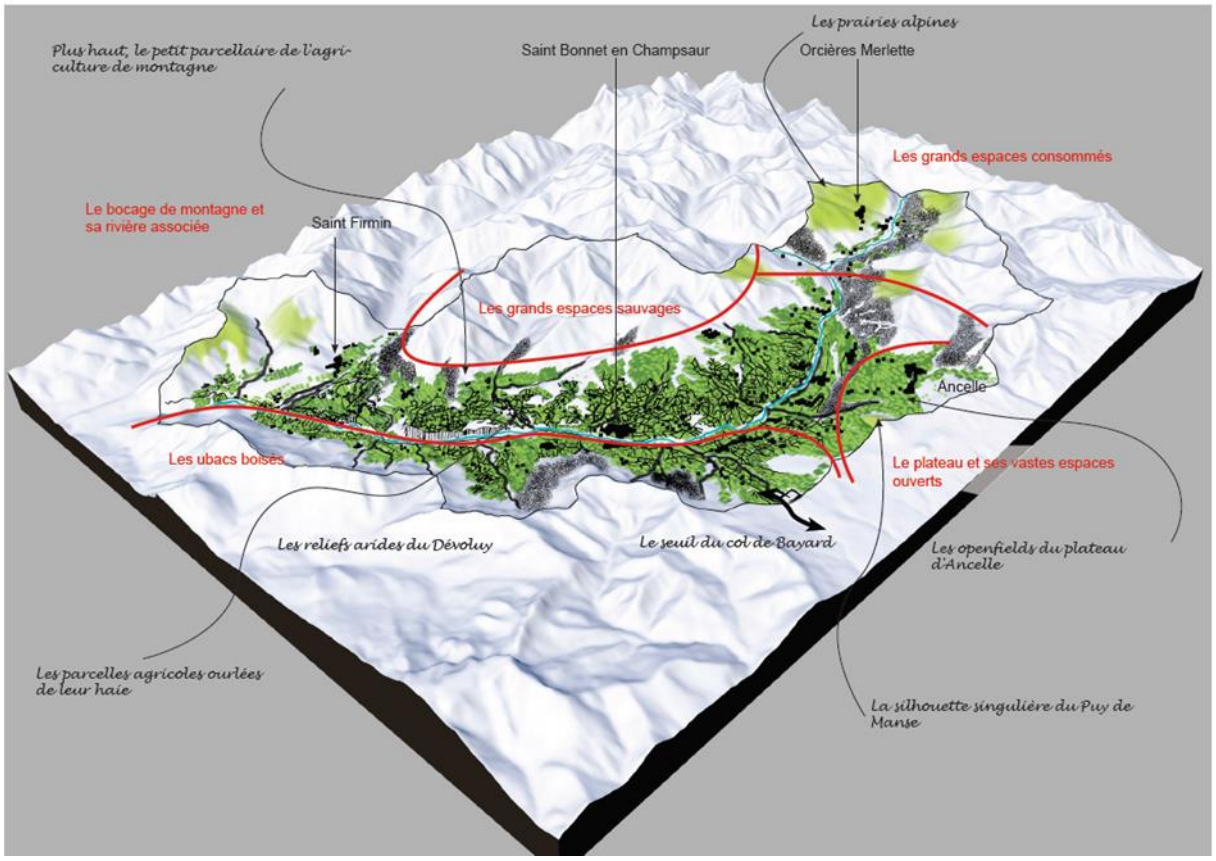


Figure 6: Landscape block diagram: Drac (source: Atlas paysager – La vallée des Drac - Département des Hautes Alpes)

The narrow valley is very much a mountain scene, with slopes, mountain streams, escarpments and mountain pastures. There are various types of landscape, including vast spaces, open spaces, wooded mountain countryside and wooded north-facing slopes.

The Drac valley landscape unit is also linked to the Massif du Dévoluy via the Col du Noyer mountain pass.

Water also shapes the landscape. Water flows into the Drac from its tributaries, which flow through secondary valleys (Torrent de Buissard, Torrent d'Ancelle, Torrent de la Séveressaite, Torrent de la Séveraisse, etc.).

Between Saint-Bonnet-en-Champsaur and Chauffayer, the Drac flows deep through the black schist alongside the hard bedrock of Mont Pelvoux. These metamorphic rocks have created a plateau where human beings can settle and prosper.

The Drac valley provides access to the Massif des Écrins via the Valgaudemar, Champoléon and Orcières valleys, whereas there is only one access point from the Durance valley (via Vallouise).

The valley provides opportunities for winter, terrestrial, aquatic and airborne sports and recreation activities.
There are more than 300 km of footpaths along the Drac, including 33 signposted routes in the Valgaudemar valley and 60 signposted footpaths in the Champsaur valley. There are also numerous signposted footpaths in Écrins National Park.

The valley is a popular spot for motorists. Between 2009 and 2012, the number of vehicles observed at Chauffayer increased by 16% (from 4,858 to 5,646 vehicles).

The Drac valley is situated within Écrins National Park (a Special Protection Area), while Valgaudemar and Dévoluy are a Special Area of Conservation.

Écrins National Park is also a Site of Community Importance for Birds.

The northern part of Saint-Bonnet-en-Champsaur is also a Special Area of Conservation.

At the Drac workshop, the participants were clear that scenery was an important aspect (13 points), with several of them mentioning the link between scenery and tourism: "scenery, environments, drinking water", "long-distance tourism", "lake", "environments, scenery", and "tourism, economy".

For the Buëch and the Buëch valleys, there are four landscape units: the high-mountain Buëch, the foothills Buëch, the Serres pass, and the high valleys. These are shown on the landscape block diagram below:

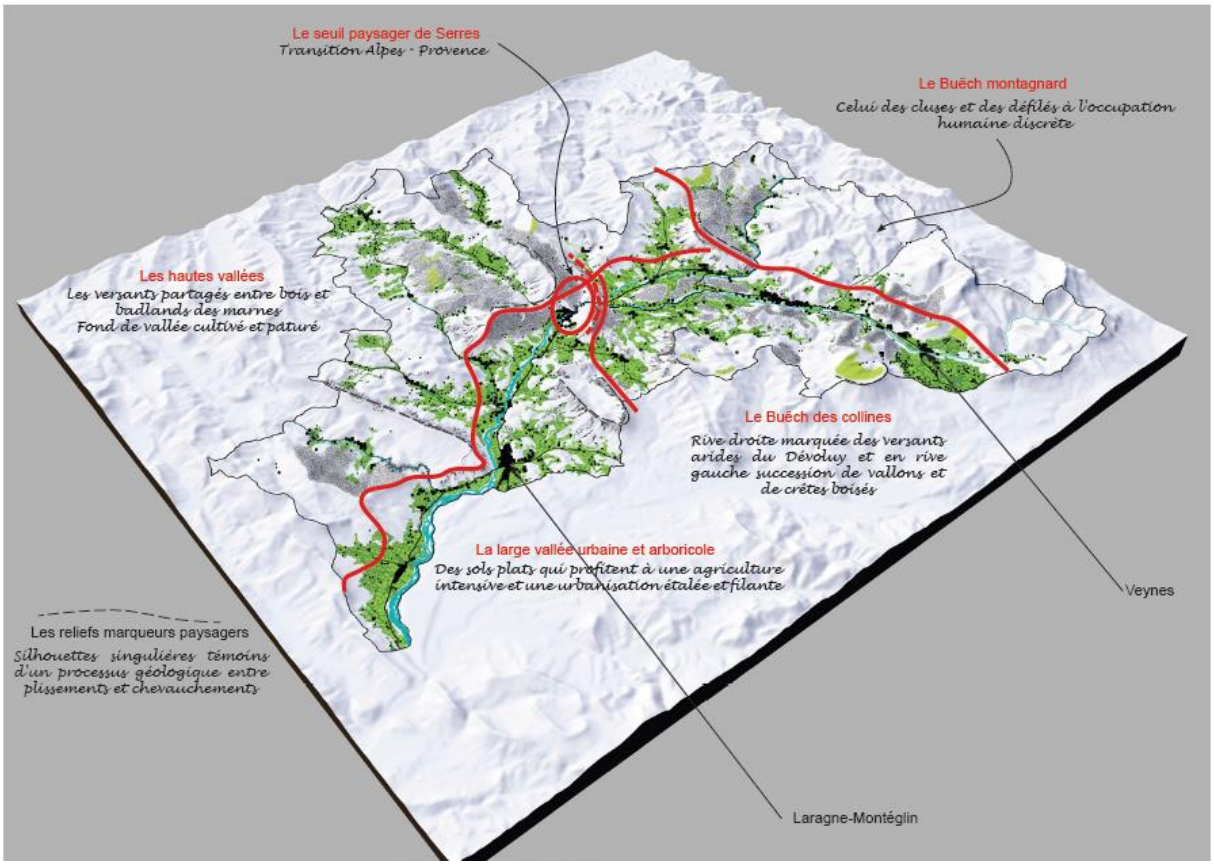


Figure 7: Landscape block diagram: Buëch (source: Atlas paysager – La vallée du Buëch - Département des Hautes Alpes)

The majority of the Buëch restoration site is located in the Serres pass section.

According to the *Atlas paysager – La vallée du Buëch - Département des Hautes Alpes*: "*Upstream of the confluence, the Petit Buëch and the Grand Buëch each flow through a series of wider and narrower channels, passing through gorges, widening out into a basin carved into the marlstone, before narrowing again when they encounter hard rocks that form a cross valley*".

