WP4.4 Pilot Case Studies indicators database for MCA

Structure of Isère Basin decisional tree

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Author
Camille JOURDAIN

Member number and name
PP9 – Joseph Fourier University

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Summary

SHORT DESCRIPTION
This document intends to describe the structure of the SESAMO tree projects and the MCA application to the Pilot Case Study of the Isère River Basin.

Document Control

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Author	Camille Jourdain – cam.jourdain@gmail.com

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Table of contents

Abstract

This report describes the general methodological approach used in the application of the multi criteria analysis (MCA) method proposed in the SHARE project to the Arc-Isère pilot case study. After a short description of the Arc-Isère Basin, and of its specificities within the SHARE project, this report focusses on:

- The alternative description
- The Arc-Isère Sesamo tree structure,
- The indicator description and evaluation,
- The attribution of weights
- The alternative ranking

This report is a description, and also a justification of this application.
At the end of the report, a few points are discussed concerning this application of the method. This part allows us to share our experience of the SHARE methodology with potential future users.

Introduction

Arc-Isère Basin

The Isère River is located in the South-East of France, on the West side of the Alps. The drainage area upstream of Grenoble is about 5800 km². This basin, presented on Figure 1, shows many contrasts. The upstream basin is made of high, glaciated mountains. Downstream, urbanized and equipped mountains present a high concentration of ski resorts, as well as the most important hydroelectric system of France (Maurienne and Tarentaise Valleys). Last, near Grenoble and in the Grésivaudan Valley, an alluvial plain allows for a high density of inhabitation and agriculture. The water regime is nivo-glacial in the high basin, with low winter flows and very high spring flows. In Grenoble, the water regime retains a marked nival character (Peiry, et al., 1999).

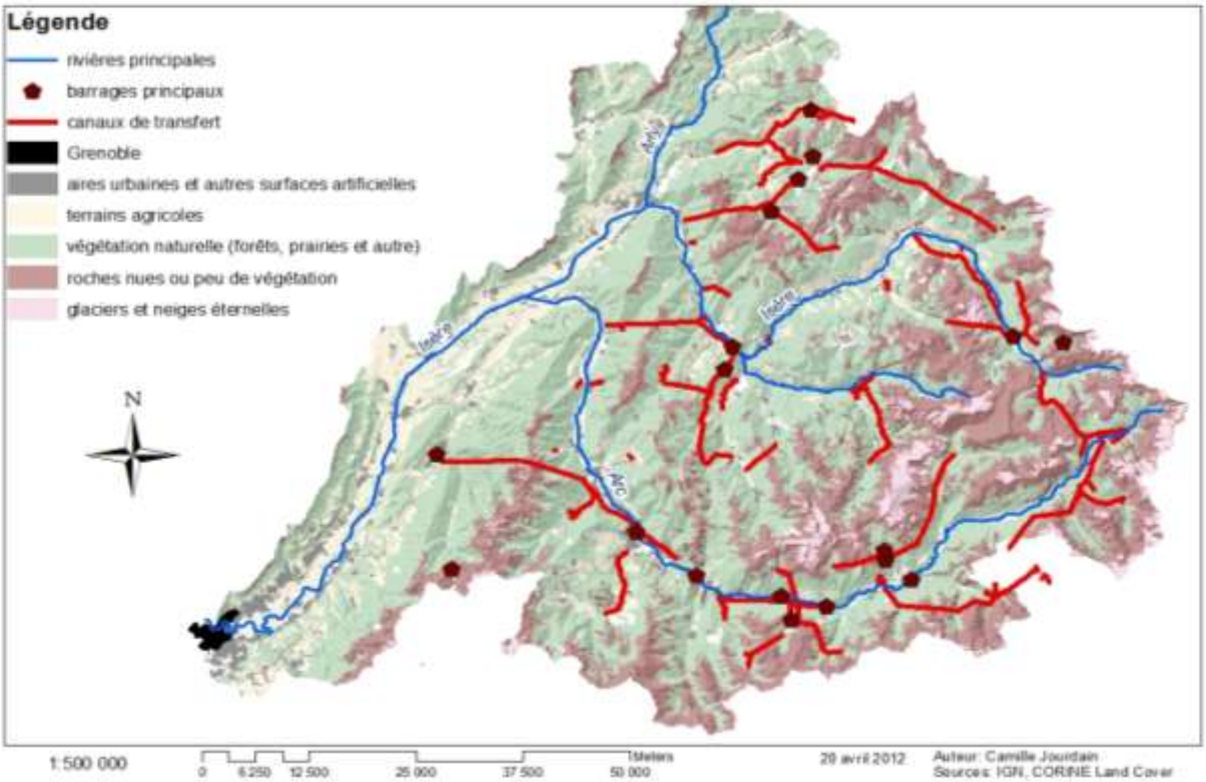


Figure 1: Presentation of Isère River Basin: hydrographic network, land use, and hydroelectric installation

The Isere Basin is highly anthropic. Bed correction works, started as soon as the XIXth century, and aiming at protecting Grenoble from floods, led to complete diking of the Isere River. The morphological style evolved from a large braided river to a channeled river, disconnected from its expansion spaces. Hydroelectric equipment of the Isere River has icreased in the second half of the XXth century in the upper basin. These works have strongly influenced the river hydrology, as well as the sediment transport continuity. They have also been supplemented by important inter basin transfers, modifying discharges event more. Lastly, large volumes of bed sediments have been mined directly from the bed during the XXth century, deeply modifying the sediment regime of the river (Peiry, et al., 1999).

Concerning watershed and hydroelectric management, the Isere River presents complex issues. Hydroelectricity, the economic driver of the region, has long been implanted in the basin. In particular, dams and reservoirs in the upstream basin allow the production of high demand energy. On the other hand, rich but fragile alpine ecosystems present an important environmental stake. The ecological situation of the Isère River is particularly critical in the Maurienne Valley upstream of Grenoble (SDAGE, 1996). Another important issue is the protection against floods, especially in Grenoble. Other factors are important, such as water demand and constraints from agriculture and industry. Recreational activities are also present in the main channel, in abandoned secondary channels, and in some reservoirs

Specifies of SHARE application in this Basin

The presence of these numerous issues and stakes make the Isère-Basin a good pilot case in the context of the SHARE project. More specifically, two aspects of the methodology proposed by SHARE are explored. On a methodological perspective, we examined how the proposed tool can be applied to a large, heterogeneous basin. On a more scientific perspective, we focused on the integration of hydro-morphological impacts of hydroelectric equipment in decision making processes concerning the management of the basin.