The cross valley is formed by the eastern flank of the Montagne d'Arambre and the western flank of the Rocher d'Agnielle. La Germanette reservoir, which was built to control the Buëch's flow rate, is home to a water sports centre that attracts many tourists to the commune.

There are three major roads linking the area with neighbouring departments and the town of Gap. Road signs for "Valence, Montélimar et Orange" indicate the proximity of the Rhône corridor. These roads are busy tourist routes used by drivers who want to avoid the major motorways.

The RD 994 leads to the Drôme department and the town of Gap. The Serre/La Roche-des-Arnauds section of the road is extremely busy, carrying commuters to Gap and tourists to the ski resorts in Le Dévoluy.

The Buëch valleys are home to two Special Protection Areas (the Bois du Chapitre and the Marais de Manteyer), as well as Special Areas of Conservation (Le Dévoluy, Buëch, Céüse and Méouge).

At the Buëch, the "disrupted landscape" (as a result of the restoration work) was mentioned as a negative impact of the restoration.

3.1.3.1.2 Emotional and intellectual interactions

Emotional and intellectual interactions are divided into two subgroups:

1. natural and cultural heritage of the river and floodplain ecosystem
2. education and science.

The first of these two ES was characterised by the number of photos and videos uploaded to Flickr. Since Google closed down Panoramio in 2016, only Flickr photos and videos were counted (tagged by keyword).

The education and science ES was characterised by the number of scientific papers on Google Scholar for a given set of keywords.

3.1.3.1.2.1 Natural and cultural heritage of the river and floodplain ecosystem

This ES is studied at the commune level.

A targeted keyword search was performed on free photo- and video-sharing platform Flickr to count the number of photos or videos of each of the communes identified in 3.1. The number of photos and videos may (or may not) indicate the appeal of a particular location, scene or ecosystem.

The number of photos and videos (as indicated by geotags, which "tag" the location of each video or photo) is listed below for each of the studied communes in the two drainage basins:

1. For the Drac:
   - Saint-Bonnet-en-Champsaur: 80 geotagged items
   - Saint-Julien-en-Champsaur: 39 geotagged items
   - Chauffayer: 22 geotagged items
   - Saint-Jean-Saint-Nicolas: 19 geotagged items
   - Chabottes: 10 geotagged items.

2. For the Buëch:
   - Eyguians: 9 geotagged items
   - Serres ("Hautes Alpes" was added to the search to eliminate results for the city of the same name in Greece): 211 geotagged items
   - Montrond ("Hautes Alpes" was added to the search to eliminate results for the commune of the same name to the west of Grenoble): 4 geotagged items
   - Méreuil: 2 geotagged items.

The methodology used here comes with a warning: unfortunately, not all of the geotagged elements listed here necessarily relate to "natural and cultural heritage of the river" since they may also include photos of everyday life (restaurant dishes, newborns, weddings, etc.). In the case of

Montrond, for instance, only two photos showed scenery and the river, while the other two were of newborn babies.

At both the Drac and Buëch workshops, the participants mentioned natural and cultural heritage of the river as an important ecosystem service (much more so for the Buëch than the Drac).

3.1.3.1.2.2 Education, science

This ES is studied at the drainage basin level.

A Google Scholar search using the keywords "Drac river" returned 2,940 results. The number was reduced to 625 with a refined search for "French Alps Drac river". A basic search on the main Google search engine (in French) for the keywords

"Rivière le Drac", then filtering by "books", returned 17,700 results.

For the Buëch, a keyword search for

- "French Alps Buëch river" returned 2,290 Google Scholar results.
- "Buëch river" also returned 1,290 results on Google Scholar.
- A basic search on the main Google search engine (in French) for the keywords "Rivière le Buëch" returned 6,900 results.

3.1.3.1.3 Water-related activities

This ES can be best characterised by identifying structured and unstructured water sports facilities and locations.

Another useful indicator is the number of rod licences and permits for other water-related recreational activities.

3.1.3.1.3.1 Fishing

This ES is studied at the drainage basin level.

There are 22 Accredited Associations for Fishing and Protection of Aquatic Environments (AAPPMAs) in the Hautes-Alpes department. These are listed in the table below, along with the number of members of each AAPPMA:

AAPPMA	VILLE	EFFECTIF EN 2015	MEMBRES ACTIFS EN 2015	% DE MEMBRES ACTIFS
La Truite du Guil	Aiguilles	617	173	28%
La Gaule Vaudoise	L'Argentière la Bessé	436	229	53%
La Truite du Buëch	Aspres sur Buëch	851	366	43%
Les pêcheurs Brianconnais	Briançon	1696	723	43%
La Truite du Haut-Champsaur	Chabottes	486	170	35%
La Gaule du Rabioux	Chateauraoux	147	62	42%
La Gaule Prégo-Dio	Chorges	430	143	33%
La Gaule Embrunaise	Embrun	2094	888	42%
La Gaule de Freissinière	Freissinières	30	11	37%
La Gaule Gapençaise	Gap	3492	1887	54%
L'Ardillon Haut-Alpin	Guillestre	908	332	37%
La Gaule Laragnaise	Laragne	388	245	63%
La Gaule Durançole	Monetier-Allemont	307	175	57%
La Vallée de la Clarée	Névache	923	243	26%
La Rive Reine	La Roche de Rame	44	26	59%
La Gaule de Savines	Savines-Le-Lac	906	252	28%
La Truite Champsaurine	Saint Bonnet	599	261	44%
Guisanne-Romanche	Saint Chaffrey	514	197	38%
La Truite de la Souloise	Agnière en Devoluy	122	50	41%
La Gaule du Valgaudemard	St Maurice en Valgaudemard	319	133	42%
La Truite Vallouisienne	Vallouise	149	58	39%
L'Amicale des Pêcheurs Veynois	Veynes	255	138	54%

Table 23: List of AAPPMAs in the Hautes-Alpes department (source: Schéma Départemental de Développement du Loisir Pêche - 2018 – Fédération de Pêche des Hautes Alpes)

When a person buys a rod licence, he or she is permitted to fish in any area covered by the issuing association. The associations have pooled their territories to simplify the membership process and to enable members to fish across a wider area. In other words, there is a reciprocal relationship between AAPPMAs.

According to the 2018 *Schéma Départemental de Développement du Loisir Pêche*, produced by the Fédération de Pêche des Hautes Alpes, these reciprocal arrangements exist at several levels:

- some associations within the same department pool their territories, or
- all associations within the same department pool their territories.

The Hautes-Alpes Department does not have reciprocal arrangements with other French departments, but a rod licence purchased in Hautes-Alpes allows the holder to fish across the entire department, at a location of his or her choosing.

There are now two ways to obtain a rod licence: by signing up through the chosen AAPPMA's membership process, or by applying online.

Fishing in the Buëch

The fishing grounds in the restored reach of the Buëch are shared by three AAPPMAs. A total of **1,646 rod licences have been issued** for the Buëch and its tributaries (according to the Fédération de Pêche des Hautes Alpes; the figure may be inflated).

The Buëch upstream of Serres, the Petit Buëch and the Méouge are considered prime fishing grounds.

There is also a fishing reservoir in the area at La Germanette, where fly fishing and coarse fishing are permitted. Equipment can be hired on site. Trout is sold by weight. La Germanette is a private fishing spot requiring a special licence.

There are also two sections of the Buëch where fishing is prohibited:

- the Garenne nursery stream (approx. 750 m) in the commune of Aspremont
- downstream of the Saint-Sauveur dam (approx. 100 m) in the communes of Serres, Méreuil, Le Bersac and Montrond. There is a "no kill" section on the Grand Buëch.

Fishing in the Drac

The fishing grounds in the restored reach of the Drac are shared by four AAPPMAs. A total of **4,664 rod licences have been issued** (according to the Fédération de Pêche des Hautes Alpes; the figure may be inflated).

The Drac and its tributary the Séveraisse are considered prime fishing grounds.

The restoration has had a positive impact on the trout population, increasing the population size.

3.1.3.1.3.2 Bathing

This ES is studied at the drainage basin level.

On the Drac, Champsaur lake is an especially popular bathing spot. The lake is situated between Saint-Bonnet-en-Champsaur and Chabottes, at the heart of the restoration site. The lake is not, however, a direct ecosystem service of the Drac, although it is affected by the restoration work (which is why activities related to the lake are included in this study).

The lake provides a range of recreational activities all summer long, including kayaking, stand-up paddle-boarding, a water slide, miniature golf, pedalos, a trampoline, treetop adventure trails, and a wake park.

Life guards are on duty daily from 11 am to 6 pm between 9 July and 31 August.

There is a playground on site for children aged 3-6 years, as well as a multisports pitch, a fitness trail, two volleyball courts, table-tennis tables, and trout fishing.

On the Buëch, bathing is only possible in a small number of suitable spots: at Les Marmites du Diable (La Faurie) and at the broken Chambons dam (RD1075 bridge in Serres and RD948 bridge in Laragne in particular). However, there are no bathing areas within the restored reach.

Hydraulic infrastructures on the Buëch have also created two lakes for tourists: La Germanette lake in Serres and Le Rious lake in Saint-Genis.

Plan d'eau de la Germanette	Plan d'eau du Riou	Plan d'eau de Veynes
Entrée payante (moyenne annuelle de 40 000 entrées*)	Entrée libre et gratuite	Entrée libre et gratuite
Pas de label	Pavillon bleu	Pas de label
Activité de baignade : Baignade surveillée Cours de natation (enfants) > Aménagements : Activités nautiques Accès baignade pour handicapés Espace jeu d'eau (enfants)	Activité de baignade : Baignade surveillée > Aménagements : Activités nautiques	Activité de baignade : Baignade surveillée Accès baignade pour handicapés > Aménagements : Activités nautiques
Activité de pêche : gérée par AAPPMA de Aspres-sur-Buëch et Serres > Aménagements : plan d'eau spécifique	Activité de pêche : gérée par AAPPMA de Aspres-sur-Buëch et Serres > Aménagements : pontons + accès handicapés	Activité de pêche: géré par une association de pêche spécifique au plan d'eau (empoissonnements) > Aménagements : emplacements de pêche
Autres aménagements : accueil, salle (expositions, concerts), restaurant, aire de pique-nique aménagé	Autres aménagements : buvette, aire de pique-nique aménagé	Autres aménagements : restaurant, aire de pique-nique aménagé

* données 2009 (Source : com. pers. D. SARAIRE, La Germanette)

La Germanette lake is located not far from the restoration site, so the description of bathing activities will concern this lake only. The lake is open to paying visitors between 01/07 and 31/08. The site holds the "*tourisme et handicap*" (tourism and disability) and "*handiplage*" (disabled-friendly beach) marks, and amphibious wheelchairs are available.

There is a 300 m^2 splash park including ground-level water jets, a snake sprinkler, a water bench, a spraying elephant and a water tunnel.

The lake also offers other water sports and activities including electric boats, pedalos, stand-up paddle-boarding and canoes.

3.1.3.1.3.3 Canoeing, kayaking and canyoning

This ES is studied at the drainage basin level.

There are 2,000 km of navigable waterways in the Hautes-Alpes Department, including 500 km for white-water sports.

There are a little over 100 canyons in the department. According to Eau Vive Passion (EVP), five to six of these canyons are used on a regular basis.

There are approximately 30 canoeing and kayaking courses in the Hautes-Alpes Department, and three or four of them are used, mainly between April and October.

Three white-water activity companies operate in the Champsaur-Valgaudemar area:

- Eau Vive Passion (based in Gap)

- Actions (based in Saint-Julien-en-Champsaur)
- Valg'Eau Vive (based on Saint-Firmin).

These companies offer the following activities:

- white-water swimming and riverboarding
- kayaking and air-boating
- rafting
- hot dog
- raft.

The Drac is ideal for white-water sports between March and November, with a regular and predictable water flow. There are a number of class II to IV difficulty courses between Saint-Bonnet-en-Champsaur and La Guinguette.

Between April and October, around **1,000 people visit each of the canyoning and canoe/kayaking sites.**

Canoeing and kayaking are practised infrequently in the **Buëch drainage basin**. The departmental federation's website contains details of a course, but this course is mainly used during the spring snowmelt season when there is sufficiently water flow. There is a white-water sports company, Véga Passion, based in La-Roche-des-Arnauds.

Canoeing and kayaking on the Buëch are therefore dependent on river water flow conditions.

At the Drac workshop, the participants said the restoration had "Temporarily [affected] kayaking activity" and, more generally, "Leisure, sport, tourism". However, the activity could be a "Positive recreational activity without excess" and the "Transverse structures are now passable for canoes/kayaks/rafts", adding extra appeal for enthusiasts and, potentially, increasing the number of people practising these activities.

At the Buëch workshop, "canoeing, kayaking and canyoning" was among the most important ecosystem services. The entire "cultural" category was rated positively in relation to other service categories.

Focus on HyMoCARES questionnaire:

The questionnaire asked the following question: "In your view, which ecosystem services are affected by hydromorphological changes such as the construction of weirs or dams, flow rate regulation, bank reinforcement, sediment extraction, etc.?" Of the 57 respondents, almost 60% said that the changes had a moderate to high impact on so-called "cultural" ES (25% and 34% respectively), while 5% said the impact was low.

3.1.4 USAGE OF ABIOTIC NATURAL CAPITAL SERVICES

According to the document entitled *D.T.1.1 Report on ES definition and systematics*, navigation is absent in Alpine rivers and this service is therefore not considered here.

Hydropower and sediments for construction will be qualified and quantified in the paragraphs below.

3.1.4.1 HYDROPOWER

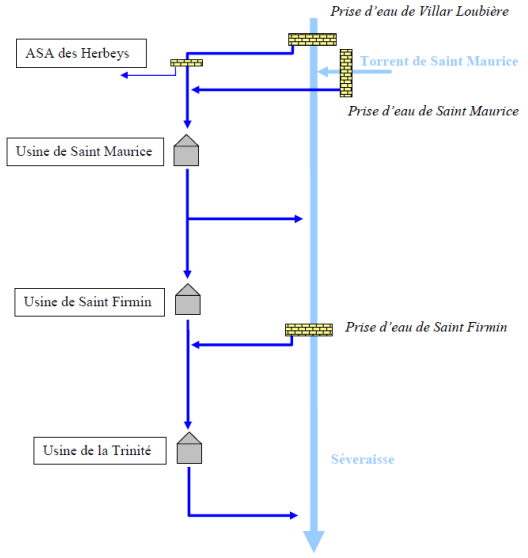
HyMoCARES defines hydropower as a usage of abiotical natural capital as opposed to usage by an ecosystem service. It will nevertheless be considered in the following paragraphs. Data for this ES come from two studies, *Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012* and *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*, as well as from the *Petite Hydroélectricité et Environnement en région PACA* database.[6]

This ES is studied at the drainage basin level.

3.1.4.1.1 Drac

Most of the hydropower plants on the Drac are located on the Séveraisse tributary (three in total) and the Torrent du Buissard. There is also a plant at Lac du Sautet/Cordéac and another at Pont Sarrazin. An overview of hydropower generation on the Séveraisse tributary is given below.

[6] http://phee.geres.eu/base-de-donnees



Cours d'eau	Nom de l'aménagement *(puissance brute)*		Longueur court-circuitée	Débit réservé (l/s)
Séveraisse	St Maurice en Valgaudemar *(11.7 MW)*		7 000	506
Séveraisse	St Firmin *(1.3 MW)*		5 000	400
Séveraisse	La Trinité *(4.6 MW)*		2 500	789
Torrent du Buissard	Centrale de l'Union des ASA de St Bonnet 2 prises d'eau *(496 kW)*	Chabottes	9 000	650
		Torrent du Buissard	700	17
Séveraissette	La Motte *(1103 kW)*		4 000	250 de novembre à mars et 300 d'avril à octobre
Sézia	La Salette *(1 700 kW)*		1200	50 en hiver 100 en été
Drac (Dépt 38)	Le Sautet/Cordéac (140 MW)		3000 sur la Sézia	800 au contre- barrage
Drac (rejet dans la Luye)	Pont-Sarrazin (Gapençais) *(1647kW)*		Transfert de bassin versant	280 et été 220

Figure 8: Overview of hydropower generation on the Séveraisse tributary, plus infrastructure description table (source: Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012)

The *Petite Hydroélectricité et Environnement en région PACA* database gives details, for each power plant, of flow rate, installed power and annual output (in kWh).

Hydropower plant/infrastructure name	Commune and description	Flow rate	Installed power	Annual output (kWh)
La Trinité	Saint-Firmin - Torrent de la Severaisse	10,000 m³/s	3,420 KW installed	14,400 MWh/year
Les Herbeys	Saint-Maurice-en-Valgodemard	unknown	400 KW installed	unknown
Saint-Maurice	Saint-Maurice-en-Valgodemard	10,000 m³/s	9500 KW installed	40,000 MWh/year
La Serre	Benevent and Charbillac - Torrent de la Severaissette	0.4 m³/s	868 KW installed	3,000 MWh/year
Saint-Bonnet-en-Champsaur	Torrent Le Drac	0.4 m³/s	470 KW installed	2,400 MWh/year

Table 24: Description of small hydropower plants in the Drac drainage basin (source: Petite Hydroélectricité et Environnement en région PACA)

The Pont Sarrazin plant, located at the Les Ricous gauging station, has been operated by ASA du Canal de Gap since 1976 (30+ years). The turbine also runs off captured water from the Drac. It is a micro hydropower plant with power of 1,645 kW, comprising two separate, identical units. The flow rate is 460 l/s.

The plant at Lac du Sautet/Cordéac has gross installed power of 140 MW. This plant is a dam installed in Isère. The Lac du Sautet section was commissioned in 1935, and the Cordéac section in 1946.

At the Drac workshop, the participants took a positive view of hydropower generation, mentioning that it supports "coordinated sediment management, which limits silting of the Lac du Sautet".

3.1.4.1.2 Buëch

The Saint-Sauveur dam is the main hydropower plant on the Buëch.

According to *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011*: "The Saint-Sauveur dam is located on the Buëch, 4 km downstream of Serres in the communes of Méreuil and Le Bersac. The dam reservoir has a capacity of 1,000,000 m³. The Saint-Sauveur reservoir has diverted part of the waters from the Buëch to Sisteron since spring 1992. The river supplies 577 Mm³ of water each year to the dam. The minimum downstream volume is 42 Mm³. In 2006, the total reported volume of water diverted was 200 Mm³."