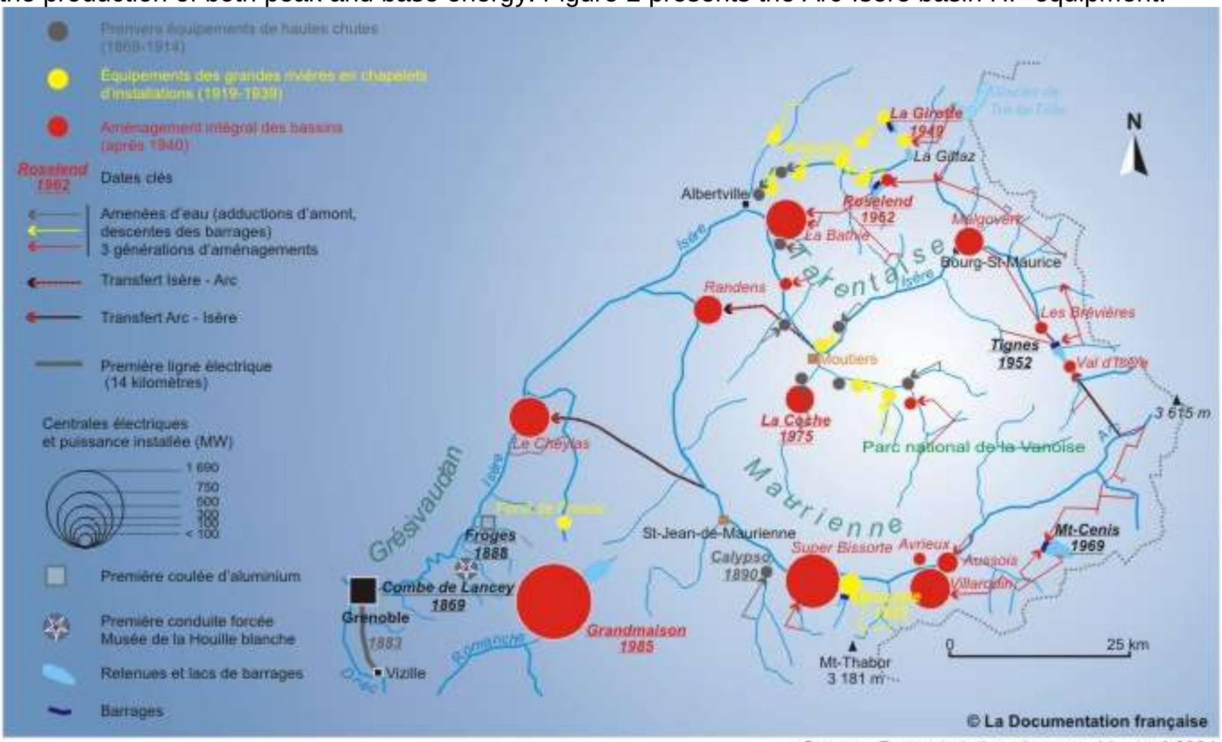
Outline of the report

This report will present the application of the SHARE methodology to the Arc-Isère Basin, focusing on the specificities of this application. First, the chosen management alternative will be explained. Then, the general structure of the tree will be described, as well as each indicator in detail. Third, we will explain how the weights were assigned. The results are provided in the next section. Lastly, a discussion of the methodology and of its application to the Arc-Isère Basin is provided, as a feedback of the PP9 experience of the application of the SHARE methodology.

Alternative description

Decisional setting

Since the Isere Basin is a case study to test a MCA method, the decisional setting is plausible, but fake. We place ourselves in an initial state of river equilibrium, with no hydroelectric equipment. This corresponds more or less to the 1950 situation. This specific choice is justified below. We wish to maximize hydroelectric production and minimize costs, while limiting the impacts of hydroelectric equipment on other factors such as flood risks or river ecosystems.
We aim at testing the impact of two types of hydroelectric installations: on the one hand, HPs that have a large storage capacity, which influence water and sediment discharges, and which allow to produced peak energy with a high monetary value. This type of installations occurs in the upstream basin. On the other hand, we consider installations that are more common downstream: run-of-river dams, and inter-basin water transfers, which have a strong impact on hydrological regimes, and allow the production of both peak and base energy. Figure 2 presents the Arc-Isère basin HP equipment.



Source : Documentation photographique n° 8034

Figure 2: hydroelectric equipment of the Arc-Isère River Basin (Maurienne and Tarentaise Valley)

Storage Dams

Reservoirs along the Arc and Isère Rivers upstream of their confluence have a storage capacity as high as 850 10^6 m^3. The main purpose of these installations is energy production. The exploitation of this energetic source has strongly contributed to the socio-economic development of the area. However, these installations have strongly modified the hydraulic characteristics of the Arc and Isère Rivers. The control of output discharges and the possibility to store large volumes of water in order to ensure energy production during low flow periods affect the natural functioning of the Isère River in a significant fashion. Solid transport depends directly upon the flow conditions in the river, so that the hydrological alteration modifies the capacity of the river to transport sediment material.

Pump storage dams, and inter-basin transfer canals

Pump storage dams (STEP in French) are installations which rest on two reservoirs. The water of the upper basin, located upstream, is turbinated at high electricity demand periods, and then is restituted to the lower, downstream reservoir. At low demand periods, water is pumped up to the upstream reservoir. This system allows the use of excess nuclear energy produced during the night, in order to

pump the water up to the upstream reservoir. This additional storage is then exploited during the day, in time of peak consumption.
EDF (GEH vallée de la Maurienne) is in charge of the two powerful pump storage dams of *Super Bissorte* and of *Cheylas*. The Tarentaise valley also hosts the *Cloche* pump storage dam. An important canalization network also exists, allowing the transfer of water within or between basins in order to refill reservoirs when necessary. These installations amplify the modification of the water and sediment regimes induced by storage dams.
As an example, the Arc-Isere derivation deprives the Isère River of 30% of its module between the Arc confluence and the Cheylas restitution. In the short-circuited section, high spring flows are markedly decreased. The consequence of the resulting decrease in solid transport appears very clearly in the geomorphologic functioning of the Isère River: since about 15 years, vegetation colonizes sand bars in this part of the river.

Micro-HP

France aims at developing its yet non-exploited renewable energy potential. Main energy sources are in upstream basins, in high slope streams.

Chosen alternatives

In the case of the Isère Pilot case study, it is not interesting to test the impact of micro-HP, because their impacts on downstream reaches are negligible.
New installation perspectives are relatively weak. It seemed more interesting to us to apply this method to an *a posteriori* evaluation of big HP realized in the XXth century, and especially since 1960, but with current management preoccupations.
The analysis of the management scenario has bought us to define 3 management alternatives to test the MCA method to the Isere Pilot case study.

Alternative 1: No hydroelectric installation in the upstream basin

Description: This alternative represents a hypothetical pristine state of the river: the river is not influenced by the hydroelectric system. Yet, other anthropic disturbances such as sediment mining or dykes are present.

Implications:
- Environment: this alternative is closest to a “natural state” and such it is most suitable for the environment
- Energy: No energy is produced in this alternative

Alternative 2: Important reservoir dams are present in the Tarentaise and in the Maurienne Valley

Description: This alternative is characterized by hydroelectric installations at a high altitude, with important reservoir capacities and high falls

Implications:
- Ecosystem requirements: the upper part of the basin is where the highest habitat diversity ocurs, and in turn the highest biodiversity
- Energy: this part of the basin is crucial because the high reservoir capacities allow to produce peak energy, which has a high economical and societal value
- Tourism: the upper part of the basin is the most touristic area of the basin, in particular due to numerous ski resorts.

Alternative 3: Downstream dams and “STEPS”, inter-basin transfers

Description: This alternative shows hydroelectric installations in the downstream basin. It takes into consideration the inter-basin transfer from Isère to Arc and from Arc to Isère. The dams associated with these transfers are also taken into account.

Implications:

- Ecosystem requirements: The downstream part of the basin is less interesting than the upstream part in terms of biodiversity and habitat.
- Energy: the inter-brasin transfers allow to produce both high demand energy and base energy.
- Flood risks: this is the major issue captured in this alternative, as the downstream part of the basin is highly urbanized, and flood risk is a major issue, especially in the Gresivaudant/Grenoble area.

Alternative 4: All hydroelectric equipment

Description: This alternative is the combination of alternative 2 and 3. It represents the present state of the river, and is a reference alternative, at the other end of the spectrum compared to alternative 1.