3.1.4.2 SEDIMENTS FOR CONSTRUCTION

Stream bed extraction is one of the major causes of channel deepening and regressive erosion on the Drac and the Buëch. This ES is studied at the drainage basin level.

According to UNICEM[7]/MEDDE SOeS, total revenue for the Hautes-Alpes quarry and construction material industry stood at €20 million in 2015.

According to the *Schéma départemental des carrières des Hautes-Alpes 2013*, sediment extraction happens in the Champsaur section is concentrated in the communes of Champoléon, Buissard, Chabottes and Beaufin/Le Glaizil (at Le Motty).

Sediments are also extracted in the commune of Champoléon at Pont de Corbières and in Saint-Jean Saint-Nicolas at Les Ricous.

The *Schéma départemental des carrières des Hautes-Alpes* does not feature any extraction points in the communes identified as being within the restoration site on the Buëch (Upper and Lower Buëch), Veynois and Laragnais.

For the Buëch (Grand Buëch specifically), there are several locations that could potentially be extraction sites in the pre-identified communes. These include:

- the high terraces to the west of Montrond and to the north and south of Méreuil (improperly classified fluvo-glacial formations with quartzite pebbles)

[7] *Union nationale des industries de carrières et matériaux de construction* (National union of quarry and construction material industries)

- the low and mid-range terraces to the south of Montrond, which are of high agricultural value
- the high terraces of Serre de Devers.

Extremely high extraction potential has been identified on the wider river floodplain, especially at Montrond (where conditions are right for floodplain extraction).

Commune	Lieu-dit	Exploitant	Quantité autorisée (T)	Nature matériau	Usage	AP en cours	Echéance
CERVIERES	Clapes du Lasseron	GUERIN	100000	éboulis	Granulats	18/12/1996	10/10/2016
CHABOTTES	Sante et Les Pellas	PASCAL ANDRE	100000	alluvions	Granulats	08/08/2011	08/08/2036
CHAMPOLEON		GUERIN	42000	grès	Granulats	06/04/2006	30/04/2026
GUILLESTRE	Le Riou Bel	SECAM	2800	pierre marbrière	Pierres de taille	10/01/1996	10/01/2026
LA BÂTIE-MONTSALÉON	Garenne	CLAVEL EMERY	80000	alluvions	Granulats	28/07/2011	28/07/2041
LA CLUSE	Dessous le Rocher	CARRIERES ET BALLASTIERES DES ALPES	48000	éboulis et roche massive	Granulats	20/08/2003	20/08/2018
LARDIER ET VALENCA	Plan de Lardier et Iscles	CARRIERES ET BALLASTIERES DES ALPES	80000	alluvions	Granulats	05/07/2013	05/07/2023
LAZER		PLACOPLATRE	150000	gypse	Industrie	17/11/1988	17/11/2028
MONÊTIER-ALLEMONT	Rocher de Chantelle	SABLIERES DU BUECH - SARL SAB	20000	éboulis	Granulats	03/04/2009	03/04/2019
MONTMAUR	Le Rocher Roux	CARRIERES ET BALLASTIERES DES ALPES	450000	roche massive	Granulats	07/01/1997	07/01/2017
MONTMAUR	Le Boutariq	SABLIERES DU BUECH - SARL SAB	24000	roche meuble	Granulats	28/07/2011	28/07/2021
REMOLLON	Le Plantas	GUIRAMAND	50000	roche massive	Granulats	31/07/2012	31/07/2022
SAINT-CRÉPIN	Barrachin les Balmes	CHARLES QUEYRAS TP	240000	roche massive	Granulats	27/01/1997	27/01/2017
SIGOTTIER	La Villette	CLAVEL EMERY SARL	4400	alluvions	Granulats	25/07/2008	25/07/2028
VENTAVON	Le Beynon	SABLIERES DU BUECH (SAB)	490000	alluvions	Granulats	04/12/2006	04/12/2036

Table 25: List of quarries in the Hautes-Alpes (source: Schéma départemental des carrières des Hautes-Alpes 2013)

For the communes included within the restoration site, the *Schéma départemental des carrières des Hautes-Alpes 2013* features the Chabottes quarry on the Drac, operated by company Pascal André and extracting 100,000 tonnes of granulate per year.

The "sediments for construction" ES was only mentioned at the Drac workshop.

The participants spoke in largely positive terms, including the following direct quotations:

- "coordinated management, which has supported an ongoing business and helped limit terrace extractions while retaining river extractions"
- "activities for (small) businesses"
- "construction materials".

However, some participants used more negative language: "restoration = the end of quarries and extraction?" and "excessive extraction of materials can compromise other ecosystem services: biodiversity, leisure, water quality".

Focus on HyMoCARES questionnaire:

The questionnaire asked the following question: "In your view, which ecosystem services are affected by hydromorphological changes such as the construction of weirs or dams, flow rate regulation, bank reinforcement, sediment extraction, etc.?" Of the 57 respondents, 45% said that the changes had a "strong" impact on "usage of abiotic natural capital" services, especially hydropower. Some 14 respondents had no opinion or did not reply.

The table below gives a summary of the relative "weight" of different ES and their main characteristics. For each ES, the table gives the data source, along with the scale(s) at which the ES was studied.

The table also contains two key concepts:

1- **Effect of the restoration on the ES in question**: on a 5-step scale from "very negative" to "very positive". Blue indicates that the effect is neutral, or that it was not possible to measure the effect of the restoration on that particular ES. The effect scores are based on ecological summary work and, where applicable, participants' feedback on the effects at the workshops.

2- **ES priority**: on a scale ranging from "--" to "++", with "+/-" signifying a neutral opinion, or that the ES in question is neither high nor low priority. "Unknown" indicates that the priority of that particular ES is unknown. The priority scores are based largely on the interviews and workshops, as well as on responses to the HyMoCARES standard questionnaire (WP4 action 4.2).

Main group	Subgroup	Ecosystem service (ES)	ES considered: Y/N	Scale	Data sources (for qualification and quantification)	Priority: Buëch	Effect of restoration: Buëch	Priority: Drac	Effect of restoration: Drac
Provisioning	**Nutrition**	Cultivated crops	YES	Commune	*Recensement Général Agricole* (RGA) 2010	+/-		+/-	
		Plant resources for agricultural use - Pasture	YES	Commune	*Recensement Général Agricole* (RGA) 2010	++		+/-	
		Surface water for drinking purpose	YES	Commune	Agence de l'Eau Rhône Méditerranée Corse water charging data, February 2015 CEREMA data from the AlpES project	++		+/-	
		Ground water for drinking purpose	YES	Commune	Agence de l'Eau Rhône Méditerranée Corse water charging data, February 2015	+		++	
	Resources	Fibres and other resources from plants for direct use or for processing - Resources related to the riparian forests, wood	YES	Commune	*Occupation du sol 2016*, CRIGE PACA CEREMA data from the AlpES project	Unknown		-	
		Water for non-drinking purposes in industry and agriculture (surface water and ground water)	YES	Drainage basin	*Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012* & *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011* Agence de l'Eau Rhône Méditerranée Corse water charging data, February 2015	+/-		++	
	Biomass-based energy resources	Plant-based resources from agriculture, short rotation coppice, forestry	YES	Commune	*Recensement Général Agricole* (RGA) 2010 Observatoire régional de la forêt méditerranéenne - *Données & chiffres-clés 2014*	+/-		-	

Regulation & maintenance	**Retention (Self-purification)**	Retention of nutrients	YES	Measuring station	*Evaluation des effets écologiques de la restauration hydromorphologique de deux tronçons de cours d'eau et évaluation des services écosystémiques associées - cas d'étude du Drac et du Buëch – Maison Régionale de l'Eau*	+		+	
	Global climate regulation	Reduction of greenhouse gas emission/carbon sequestration	YES	Commune	*Occupation du sol 2016*, CRIGE PACA	+/-		+/-	
	Extreme discharge mitigation	Flood risk mitigation (flooding and risk related to morphological dynamics of rivers)	YES	Drainage basin	*Technical note about the monitoring of hydromorphological restoration of the Buëch/Drac River (Hautes-Alpes, France)*, IRSTEA	+		++	
		Drought risk mitigation	YES	Drainage basin	*Technical note about the monitoring of hydromorphological restoration of the Buëch/Drac River (Hautes-Alpes, France)*, IRSTEA	++		Unknown	
	Sediments (incl. suspended)	Soil formation in floodplains	YES	Drainage basin	*Technical note about the monitoring of hydromorphological restoration of the Buëch/Drac River (Hautes-Alpes, France)*, IRSTEA	+/-		+/-	
	Micro and regional climate regulation	Regulating temperature/Cooling (water bodies and ground)	YES	Commune/measuring station	*Occupation du sol 2016*, CRIGE PACA *Evaluation des effets écologiques de la restauration hydromorphologique de deux tronçons de cours d'eau et évaluation des services écosystémiques associées - cas d'étude du Drac et du Buëch – Maison Régionale de l'Eau*	+/-		-	
	Habitat-related services	Habitat-related services	YES	Drainage basin & measuring station	*Occupation du sol 2016*, CRIGE PACA *Evaluation des effets écologiques de la restauration hydromorphologique de deux tronçons de cours d'eau et évaluation des services écosystémiques associées - cas d'étude du Drac et du Buëch – Maison Régionale de l'Eau* CEREMA data from the AlpES project	++		+	

Cultural	**Scenery**	Aesthetics of landscape	YES	Drainage basin	*Atlas paysager – La vallée des Drac - Département des Hautes Alpes* *Atlas paysager – La vallée du Buëch - Département des Hautes Alpes*	++		++	
	Emotional and intellectual interactions	Natural and cultural heritage of the river and floodplain ecosystem	YES	Commune	Flickr	++		++	
		Education, science	YES	Drainage basin	Google Scholar & Google Search	++		-	
	Water-related activities	Water-related activities (recreational)	YES	Drainage basin	*Schéma Départemental de Développement du Loisir Pêche - 2018 – Fédération de Pêche des Hautes Alpes* Lake websites Phone or written interviews with white-water sports companies	++		++	
Usage of abiotic natural capital		Hydropower	YES	Drainage basin	*Études d'estimation des volumes prélevables globaux - Sous bassin versant du Haut Drac – Septembre 2012 &* *Étude de détermination des volumes maximum prélevables sur le bassin versant du Buëch- Juillet 2011* *Petite Hydroélectricité et Environnement en région PACA*	+++		-	
		Navigation	NO, no navigation in the area covered by the study						
		Sediments for construction	YES	Drainage basin	*Union nationale des industries de carrières et matériaux de construction* *Schéma départemental des carrières des Hautes-Alpes 2013*	+/-		+	

3.2 MONETISATION OF ECOSYSTEM SERVICES

3.2.1 MONETISATION: DEFINITIONS AND METHODS

The Department commissioned a study of the monetisation of ES for the Drac only.

This section addresses the following question: can the additional well-being obtained through restoration of the Drac be ascribed a monetary value and, if so, for what aspects?

A monetary value can be placed on the variation in the services that the ecosystem provides between its two states.

Consequently, wherever possible, the focus of this section is on the monetary value of the restoration.

The previous sections of this report (qualification and quantification) give an overview of how and why economic agents use ecosystems and the services they provide. The task now is to determine what the restored ES are "worth" (in monetary terms) to users.

Since value can be quantified or monetarised, it is important to find an equivalence between price and value by, for instance, using the notion of willingness to pay or receive payment, cost-benefit analysis, etc. These methods and analyses are tests – additional tools for qualifying and quantifying ES. These methods are used in the WFD-CBA tool (see 3.2.2), along with all the usual pros and cons (inflation of value, geographical scale that does not match the area studied, etc.). Nevertheless, for all their faults, these methods have one major advantage: they exist (and are summarised in the WFD-CBA tool).

There are various methods for calculating the economic value of an ES (and therefore, the monetary value of that service), as shown in the figure below:

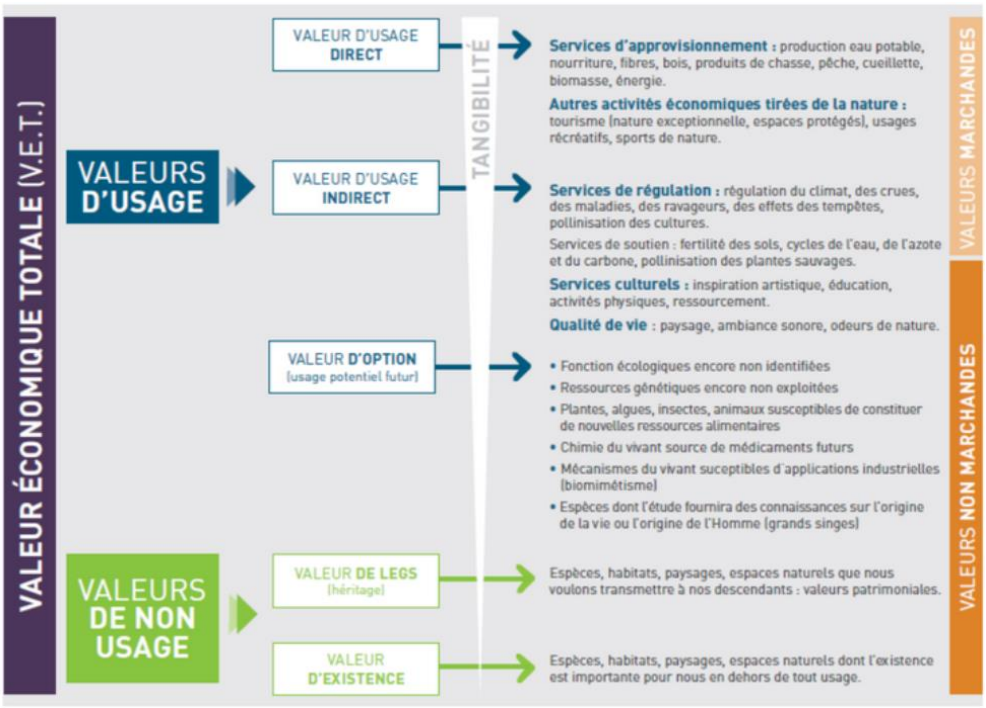


Figure 9: Different concepts of value (source: http://www.espaces-naturels.info/quelles-valeurs-s-agit-il)

According to the "References" guide *Evaluer les bénéfices issus d'un changement d'état des eaux (actualisation en vue du 2ème cycle DCE)*, published by the Commissariat Général au Développement Durable in May 2014, there are generally two types of value in environmental economics:

- Use values, which refers to the direct benefits obtained from consumption or practices associated with natural assets. This category is divided into three subgroups:
  - Direct use value: the value of a service used directly by an economic agent (e.g. drawing water for drinking, fishing, bathing in a lake)
  - Indirect use value: the value of a service used indirectly in the production of another good or service (e.g. self-purification, flood regulation)
  - Option value: the value placed on preserving an asset for potential future use.

- Non-use values, which people assign to an environmental good even if they do not use it. This category is subdivided into:

  - Bequest value: the value placed on bequeathing an environmental asset to future generations
  - Altruistic value: the value placed on preserving an environmental asset so that future generations may make use of it

- Existence value: the intrinsic value placed on the very existence of an environmental good or service, regardless of its use (e.g. an endemic species, even if it is of no actual or potential economic value).

The "References" guide includes a template for carrying out a cost-benefit analysis, known as the "WFD-CBA" tool.

The "WFD-CBA" tool was developed in 2007 by the French Ministry of Sustainable Development's Department of Economic Research and Environmental Evaluation to conduct CBAs at the level of water bodies (river, lake, etc.).

It is an **Excel spreadsheet** incorporating values drawn from a 2007 literature review. It is a relatively simple way to conduct a CBA and can be used to calculate the costs and benefits arising from the status change of a water mass (through value transfer). The version published on 1 April 2014 was used for the purpose of this study. The data therefore come from 2014, and have been converted to 2019 values.

Only the "benefits" section of the tool will be used in this study.

The tool allows users to estimate benefits against a set of "guide values" (it lists the reference values from various studies performed, among others, by the CGDD and by water agencies). The reference values derived from the literature review are similar to the key concepts and value estimation methods seen above. This method is situated mid-way between the less detailed qualitative approach and the more detailed in-situ study approach. The figures should be interpreted as guidelines as opposed to intangible values per se.

To recap, the Water Framework Directive (WFD) of 23 October 2000 established a framework for Community action in the field of water policy. It requires Member States to achieve good status of their water bodies by 2015.

While the restoration of the Drac is does not necessarily fit within the "good status" framework, the work did have a beneficial effect on the Drac (the water body) and improved its quality.

Other than literature reviews, which can only be carried out on a case-by-case basis, there is no other tool available for analysing ES to this degree of detail. It was therefore decided that the tool should be used.

The tool was adapted to the circumstances of the Drac, since it can be configured with local parameters such as the number of households, the number of users, or other factors.

As a standalone tool it is not necessarily suitable. For this reason, it will be combined with specific analyses and adapted to the circumstances of the Drac using data and information from expert insights, workshops, phone interviews, and wetland-specific methods and values.

3.2.2 RESULTS OBTAINED WITH THE "WFD-CBA" TOOL

The benefits can be modelled for different environments. In this case, the "water course" environment was used.

Consequently, the results focus on the most realistic benefits that best match the case study in question.

Asset value (non-use): River restoration (10-15 km/year) and maintenance (5-10 km/year) project, using manual techniques. Small drainage basin (main river: 19 km), in a rural area.

The proposed values are also linked to the "walking" use.

€20.10 per household per year (€ $_{2012}$) is the CGDD-recommended value (to be used as a priority). This applies to primarily to households in communes through which the rivers pass.

The total benefit for the asset value is obtained by applying a high and low range of affected households (in the communes through which the rivers pass). Here, the "households" figure can be obtained from INSEE data (see table below). A number of 2,053 households is therefore entered in this field.

Households in the Drac communes in 2015	
Commune	**No. of households**
Chauffayer	175
Saint-Bonnet-en-Champsaur	905
Saint-Julien-en-Champsaur	151
Chabottes	380
Saint-Jean-Saint-Nicolas	442
TOTAL	**2,053**

Ecosystem value: target of restoring fish population balance (fish richness):

€35.90 per household per year in €$_{2012}$, to be applied to households at the site (2,053).

The total sum of ecosystem value benefits plus supplementary uses is **€73,702 per year**.

Supplementary benefits for fishing:

- Non-market benefits for existing recreational fishers

The ecological summary revealed a sharp increase in the brown trout population; the associated value, deriving from the fact that wild fish (pike, trout) can live and reproduce in the aquatic environment (unlike previously, when they were absent or only present in small number) is estimated at €8.80 per fisher per year (€$_{2012}$).