Implications:
- Ecosystem requirements: this is the most perturbed alternative, and thus potentially the worse in terms of biodiversity.
- Energy: most energy is produced in this alternative.

Structure of Arc-Isère Basin decisional tree

The macro-criteria were selected following discussions between the SHARE project partners. They are generalist. At lower levels, the Arc-Isère tree is more site specific.

7 macro-criteria are considered:
- **(1) ENERGY PRODUCTION**
- **(2) ECONOMY**
- **(2) RIVER ECOSYSTEM**
- **(3) LANDSCAPE**
- **(4) TOURISM**
- **(5) RIVER FRUITION**
- **(6) OTHER STAKEHOLDERS**
- **(7) FLOOD RISKS**

It is important to note that not all macro-criteria are relevant in all sections of the study area. This will be taken into consideration mostly at the phase of coefficient attributions.

MCA tree

The Structure of the Arc-Isère Pilot Case study is presented on figure 3.

```
Pilot_Case_Isère
  ENERGY_PRODUCTION
    Local
      HP_residual_potential_or_Discharge_Energy_Coefficient_[%] (F)
    Global
      Energy_renewable_directive_[index] (F)
      National_Energy_improvement
        Base_Energy_[MW] (F)
        High_demand_Energy_[MW] (F)
  ECONOMY
    Benefit_HP_Producer_[euros] (F)
    Local_Economy_[euros] (F)
  RIVER_ECOSYSTEM
    Local
      Hydromorphological_parameters
        Flow_regime
          Quantity_and_dynamics_of_water_flow
            Index_for_hydrological_alteration_[index] (F)
        River_continuity
          Longitudinal
            sediment_transport_[index] (F)
            Fish_migration_[possible/impossible] (F)
          transversal
            formation_of_terraces_[Yes/No] (F)
        morphological_conditions
          variation_of_depth_and_width (F)
            degree_of_alteration_of_w/d_ratio_[increase/decrease] (F)
          Structure_and_substrate_of_the_river_bed
            degree_of_alteration_of_bed_slope_[increase/decrease] (F)
            degree_of_alteration_of_particle_size_distribution__change_in_d50__[increase/decrease] (F)
    Global
      CO2_offset_[MW] (F)
  TOURISM_[class] (F)
  RIVER_FRUITION
    Fishing_[class] (F)
    Rowing&rafting_[class] (F)
  LANDSCAPE
    Landforms,_Flora,_fauna_[class] (F)
    infrastructures_[class] (F)
  OTHER_STAKEHOLDERS
    Water_abstraction:_Irrigation,_Industry_and_drinking
      From_river_[index] (F)
      from_ground_[index] (F)
    Wastewater_discharge_dilution:_urban,_pluvial,_industrial_[index] (F)
  FLOOD_RISKS
    Maintenance_costs_for_flood_control_structures
      Erosion/deposition_[increase/decrease] (F)
    New_flood_control_structures
      Erosion/deposition_[increase/decrease] (F)
```

Figure 3 : Structure of decision tree for Isère River

Indicators description and evaluation – Isère River

This section provides an explanation, detailed description, and justification of the Arc-Isere decision tree. The numeric codes and text colours correspond to each of the branches, from the main branches to the leaves. Specifically, **red** represents the main branches (macro-criteria) of the tree, then **blue** follows representing criteria, then **burgundy**, etc.

ENERGY PRODUCTION

The **ENERGY PRODUCTION (1)** macro-criterion considers two criteria also according to the spatial scale: **Local (1.1)** and **Global (1.2)**.

- The **local** branch of the decision three has only one leaf, **HP residual potential (1.1.1)** or power utilization from river (potential of a river to generate electricity).
- The branch called **global** has two sub-criteria, **the Energy renewable directive (1.2.1)** and **National energy improvement (1.2.2)**, the later is divided into **base energy (1.2.2.1)** and **high demand energy (1.2.2.2)**

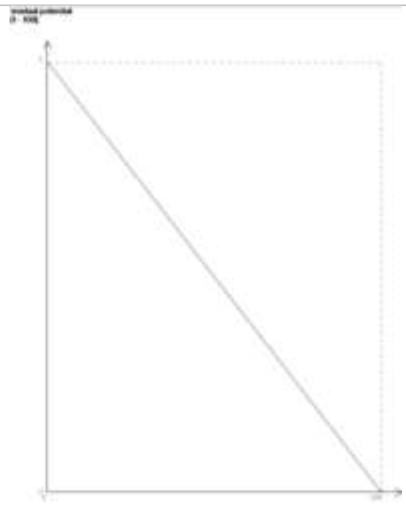
Indicator description

Pilot case Isère | ENERGY PRODUCTION | LOCAL | HP residual potential or Discharge Energy Coefficient

FIELD	DESCRIPTION
INDICATOR NAME	HP residual potential, or discharge energy coefficient (%)
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	It refers to the ability of a river to produce energy in relation to the power that will be generated by the alternative.
AIM	to assess the energy performance of the alternative
KEY MESSAGE	Energy performance
MEASURE UNIT	%
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	The calculation in percentage is: power produced by the alternative/power with the ability possessed by the River.
INDICATOR LIMITS	/
EVALUATION	see table below
AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR decreasing (0 – 100%)

EVALUATION:

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	100	50	100	50
Reach 2	100	50	100	50
Reach 3	100	50	100	50
Reach 4	100	50	100	50
Reach 5	100	100	100	100
Reach 6	100	50	100	50
Reach 7	100	100	50	50

	
SHARE RELATED IND.	
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	DREAL
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	EUROPEAN
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | ENERGY PRODUCTION | GLOBAL | National Energy improvement | Base Energy

FIELD	DESCRIPTION
INDICATOR NAME	Base Energy (MW)
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Energy that is contributed by the alternative to improve the energy available during periods of low electrical demand (e.g. night). Energy provided mostly by "run-of-a-river" type dams
AIM	determine contribution to energy demand

<table>
<tr><td>KEY MESSAGE</td><td>Energy demand</td></tr>
<tr><td>MEASURE UNIT</td><td>MW</td></tr>
<tr><td>REFERENCES</td><td>/</td></tr>
<tr><th>FIELD</th><th>METHODS AND MONITORING STANDARDS</th></tr>
<tr><td>INDICATOR ELABORATION</td><td>from dam operating documents</td></tr>
<tr><td>INDICATOR LIMITS</td><td>/</td></tr>
<tr><td>EVALUATION</td><td>
<table>
<tr><th></th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th><th>Alternative 4</th></tr>
<tr><td>Reach 1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 2</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 3</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 4</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 5</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 6</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Reach 7</td><td>0</td><td>0</td><td>250</td><td>250</td></tr>
</table>
</td></tr>
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is LINEAR growing (0 – 1000 MW)
</td></tr>
<tr><td>SHARE RELATED IND.</td><td></td></tr>
<tr><td>COUNTRY CODE</td><td>FR</td></tr>
<tr><td>WFD HER</td><td>FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE</td></tr>
<tr><th>FIELD</th><th>DATASOURCES</th></tr>
<tr><td>DATA SOURCE</td><td>Diverse</td></tr>
<tr><td>TIME COVER</td><td>/</td></tr>
<tr><td>UPDATE FREQUENCY</td><td>/</td></tr>
</table>

NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	moderate
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | ENERGY PRODUCTION | GLOBAL | National Energy improvement | High Demand Energy