The Fédération de Pêche des Hautes Alpes provided details of the number of fishers in the area covered by the three Drac AAPPMAs (4,644 fishers). Consequently, the non-market benefits for existing fishers on the Drac is €40,867 (€$_{2012}$), or €42,726 (€$_{2018}$).

- The restoration, which caused a spike in the brown trout population, may also provide non-market benefits for supplementary fishers. The calculated benefits relate to sedentary salmonid (brown trout) fishing.

According to the CGDD tool, these benefits can only be counted if the number of fishers rises significantly. Since the ecological summary points to a sharp rise in the brown trout population, it is reasonable to conclude that the number of fishers will rise sharply too.

The unit benefit per visit and per fisher is estimated at €3.02 ($€_{2012}$) and the minimum number of fishing trips per fisher per year is set at 17, capped at a maximum of 36. According to the *Schéma départemental de pêche des Hautes-Alpes*, each fisher makes an estimated 36 trips per year:

> À la question 14, estimez votre nombre de sorties pêche en 2015 ?
> (le champ était libre de réponses pour le département des Hautes-Alpes et une autre réponse extra départementale).
> - Moyenne pour le département des Hautes-Alpes : 36 jours/an
> - Moyenne extra département 21 jours/an

It was decided, arbitrarily, that one-quarter of the rod licence-holders in the Drac (or approx. 1,000 fishers) fish for salmonids (the initial premise being that not all fishers go fishing for the same reasons, the same motivations or the same fish).

The additional benefit arising from supplementary fishers is therefore between €513,400 ($€_{2012}$) and €1,087,200 ($€_{2012}$), or €536,760 ($€_{2018}$) and €1,136,668 ($€_{2018}$).

These benefits should be contextualised using the qualitative and quantitative data contained in the February 2014 study by BIPE and the Fédération Nationale de Pêche, entitled *Impacts socio-économiques de la pêche de loisir en eau douce en France*, and by expert insights from the Fédération de Pêche des Hautes Alpes.

In France, fishers spend €681 on average each year on their pursuit (excluding rod licence fees). Travel and food/drink spending stand at €145 and €55 respectively. The costliest single item is equipment, at €155.

For an overnight fishing trip, travel and food/drink spending are €49 and €31 respectively.

Starting from the premise that fishers spend €681 on average each year (average spend for 2011) on their pursuit, and that there were 4,644 rod licence-holders in the Drac in 2018, and that (according to the Fédération de Pêche des Hautes Alpes) 51% of licence-holders come from outside the department (2,368 licence-holders), spending on fishing (and, therefore, the supplementary benefit for the Drac and Hautes-Alpes economy as a whole) is in the region of €1,612,908 ($€_{2014}$), or €1,663,392 ($€_{2018}$).

These spending figures give a brief snapshot of the potential macro-economic benefits.

According to the February 2014 study by BIPE and the Fédération Nationale de Pêche, entitled *Impacts socio-économiques de la pêche de loisir en eau douce en France*, fishing generally has the following economic benefits:

- ⇨ direct (accommodation, rod licences, etc.)
- ⇨ indirect: food/drink, services, guides, equipment, etc.

The economic benefits may be even greater, but they are difficult to quantify. According to the Fédération de Pêche des Hautes Alpes, the department's economy could benefit to the tune of around €7 million (expert estimations), and a further €100 should be added for accommodation for fishers coming from outside the department.

Supplementary non-market benefits for existing kayakers - occasional users (day users)

According to the CGDD tool, the recommended value (to be used as a priority) is €8.70 per household per year ($€_{2012}$).

A high and low range of supplementary kayakers was applied, based on the number of households in the area covered by the study (2,053 households).

For this study, the low range was taken as 10% of the number of households concerned by the effect of the restoration work on kayaking (205 households).

The high range was 20% of households, or 410 additional households.

- ⇨ The supplementary benefit arising from the restoration for existing kayakers is therefore between €1,784 ($€_{2012}$) and €3,567 ($€_{2012}$), **or between €1,865 and €3,729 ($€_{2018}$).**

Non-market benefits for existing bathers: these benefits are difficult to quantify without interviewing tourist office representatives or running field surveys, since it is hard to estimate the number of supplementary bathers.

However, the CGDD's CBA tool recommends a figure of €35.40 per bather per year ($€_{2012}$).

The low-range value (+10% bathers) was chosen, implying a supplementary benefit of €7,292 ($€_{2012}$), or €7,624 ($€_{2018}$).

3.2.3 RESULTS OBTAINED FOR "OTHER" ECOSYSTEM SERVICES

There are different data sources, and therefore different reference values, for the other ES that could potentially be "monetised" post-restoration.

These sources include:

- *Les services écosystémiques des forêts et leur rémunération éventuelle*, by Bernard Chevassus-au-Louis and Romain Pirard, published in 2011, which gives a series of reference values for different service types:

Services		Valeur (€/ha/an)
I. Approvisionnement	Bois Autres cueillettes	75-160 10-15
II. Régulation	Fixation du carbone Stockage du carbone Eau (quantité) Eau (qualité) Protection Habitats et biodiversité	115 414 Non évalué 90 Non évalué Non évalué
III. Culturels	Visites Chasse	200 (0-1 000) 55-69
Total		Environ 1 000

Figure 10: Les services écosystémiques des forêts et leur rémunération éventuelle, Bernard Chevassus-au-Louis, Romain Pirard

- The ONEMA guide, which also gives a battery of values for use in economic valuation, especially for floods.

Type de bénéficiaire	Détail/information	Unité	Domaine d'application	Prix unitaire Min	Prix unitaire Max	Milieu/ Catégorie de masses d'eau	Lieu de l'étude
Lutte contre les inondations	Valeur économique moyenne de 15 études françaises	€/ha		37 €	617 €	Zone humide	National
Lutte contre les inondations	Valeur économique moyenne selon la méta-analyse de Brander et al. (2003) à partir de 89 sites	€/ha		438 €		Zone humide	International

Figure 11: Les évaluations économiques en appui à la gestion de l'eau et des milieux aquatiques, Maria Salvetti, ONEMA, Ministère de l'écologie, du développement durable et de l'énergie

- Other, more focused studies that give threshold and ceiling values for major categories of ES. For instance, the table below contains per-hectare values for services provided by wetlands in the Marais du Cotentin et du Bessin Regional Nature Park (in euros):

Services	Min.	Max.
Services de régulation		
• Recharge des aquifères et soutien d'étiage	190	370
• Purification de l'eau	830	890
• Régulation du climat	1 800	1 800
Services de production		
• Agriculture	585	750
• Conchyliculture	120	120
Services culturels		
• Chasse	170	340
• Pêche amateur	165	230
• Valeur éducative et scientifique	10	15
• Valeur esthétique et récréative	290	1 170
• Appartenance au site	Non évaluée	Non évaluée
• Biodiversité (non-usage)	225	870
Valeur économique totale	2 400	4 400

Figure 12: Per-hectare values of services provided by wetlands in the Marais du Cotentin et du Bessin Regional Nature Park

Regrettably, it is difficult to monetise the effect of the morphological restoration within the narrow confines of the restoration site only.

As the examples below show, there is a major difference between considering an ES within the restored site only, and considering it across the Drac territory as a whole (all the communes affected by the restoration).

3.2.3.1 EXAMPLE 1: CARBON SEQUESTRATION

In their study entitled *Les services écosystémiques des forêts et leur rémunération éventuelle* (2011), Bernard Chevassus-au-Louis and Romain Pirard estimate the value of carbon sequestration at €414 per hectare per year ($€_{2011}$). Factoring in all resources capable of sequestering carbon (estimated at 7,431 ha), the total value stands at €3,070,500 ($€_{2011}$), or €3,279,458 ($€_{2018}$).

3.2.3.2 EXAMPLE 2: PROVISIONING – WOOD

Total woodland in the area covered by the study stands at 3,364 ha. Applying the reference values (€75-160 ($€_{2011}$) per hectare per year) gives a value of between €252,300 ($€_{2011}$) and €538,240 ($€_{2011}$), or between €268 944 ($€_{2018}$) and €573,748 ($€_{2018}$).

In summary, it is difficult to monetise ES such as wood, agriculture (provisioning), carbon sequestration, extreme discharge/flood risk mitigation, or climate regulation. This is because the size of the area impacted by the restoration is either unknown or difficult to quantify (for instance, the impact of the restoration on the number of hectares of forest, on CO_2 stock, on affected farmland in hectares, etc.). The results obtained by applying default values, which cover the entire territory, over-value ES and represent a territory in its entirety as opposed to a particular restoration site.

3.2.3.3 MONETISATION OF USAGE OF ABIOTIC NATURAL CAPITAL

It is extremely difficult to put a monetary value on the effect of the restoration on hydropower generation, other than using the revenue earned per plant. Moreover, most plants are located upstream of the restoration site. Therefore, in theory, they should derive no monetary benefit from the restoration work.

The restoration of the degraded reach upstream of Saint-Bonnet-en-Champsaur (2013-2014) involved widening the active strip of the channel by injecting more than 450,000 m^3 of coarse sediment. Little data is available, however, about sediment extraction associated with the restoration work. The information that is available comes from the following document: *Evaluation économique des services rendus par les zones humides – Etudes et documents – n° 23 - Juin 2010 – Commissariat général au développement durable*, which mentions a figure of €5,000 hectares per year. Regrettably, this figure is unusable for this monetisation exercise.

3.2.4 CONCLUSIONS ON THE MONETISATION OF ECOSYSTEM SERVICES

In conclusion, monetising the ES provided by the restoration of the Drac is not a straightforward process, and it is hard to identify the effects of the restoration work on certain services (supplementary carbon sequestration resulting from the restoration, increase or decrease in the number of hectares of woodland and crops, supplementary water filtration capacity, flood risk mitigation, etc.). This is due, in part, to the fact that it is almost impossible to quantify the geographical footprint of the restoration for each of these ES. Consequently, monetary values are not applicable. However, it may be possible to calculate monetary values on a much larger scale than the restoration site alone (all UAA in the five communes, wooded land, etc.), but the resulting values are extremely high.

Using the "WFD-CBA" tool, developed by the French Ministry of Sustainable Development for conducting CBAs at the level of water bodies, **the monetary value of the benefits derived from ES provided by the Drac ranges between €709,174 and €1,310,947 ($€_{2018}$)**. These figures do not include indirect benefits for the wider Hautes-Alpes economy (an additional €1,663,392). However, the underlying methods behind the CGDD tool pose a double counting risk, and this value is hard to extrapolate within the context of the restoration of the Drac.

4 GENERAL CONCLUSIONS

The term "ecosystem services" can be defined from various literature sources. The initial list produced by the HyMoCARES project is a useful resource for characterising the 18 ES provided by Alpine territories (the territories in which the Drac and Buëch restoration works took place).

The first step was to qualify, quantify and rank the various ES to the fullest possible extent.

The most common analysis scale is the commune, especially for "provisioning" services. The "station" scale is used more frequently for so-called "regulation and maintenance" services. It was possible to study these services at this more granular scale thanks to the work of the Maison Régionale de l'Eau and the available data.

For "cultural" services, the analysis scales vary. In some cases, it is convenient to qualify an ES (such as scenery) at the drainage basin scale, whereas a more granular scale can be used for others (especially water-related activities, such as a lake, fishing spot or bathing spot).

These ES were qualified and quantified using information from various databases and sources (CRIGE PACA, CEREMA, MRE ecological summary), as well as from other, more global studies such as withdrawable volume estimates and master plans. The data sources are not uniform, which can introduce bias into how they are interpreted and understood.

Wherever possible, services were quantified using existing data. In some cases, however, quantification proved complex, especially for the "aesthetics of landscape" and "natural and cultural heritage of the river and floodplain ecosystem" services. Here, most of the available information was qualitative and the analysis scales varied markedly.

For the Buëch, "water-related activities" emerged as one of the most important subgroups, with the workshop participants considering this to be a representative service. The entire "cultural" category was rated positively. The participants also pointed to the "nutrition" subgroup as being important, whereas they felt the "regulation and maintenance" group was less of a priority. This was especially true of "regulation" services, which the exception of the "habitat" subgroup (possible because fishing interests were over-represented at the workshop when compared with other stakeholders).

It is also important to note that, at the workshop, many participants raised questions about the cost of the morphological restoration work, as well the supply of information and the longevity of the changes.

For the Drac, there was no clear ranking of one subgroup over services over another. However, the participants considered the following ES to be priorities: "flood risk mitigation", "ground water for drinking purpose" and "aesthetics of landscape". The following ES were also deemed to be important, albeit to a lesser extent: "water for non-drinking purposes in

industry and agriculture", "natural and cultural heritage of the river and floodplain ecosystem" and "water-related activities".

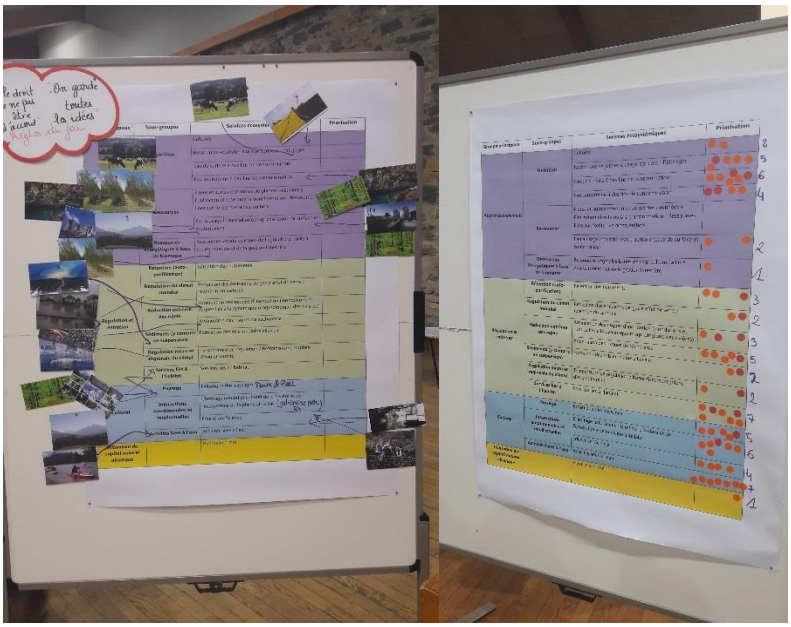
At the Drac workshop, the participants asked a number of questions about funding, the high cost to the community, and the social cost of the restoration work.

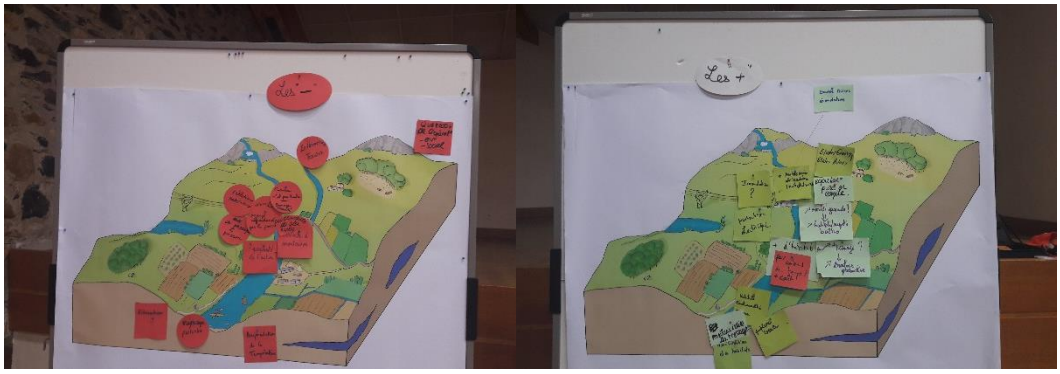
Lastly, the monetary value of the benefits derived from ES provided by the Drac was modelled, primarily using the CGDD's "WFD-CBA" tool**. The value obtained ranged between €709,174 and €1,310,947 (€$_{2018}$)**.

However, it is difficult to monetise certain ES such as wood, agriculture (provisioning), carbon sequestration, extreme discharge/flood risk mitigation, or climate regulation. This is because the size of the area impacted by the restoration is either unknown or difficult to quantify (for instance, the impact of the restoration on the number of hectares of forest, on CO2 stock, on affected farmland in hectares, etc.). The results obtained by applying default values, which cover the entire territory, over-value ES and represent a territory in its entirety as opposed to a particular restoration site. The findings of this analysis could be supplemented with more geographically focused surveys and inventories, so as to obtain a more precise value of an ES provided by morphological restoration.