FIELD	DESCRIPTION
INDICATOR NAME	High Demand Energy (MW)
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Peak demand (peak load) during the daily, monthly, seasonal and yearly cycles periods. Provided by Storage and Pump Storage dams.
AIM	determine contribution to energy demand
KEY MESSAGE	Energy demand
MEASURE UNIT	*MW*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	from dam operating documents
INDICATOR LIMITS	/
EVALUATION	see table below
AVAILABLE UF	YES

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	0	700	0	700
Reach 2	0	1000	0	1000
Reach 3	0	700	0	700
Reach 4	0	800	0	800
Reach 5	0	0	0	0
Reach 6	0	700	0	700
Reach 7	0	0	0	0

UF	The Utility Function adopted is LINEAR growing (0 – 1000 MW) 
SHARE RELATED IND.	
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Diverse
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	moderate
SHARE PILOT CASE STUDY	Arc-Isère

ECONOMY

The **ECONOMY (2)** macro-criterion considers two criteria that take in count the direct economical **benefit for HP producers(2.1)** and the undirected economical benefit: **benefit on the local (2.2)**.
Tables

Indicator description

Pilot case Isère | ECONOMY | Benefit to HP Producer

FIELD	DESCRIPTION
INDICATOR NAME	Benfit to HP Producer
ACRONYM	/

DPSIR	D (Driving Forces)
DESCRIPTION	Fruitful net of the firm (benefit=revenues-costs).
AIM	Describe the economic value of energy
KEY MESSAGE	Economic benefit of firms
MEASURE UNIT	*euro*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	From base and high energy production, including maintenance of HP facilities.
INDICATOR LIMITS	/
EVALUATION	This Criterion is not evaluated, because it has a weight of 0, in order to prevent double counting of energy production (more details in section "attribution of weights"). The criterion is present in the tree for a matter of macro criteria homogenization.
AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR growing 
SHARE RELATED IND.	
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Diverse

TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | ECONOMY | Local Economy

FIELD	DESCRIPTION
INDICATOR NAME	Local Economy
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Corresponds to the economic benefit that a HP plant gives indirectly. For example a HP with dams creates an artificial lake, which allows for the development of aquatic sports, fishing and tourism, sources of economic value
AIM	Describe the economic gain of HP plants for the local economy
KEY MESSAGE	Local benefit
MEASURE UNIT	*euro*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	/
INDICATOR LIMITS	/
EVALUATION	This Criterion is not evaluated, because it has a weight of 0, in order to prevent double counting of tourism and river fruition (more details in section "attribution of weights"). The criterion is present in the tree for a matter of macro criteria homogenization.
AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR growing

	
SHARE RELATED IND.	
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Diverse
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

RIVER ECOSYSTEM

The **RIVER ECOSYSTEM (3)** macro-criterion considers two criteria: **Local Environment (3.1),** and **Global environment (3.2).** Hydropower affects the local environment in many different ways, by refashioning the river environment through chemical, morphological, and consequently biological and biodiversity impacts. Only the hydromorphological effects are considered here, in relation to PP9 area of expertise. It affects the global environment more indirectly, mostly as “clean energy,” replacing the use of fossil fuels.

- **Local Environment (3.1)**. This criterion is defined by **Hydromorphological parameters (3.1.2)**. This criterion is explicitly considered by the Water Framework Directive (WFD).
    - **Hydromorphological parameters (3.1.2):** The Annex V of the WFD states that the evaluation of the hydromorphological condition must considerer three elements: The **hydrological regime (3.1.2.1)**, the **river continuity (3.1.2.2)** and the **morphological condition (3.1.2.3)**. Each one of these sub-criteria is composed of others elements that characterize it.
- **Global Environment (3.2):** We consider in this criteria the benefits that hydropower can bring to to the global environment as compared to other energy sources. HP, as it is a substitute to the consumption of fossil fuels, can be seen as a mitigator of global warming. One sub-criteria represents this dimension, namely **CO2 offset (1.2.1)**. Despite its strong link with the ENERGY

macro-criteria explained above, CO_2 is included here as a recognition that energy production affects the environment globally.

Indicator description

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | Flow regime | Quantity and dynamics of water flow | Index for Hydrological Alteration

<table>
<tr><th>FIELD</th><th>DESCRIPTION</th></tr>
<tr><td>INDICATOR NAME</td><td>Index for hydrological Alteration</td></tr>
<tr><td>ACRONYM</td><td>FQ</td></tr>
<tr><td>DPSIR</td><td>D (Driving Forces)</td></tr>
<tr><td>DESCRIPTION</td><td>The alteration of the hydrological regime FQ is defined in this model as the relative variation of the number of days of exceedance of the channel forming discharge per average year.</td></tr>
<tr><td>AIM</td><td>To describe hydrological alteration of the channel forming discharge, which is relevant to description of morphological impacts of dams.</td></tr>
<tr><td>KEY MESSAGE</td><td>Flow alteration</td></tr>
<tr><td>MEASURE UNIT</td><td>index</td></tr>
<tr><td>REFERENCES</td><td>Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale. San José, Costa Rica, admis.</td></tr>
<tr><th>FIELD</th><th>METHODS AND MONITORING STANDARDS</th></tr>
<tr><td>INDICATOR ELABORATION</td><td>$$FQ = \frac{NQ_{post}}{NQ_{pre}} - 1$$
where FQ is the index for the frequency change of a channel-forming discharge; NQ_{post} and NQ_{pre} are the numbers of days of exceedance of the channel-forming discharge respectively after and before the disturbance.

The channel forming discharge is considered to be the discharge with a recurrence interval of 2,5 years.</td></tr>
<tr><td>INDICATOR LIMITS</td><td>Limit in defining channel flow discharge through a given recurrence interval.</td></tr>
<tr><td>EVALUATION</td><td>
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<tr><td>Reach 2</td><td>0</td><td>-0,192298736</td><td>0</td><td>0,073682435</td></tr>
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<tr><td>Reach 4</td><td>0</td><td>-0,073235083</td><td>0</td><td>-0,073235083</td></tr>
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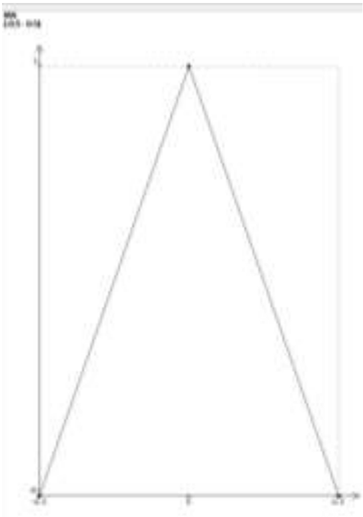
</table>

AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR with a maximum at 0 (no change) and a minimum at 0.5 and -0.5 (maximum change). 
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	30 years
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

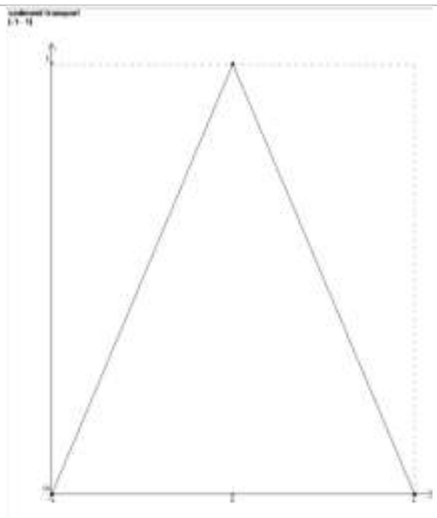
Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | River continuity |LONGITUDINAL | Sediment Transport

INDICATOR NAME	Sediment transport
ACRONYM	*AS*
DPSIR	D (Driving Forces)

DESCRIPTION	The alteration of sediment supply, evaluated considering three different characters: (i) lithology (rock type and mechanical resistance properties) and soil type (erodability), (ii) hillslope gradient, and (iii) land-cover and land-use.
AIM	To describe alteration of sediment supply
KEY MESSAGE	Sediment supply
MEASURE UNIT	*index*
REFERENCES	Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. *Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale.* San José, Costa Rica, admis.
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	$AS = \frac{SS_{post}}{SS_{pre}} - 1$ (3) where AS is the index for sediment supply alteration; SS_{pre} and SS_{post} are the indexes for sediment supply respectively before and after the disturbance. Indexes for sediment supply result from a geospatial analysis of lithology, hillslpoe gradient, and land-cover.
INDICATOR LIMITS	Original method, for no available method for a simple evaluation of the solid material supply to a river.
EVALUATION	(see table below)
AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR with a maximum at 0 (no change) and a minimum at -1 and 1 (maximum change).

EVALUATION:

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	0	-0,205641374	-0,970514793	-0,970514793
Reach 2	0	0,188868329	0	-0,153030675
Reach 3	0	-0,98448531	-1	-1
Reach 4	0	-0,888689209	-1	-1
Reach 5	0	-0,3465047	-0,547927325	-0,566792278
Reach 6	0	-0,638660747	-0,916221225	-0,899294866
Reach 7	0	-0,248092607	-0,516004255	-0,517432369

	
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | River continuity |LONGITUDINAL | Fish Migration

INDICATOR NAME	Fish Migration
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Assesses whether fish migration is possible or impossible (impossible if dam is present with no fish ladder)
AIM	To describe possibility of Fish migration

KEY MESSAGE	Migration of fish can be limited by the presence of dams
MEASURE UNIT	*Yes/No*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Yes if no dam downstream of reach, or dams with fish ladders. No if dam(s) present downstream of reach with no fish ladder.
INDICATOR LIMITS	/
EVALUATION	(see table below)

EVALUATION

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	Yes	No	Yes	No
Reach 2	Yes	Yes	Yes	Yes
Reach 3	Yes	No	Yes	No
Reach 4	Yes	No	Yes	No
Reach 5	Yes	Yes	Yes	Yes
Reach 6	Yes	No	Yes	No
Reach 7	Yes	Yes	Yes	Yes

AVAILABLE UF	YES
UF	The Utility Function adopted is BINARY → No is 0, Yes is 1.

SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	GIS and field
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714

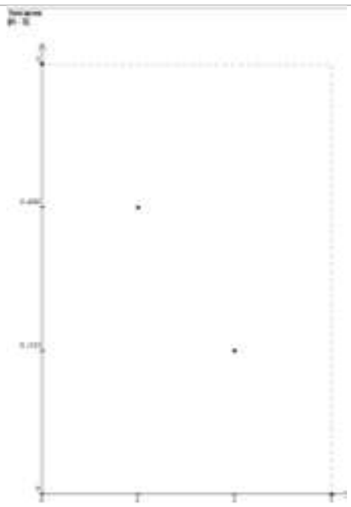
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | River continuity |TRANSVERSAL | Formation of Terraces

INDICATOR NAME	Formation of Terraces
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Important bed incision can lead to the formation of terraces, which implies a loss of connectivity between the river and the floodplain.
AIM	To take into account the ecological significance of the floodplain
KEY MESSAGE	Connectivity of river and floodplain, Morphology
MEASURE UNIT	*Yes/No (with degrees of intensity of the formation)*
REFERENCES	Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. *Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale.* San José, Costa Rica, admis.
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Elaborated by Alcayaga's expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alteration recorded in the literature. For more information on methodology see Alcayaga 2012.
INDICATOR LIMITS	/
EVALUATION	see table below
AVAILABLE UF	YES
UF	The Utility Function adopted is POINT LINEAR.

EVALUATION:

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	No Formation	Formation	Formation	Formation
Reach 2	No Formation	No Formation	No change	Formation
Reach 3	No Formation	Formation	Formation	Formation
Reach 4	No Formation	Formation	Formation	Formation
Reach 5	No Formation	Formation	Formation	Formation
Reach 6	No Formation	Formation	Formation	Formation
Reach 7	No Formation	Formation	Formation	Formation

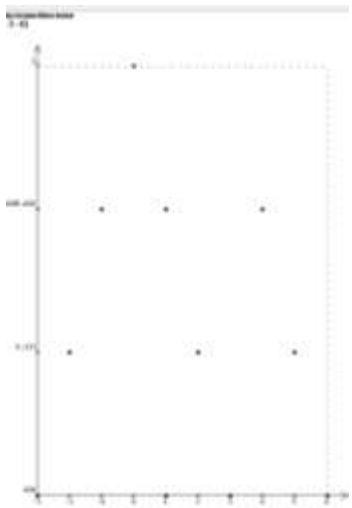
	
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | morphological condition |variation of the depth and width | degree of alteration of the w/d ratio

INDICATOR NAME	Degree of alteration of width over depth ratio
ACRONYM	*w/d*
DPSIR	D (Driving Forces)
DESCRIPTION	The width over depth ratio delivers an index related to the slope of the bed and the average speed of transversal section, therefore the potential erosion of the bed and banks
AIM	Parameter to assess the Morphological status of a waterbody

KEY MESSAGE	Morphological status
MEASURE UNIT	*Increase/Decrease*
REFERENCES	Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. *Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale.* San José, Costa Rica, admis.
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Elaborated by Alcayaga's expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alterations recorded in the literature. For more information on methodology see Alcayaga 2012.
INDICATOR LIMITS	/.
EVALUATION	(see table below)

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	no change	Decrease/Increase	Decrease	Decrease
Reach 2	no change	Increase/Decrease	No change	Decrease/Increase
Reach 3	no change	Decrease	Increase	Decrease
Reach 4	no change	Decrease	Increase	Decrease
Reach 5	no change	Decrease/Increase	Decrease	Decrease
Reach 6	no change	Decrease	Decrease	Decrease
Reach 7	no change	Decrease/Increase	Decrease	Decrease

AVAILABLE UF	YES
UF	The Utility Function adopted is POINT LINEAR, with a maximum at 0 (no change). 
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/

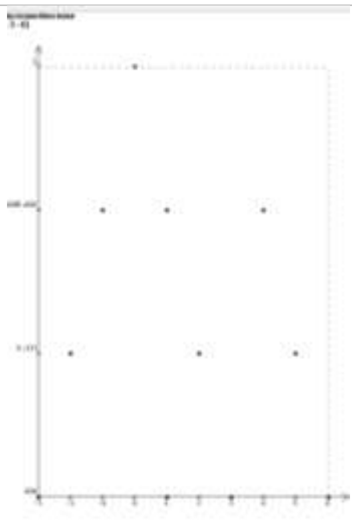
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | morphological condition |Structure and Substrate of the River Bed | degree of alteration of bed slope

INDICATOR NAME	Degree of alteration longitudinal profile (average slope bed in the reach)
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	A measure of the alteration of the longitudinal profile
AIM	Parameter to assess the Morphological status of a waterbody
KEY MESSAGE	Morphological status
MEASURE UNIT	*Increase/Decrease*
REFERENCES	Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. *Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale.* San José, Costa Rica, admis.
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Elaborated by Alcayaga's expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alteration recorded in the literature. For more information on methodology see Alcayaga 2012.
INDICATOR LIMITS	/
EVALUATION	see table below
AVAILABLE UF	YES
UF	The Utility Function adopted is POINT LINEAR, with a maximum at 0 (no change).