ANNEXES

ANNEX 1: BUËCH WORKSHOP





ANNEX 2: DRAC WORKSHOP

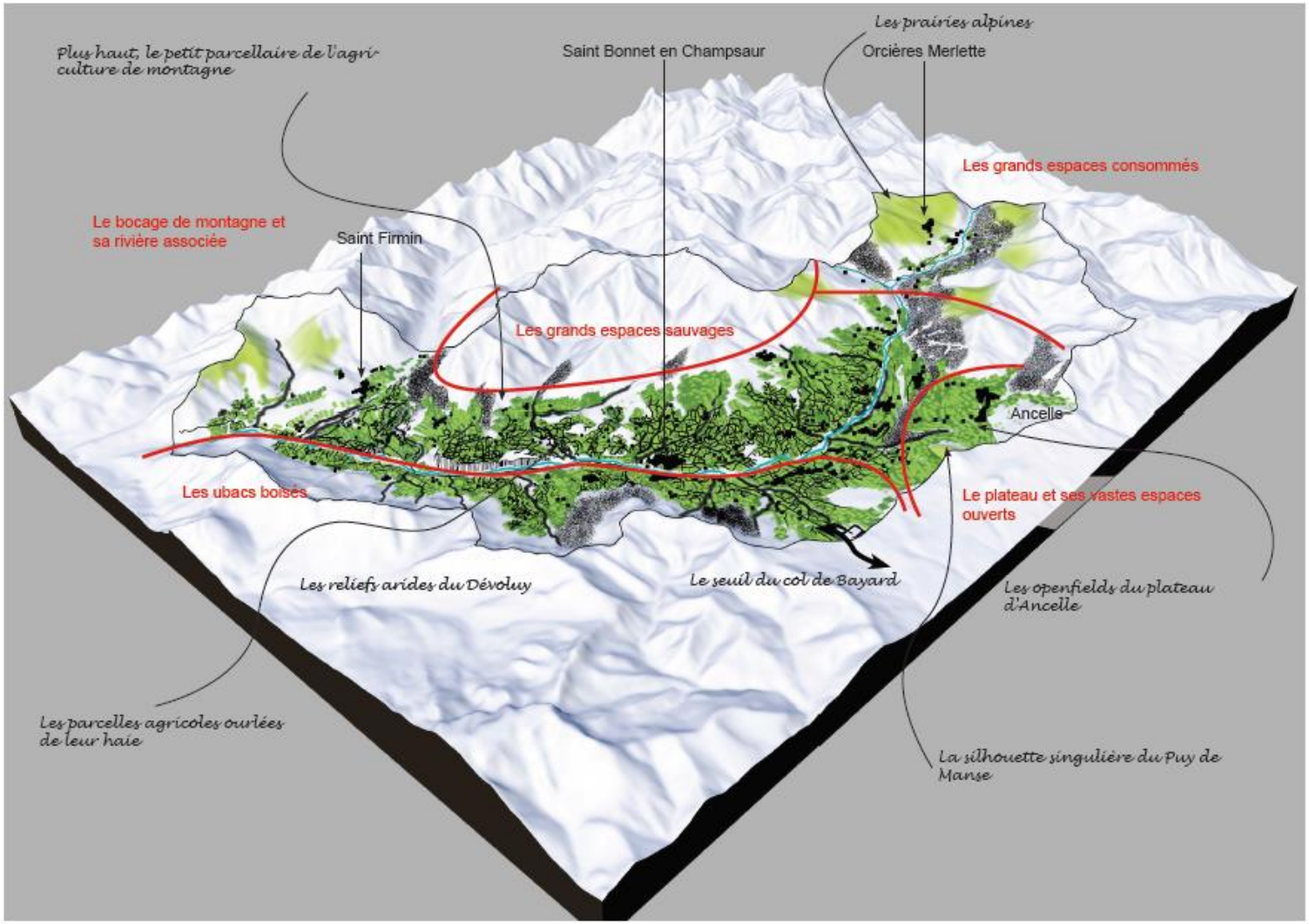

Coût Social ?
Coût / Avantages
Coût Financier
Loisirs Sport Tourisme


On a le droit de ne pas être d'accord
On garde toutes les idées
Règles du jeu
Plan d'eau

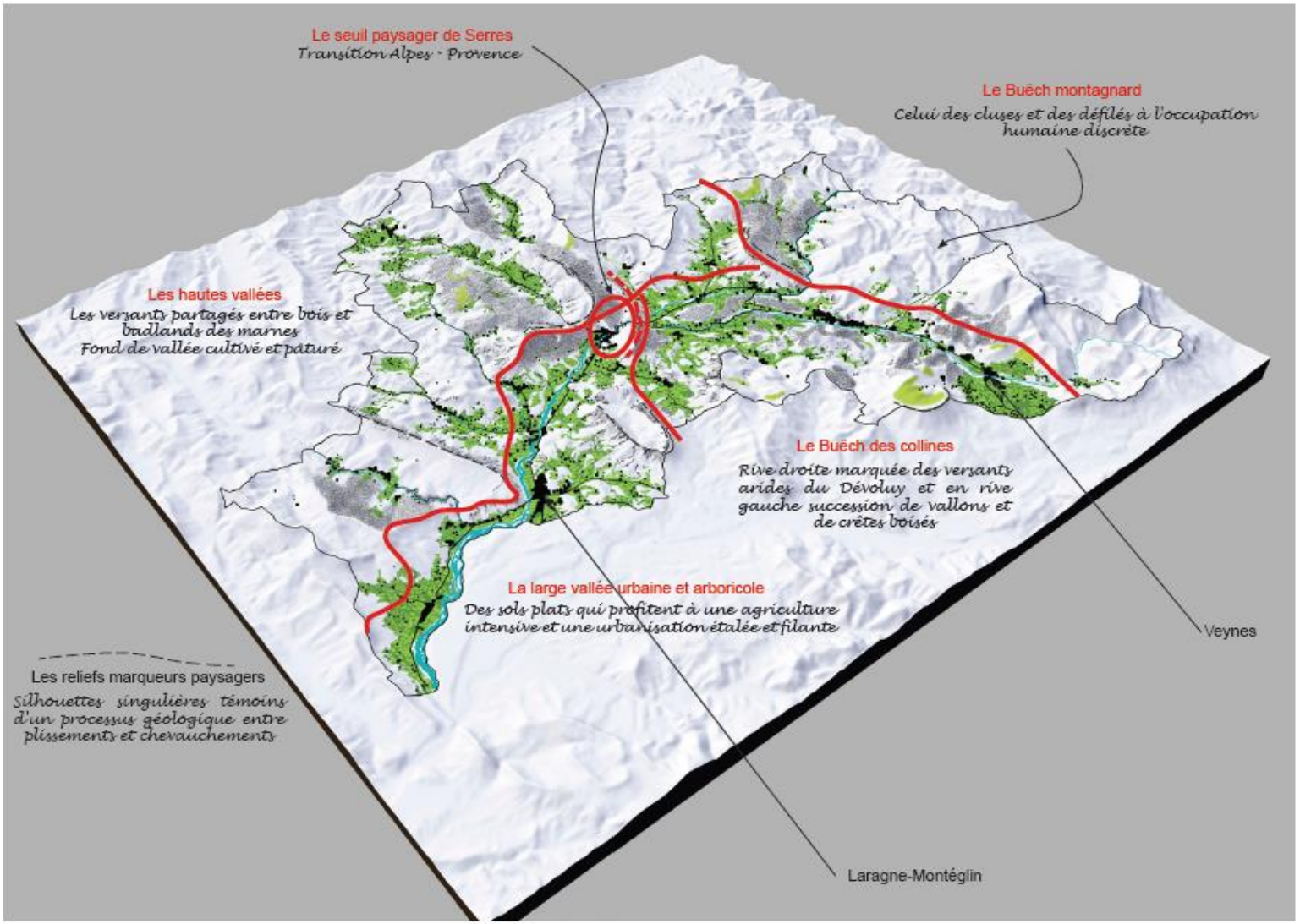
ANNEX 3: PARTICIPATORY WORKSHOP GUIDELINES

INTRODUCTION AND OPENING	5-10 min.	Introduction: explain that everyone is here today to talk about the same subject: ecosystem services (ES). Define what ES are in easy to understand terms. Present the three types of ES: provisioning/regulation & maintenance/cultural. Explain the objectives of the workshop to participants. Explain how the workshop will proceed, and the "spirit" in which it should be conducted. The "main" sequences.
Sequence 1: PERSONAL INTRODUCTIONS	5 min. 25 min.	Break the ice and create a group dynamic: each person introduces his/her neighbour. 5-minute discussion. Introductions: each participant introduces his/her neighbour. Aim: to identify similarities and differences between the organisations represented at the workshop.
Sequence 2: PHOTOLANGUAGE	45 min.	Assess how much the participants know about the ES provided by the Drac and the Buëch. Hand out pictures representing the ES (one image per ES); each participant chooses two and sticks them to an A4 sheet. In turn, the participants explain their choice and attempt to define what the picture represents. Together, place the ES in the categories to which they belong: provisioning/regulation & maintenance/cultural. Recap: On the board, present those ES that the Drac and the Buëch actually provide (HyMoCARES classification scheme).
Sequence 3: GROUP DISCUSSION/MAPPING	45 min.	Base this sequence on the landscape block diagram. Explain how a landscape block diagram works. Aims: 1) What ES does the restoration impact? 2) See whether certain ES "overlap" or not. Hand out cards (2-3). Each participant writes down the name of the ES in question, qualifies it, and indicates whether it is in conflict with or complements another ES. Situate ES spatially and identify them: Each participant pins his/her ES on the diagram, explaining what he/she has written on the cards.
END OF THE WORKSHOP: Debrief	15-20 min.	Sum up the workshop. Invite any final comments. Has anything important been overlooked? The participants are unlikely to have mentioned all ES, so talk about any that were "forgotten". Open-ended discussion.

ANNEX 4: LANDSCAPE BLOCK DIAGRAM: DRAC


Les prairies alpines
Plus haut, le petit parcellaire de l'agriculture de montagne
Saint Bonnet en Champsaur
Orcières Merlette
Les grands espaces consommés
Le bocage de montagne et sa rivière associée
Saint Firmin
Les grands espaces sauvages
Ancelle
Les ubacs boisés
Le plateau et ses vastes espaces ouverts
Les reliefs arides du Dévoluy
Le seuil du col de Bayard
Les openfields du plateau d'Ancelle
Les parcelles agricoles ourlées de leur haie
La silhouette singulière du Puy de Manse

ANNEX 5: LANDSCAPE BLOCK DIAGRAM: BUËCH


Le seuil paysager de Serres
Transition Alpes - Provence
Le Buëch montagnard
Celui des cluses et des défilés à l'occupation humaine discrète
Les hautes vallées
Les versants partagés entre bois et badlands des marnes
Fond de vallée cultivé et pâturé
Le Buëch des collines
Rive droite marquée des versants arides du Dévoluy et en rive gauche succession de vallons et de crêtes boisés
La large vallée urbaine et arboricole
Des sols plats qui profitent à une agriculture intensive et une urbanisation étalée et filante
Les reliefs marqueurs paysagers
Silhouettes singulières témoins d'un processus géologique entre plissements et chevauchements
Veynes
Laragne-Montéglin