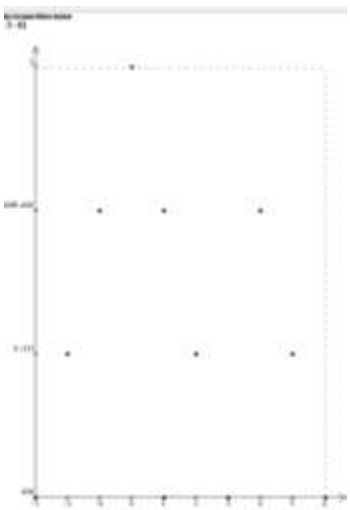
EVALUATION

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	no change	Decrease/Increase	Decrease	Decrease
Reach 2	no change	Increase	No change	Decrease
Reach 3	no change	Decrease	Decrease	Decrease
Reach 4	no change	Decrease	Decrease	Decrease
Reach 5	no change	Decrease	Decrease	Decrease
Reach 6	no change	Decrease	Decrease	Decrease
Reach 7	no change	Decrease	Decrease	Decrease

	
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | LOCAL | Hydromorphological parameters | morphological condition |Structure and Substrate of the River Bed | degree of alteration of particle size distribution – change in d50

INDICATOR NAME	Degree of alteration of particle size Distribution – D50
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Affects quality of aquatic habitat

<table>
<tr><td>AIM</td><td>Parameter to assess the Morphological status of a waterbody</td></tr>
<tr><td>KEY MESSAGE</td><td>Morphological status, substrate, habitat</td></tr>
<tr><td>MEASURE UNIT</td><td>Increase/Decrease</td></tr>
<tr><td>REFERENCES</td><td>Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale. San José, Costa Rica, admis.</td></tr>
<tr><td>FIELD</td><td>METHODS AND MONITORING STANDARDS</td></tr>
<tr><td>INDICATOR ELABORATION</td><td>Elaborated by Alcayaga's expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alteration recorded in the literature. For more information on methodology see Alcayaga 2012.</td></tr>
<tr><td>INDICATOR LIMITS</td><td>/</td></tr>
<tr><td>EVALUATION</td><td>
<table>
<tr><td></td><td>Alternative 1</td><td>Alternative 2</td><td>Alternative 3</td><td>Alternative 4</td></tr>
<tr><td>Reach 1</td><td>no change</td><td>Decrease/Increase</td><td>Increase</td><td>Increase</td></tr>
<tr><td>Reach 2</td><td>no change</td><td>Decrease</td><td>No change</td><td>Increase</td></tr>
<tr><td>Reach 3</td><td>no change</td><td>Increase</td><td>Increase</td><td>Increase</td></tr>
<tr><td>Reach 4</td><td>no change</td><td>Increase</td><td>Increase</td><td>Increase</td></tr>
<tr><td>Reach 5</td><td>no change</td><td>Increase</td><td>Increase</td><td>Increase</td></tr>
<tr><td>Reach 6</td><td>no change</td><td>Increase</td><td>Increase</td><td>Increase</td></tr>
<tr><td>Reach 7</td><td>no change</td><td>Increase</td><td>Increase</td><td>Increase</td></tr>
</table>
</td></tr>
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is POINT LINEAR, with a maximum at 0 (no change).
</td></tr>
<tr><td>SHARE RELATED IND.</td><td>/</td></tr>
<tr><td>COUNTRY CODE</td><td>FR</td></tr>
<tr><td>WFD HER</td><td>FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE</td></tr>
<tr><td>FIELD</td><td>DATASOURCES</td></tr>
<tr><td>DATA SOURCE</td><td>Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.</td></tr>
</table>

TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | RIVER ECOSYSTEM | GLOBAL | CO2 offset

INDICATOR NAME	Index of CO2 emissions reduction
ACRONYM	CO2
DPSIR	P – Pressures indicator
DESCRIPTION	Evaluation of the alternative in comparison with other sources of energy, for example thermal power plants
AIM	Recognition that energy production affects the environment globally
KEY MESSAGE	Global environment is taken into account
MEASURE UNIT	MW equilvalent
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	This indicator considers the "clean" energy gained for each alternative. In the relative assessment of alternatives, it can be considered to be the same value as the sum of "base energy" and "peak energy."
INDICATOR LIMITS	/
EVALUATION	(see table below)
AVAILABLE UF	YES

EVALUATION

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	0	700	0	700
Reach 2	0	1000	0	1000
Reach 3	0	700	0	700
Reach 4	0	800	0	800
Reach 5	0	0	0	0
Reach 6	0	700	0	700
Reach 7	0	0	250	250

	The Utility Function adopted is LINEAR growing (0 – 1000 MW) 
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
INDICATOR ELABORATION	This indicator considers the “clean” energy gained for each alternative. In the relative assessment of alternatives, it can be considered to be the same value as the sum of “base energy” and “peak energy.”
FIELD	**DATASOURCES**
DATA SOURCE	Diverse – freely available documents about HP plants
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	EUROPEAN
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

TOURISM

The **TOURISM (5)** macro-criterion is linked to the **ECONOMY**, **LANDSCAPE**, and **RIVER FRUITION** macro-criteria. However it is included as a separate criterion since in the context of decision-making it may be necessary or interesting to consider it separately. Tourism can be positively impacted by the creation of artificial lakes and the possibility of new recreational activities, and it can be negatively affected in the case of a landscape loosing aesthetical value because of the massive construction of infrastructures.

Indicator description

Pilot Case Isère | Tourism

<table>
<tr><td>INDICATOR NAME</td><td>Tourism</td></tr>
<tr><td>ACRONYM</td><td>/</td></tr>
<tr><td>DPSIR</td><td>D (Driving Forces)</td></tr>
<tr><td>DESCRIPTION</td><td>A measure of whether each alternative leads to more or less tourism within the basin</td></tr>
<tr><td>AIM</td><td>Assess consequence of alternatives concerning tourism</td></tr>
<tr><td>KEY MESSAGE</td><td>Tourism can be impacted by HP development, positively or negatively</td></tr>
<tr><td>MEASURE UNIT</td><td>Classes</td></tr>
<tr><td>REFERENCES</td><td>/</td></tr>
<tr><td>FIELD</td><td>METHODS AND MONITORING STANDARDS</td></tr>
<tr><td>INDICATOR ELABORATION</td><td>Expert knowledge</td></tr>
<tr><td>INDICATOR LIMITS</td><td>/</td></tr>
<tr><td>EVALUATION</td><td>
<table>
<tr><th></th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th><th>Alternative 4</th></tr>
<tr><td>Reach 1</td><td>4</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td>Reach 2</td><td>4</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td>Reach 3</td><td>4</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td>Reach 4</td><td>4</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td>Reach 5</td><td>3</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td>Reach 6</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td>Reach 7</td><td>4</td><td>3</td><td>2</td><td>2</td></tr>
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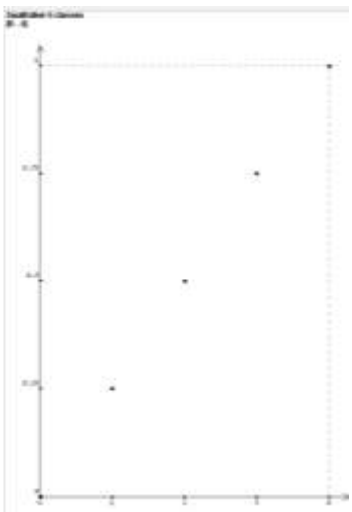
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is POINT LINEAR growing.
</td></tr>
<tr><td>SHARE RELATED IND.</td><td>/</td></tr>
</table>

COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Expert knowledge
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	poor
SHARE PILOT CASE STUDY	Arc-Isère

RIVER FRUITION

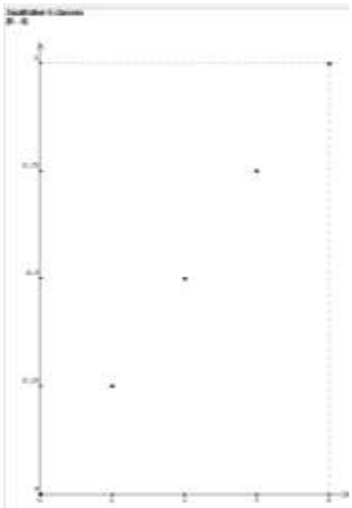
RIVER FRUITION (6): For this criterion we consider the various recreational activities:

- **fishing (6.1)** mostly as a hobby in the case of the Isère River (little or no professional fishing)
- **rowing, rafting and canyoning (6.2)** that could be affected by variations in water level that we call hydropeaking. The locations for the practice of these sports are reckoned in the SDAGE made in 1996. We consider the loss of sites due the HP alternatives.

Indicator description

Pilot case Isère | RIVER FRUITION | Fishing

INDICATOR NAME	Loss of sites for fishing
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Refers to the loss or creation of suitable sites for recreational fishing
AIM	Assess consequence of alternative for fishing
KEY MESSAGE	Fishing
MEASURE UNIT	*Classes*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Expert knowledge: estimation of the worth of each alternative for fishing

<table>
<tr><td>INDICATOR LIMITS</td><td>/</td></tr>
<tr><td>EVALUATION</td><td>
<table>
<tr><th></th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th><th>Alternative 4</th></tr>
<tr><td>Reach 1</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 2</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 3</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 4</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 5</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 6</td><td>3</td><td>0</td><td>3</td><td>0</td></tr>
<tr><td>Reach 7</td><td>3</td><td>3</td><td>0</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is POINT LINEAR.
</td></tr>
<tr><td>SHARE RELATED IND.</td><td>/</td></tr>
<tr><td>COUNTRY CODE</td><td>FR</td></tr>
<tr><td>WFD HER</td><td>FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE</td></tr>
<tr><td>FIELD</td><td>DATASOURCES</td></tr>
<tr><td>DATA SOURCE</td><td>Expert knowledge</td></tr>
<tr><td>TIME COVER</td><td>/</td></tr>
<tr><td>UPDATE FREQUENCY</td><td>/</td></tr>
<tr><td>NUT III CODE</td><td>FR717/FR714</td></tr>
<tr><td>NORMATIVE REFERENCE</td><td>LOCAL</td></tr>
<tr><td>NORMATIVE RELEVANCE</td><td>good</td></tr>
<tr><td>SHARE PILOT CASE STUDY</td><td>Arc-Isère</td></tr>
</table>

Pilot case Isère | RIVER FRUITION | Rowing&Rafting

INDICATOR NAME	Loss of sites for fishing

<table>
<tr><td>ACRONYM</td><td>/</td></tr>
<tr><td>DPSIR</td><td>D (Driving Forces)</td></tr>
<tr><td>DESCRIPTION</td><td>Refers to the loss or creation of suitable sites for aquatic sports</td></tr>
<tr><td>AIM</td><td>Assess consequence of alternative for aquatic sports</td></tr>
<tr><td>KEY MESSAGE</td><td>Aquatic sports are affected by HP plants</td></tr>
<tr><td>MEASURE UNIT</td><td>Classes</td></tr>
<tr><td>REFERENCES</td><td>/</td></tr>
<tr><td>FIELD</td><td>METHODS AND MONITORING STANDARDS</td></tr>
<tr><td>INDICATOR ELABORATION</td><td>Expert knowledge: estimation of the worth of each alternative for aquatic sports</td></tr>
<tr><td>INDICATOR LIMITS</td><td>/</td></tr>
<tr><td>EVALUATION</td><td>
<table>
<tr><td></td><td>Alternative 1</td><td>Alternative 2</td><td>Alternative 3</td><td>Alternative 4</td></tr>
<tr><td>Reach 1</td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
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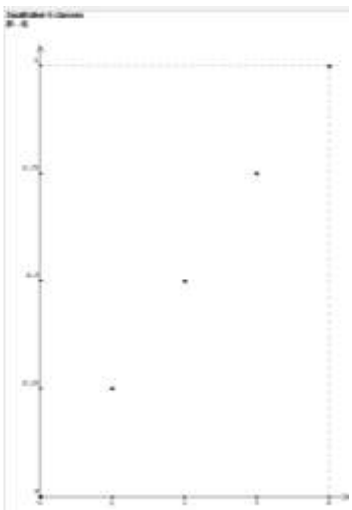</td></tr>
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<tr><td>WFD HER</td><td>FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE</td></tr>
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FIELD	DATASOURCES
DATA SOURCE	Expert knowledge
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	good
SHARE PILOT CASE STUDY	Arc-Isère

LANDSCAPE

LANDSCAPE (4): This macro-criterion corresponds to the attractiveness, the conservation, and the aesthetical value the surrounding area. This macro-criteria includes two criteria:

- **Landforms, flora and fauna (4.1)**: for example, the construction of a HP can lead to the creation of a lake which changes the landscape, and hosts migratory birds, making it potentially more attractive. It can be defined as a high/poor index.
- **The infrastructures (4.2)**, in contrast, the construction of a large dam, and a plant, as well as the construction of power cords may disturb the natural landscape and make it less attractive.

Pilot case Isère | LANDSCAPE | Landforms, Flora and Fauna

INDICATOR NAME	Landforms, Flora and Fauna
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	The construction of HP can lead to the creation of a lake which changes the landscape, and hosts migratory birds, making it potentially more attractive.
AIM	Assess consequence of alternatives concerning landscape
KEY MESSAGE	Landscape
MEASURE UNIT	*Classes*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Expert knowledge
INDICATOR LIMITS	/

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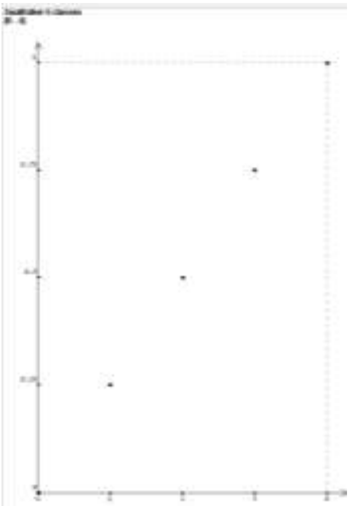</td></tr>
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Pilot case Isère | LANDSCAPE | Infrastructures

INDICATOR NAME	Infrastructures
ACRONYM	/

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<tr><td>DESCRIPTION</td><td>High/poor index to characterize the impact of hydroelectric infrastructures on the landscape</td></tr>
<tr><td>AIM</td><td>Assess consequence of alternatives concerning landscape</td></tr>
<tr><td>KEY MESSAGE</td><td>Landscape</td></tr>
<tr><td>MEASURE UNIT</td><td>Classes</td></tr>
<tr><td>REFERENCES</td><td>/</td></tr>
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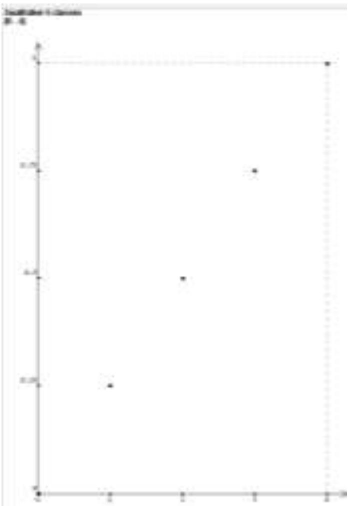</td></tr>
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<tr><td>FIELD</td><td>DATASOURCES</td></tr>
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DATA SOURCE	Expert knowledge
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	poor
SHARE PILOT CASE STUDY	Arc-Isère

OTHER STAKEHOLDERS

OTHER STAKEHOLDERS (7): For this macro-criterion we consider the following criteria:

- **Water abstraction (7.1)** for agriculture, industry and drinking. For this sub-criteria we differentiate the **superficial water abstraction (4.2.1)** and the **groundwater abstraction (4.2.2)**. It is noteworthy that in both cases the fluvial morphology plays an important role. An incision in the bed can cause problems in both types of water extractions, decreasing the water-table or the water surface level.
- **Effluent discharge (7.2)** for industry and urban treatment plant is the flow in the river available for diluting the effluents. Some HP can regulate the flow regime, in particular the HP plants that produce hydropeaking. If the intra-hourly flow variation cause the variation of water volume for a time step (water flow in the river integrate in the time), then the pollutant concentration in the river coming from the effluents (Industry and urban treatment plant) will change also.

Indicator description

Pilot case Isère | OTHER STAKEHOLDERS | Water abstraction, Irrigation, Industry and drinking |from river

INDICATOR NAME	Alteration of water abstraction from rivers
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	This indicator shows the alteration of the structures of water intake from the river (eg, by modification of the bed)
AIM	Effects of HP to water abstraction
KEY MESSAGE	water abstraction from rivers
MEASURE UNIT	*Index*
REFERENCES	/
FIELD	**METHODS AND MONITORING STANDARDS**

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<tr><td>COUNTRY CODE</td><td>FR</td></tr>
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<tr><td>SHARE PILOT CASE STUDY</td><td>Arc-Isère</td></tr>
</table>

Pilot case Isère | OTHER STAKEHOLDERS | Water abstraction, Irrigation, Industry and drinking |from ground

<table>
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<tr><td>DESCRIPTION</td><td>This indicator shows how a variation in the watertable level due to the alternative (eg, by incision of the river bed), could affect the water pumping</td></tr>
<tr><td>AIM</td><td>Effects of HP to water abstraction</td></tr>
<tr><td>KEY MESSAGE</td><td>water abstraction from rivers</td></tr>
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<tr><td>REFERENCES</td><td>/</td></tr>
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SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Expert knowledge
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	moderate
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | OTHER STAKEHOLDERS | Waste Water Discharge Dilution, Urban&Pluvial&Industrial

INDICATOR NAME	Dilution discharge of urban-industrials effluents
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	Flow available for diluting the effluents
AIM	Take into account effects to water quality
KEY MESSAGE	Dilution of pollutants

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<tr><td>REFERENCES</td><td>/</td></tr>
<tr><td>FIELD</td><td>METHODS AND MONITORING STANDARDS</td></tr>
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NORMATIVE RELEVANCE	moderate
SHARE PILOT CASE STUDY	Arc-Isère

FLOOD RISKS

FLOOD RISK (8) macro-criteria: We considered two criteria called **Maintenance cost for flood control structures (8.1)** and **new flood control structures (8.2)**, which are defined below. It is interesting to note that the flood risks are strongly link with the hydromorphology of the river, since the shape of the channel itself depends on the high flows.

- **Maintenance cost for flood control structures (8.1)**: Corresponds to the effect generated by each alternative on the cost of civil works maintenance and cleaning of the channel, which is directly related to the erosion of the bed, banks or structures and/or deposition of sediment on the bed. This is why this criteria is described by the criteria: **erosion/deposition (8.1.1)**.
- **New floods control structures (8.2):** Corresponds to cost of news structures due to the operation of HP. This criteria is also described through the indicator: **erosion/deposition (8.1.1)**.

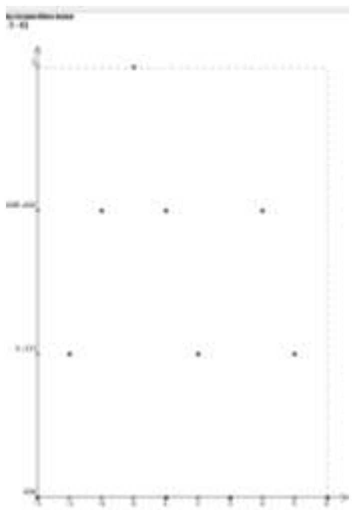
Indicator description

Pilot case Isère | FLOOD RISKS | Maintenance Cost for Flood Control Structures |Erosion/Déposition

INDICATOR NAME	Erosion/Deposition
ACRONYM	/
DPSIR	D (Driving Forces)
DESCRIPTION	The erosion or deposition of sediment for each alternative, as compared to background values. Important erosion and deposition can affect the cost of new and existing flood control strucutre, and is impacted by the alternatives. Thus this indicator is used as a proxy to evaluate additional costs.
AIM	to evaluate cost of new and existing flood control structures
KEY MESSAGE	Impacts the cost of flood control structures.
MEASURE UNIT	*Increase/Decrease*
REFERENCES	Alcayaga, H., Belleudy, P. & Jourdain, C., 2012. *Morphological responses of rivers to large hydraulic structures: A semi-quantitative model at watershed scale.* San José, Costa Rica, admis.
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Elaborated by Alcayaga's expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alteration recorded in the literature. For more information on methodology see Alcayaga 2012.
INDICATOR LIMITS	/
EVALUATION	see table below

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reach 1	no change	No Changes	Degradation	Degradation

Reach 2	no change	Aggradation	No change	Degradation
Reach 3	no change	Degradation	Degradation	Degradation
Reach 4	no change	Degradation	Degradation	Degradation
Reach 5	no change	Degradation	Degradation	Degradation
Reach 6	no change	Degradation	Degradation	Degradation
Reach 7	no change	Degradation	Degradation	Degradation

AVAILABLE UF	YES
UF	The Utility Function adopted is POINT LINEAR, with a maximum at 0 (no change). 
SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Pilot case Isère | FLOOD RISKS | New Flood Control Structures |Erosion/Déposition

INDICATOR NAME	Erosion/Deposition

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<tr><td>DESCRIPTION</td><td>The erosion or deposition of sediment for each alternative, as compared to background values. Important erosion and deposition can affect the cost of new and existing flood control structure, and is impacted by the alternatives. Thus this indicator is used as a proxy to evaluate additional costs.</td></tr>
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<tr><td>KEY MESSAGE</td><td>Impacts the cost of flood control structures.</td></tr>
<tr><td>MEASURE UNIT</td><td>Increase/Decrease</td></tr>
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<tr><td>INDICATOR ELABORATION</td><td>Elaborated by Alcayaga’s expert model. AS (alteration of sediment supply) and FQ (hydrological alteration) lead to morphological alteration recorded in the literature. For more information on methodology see Alcayaga 2012.</td></tr>
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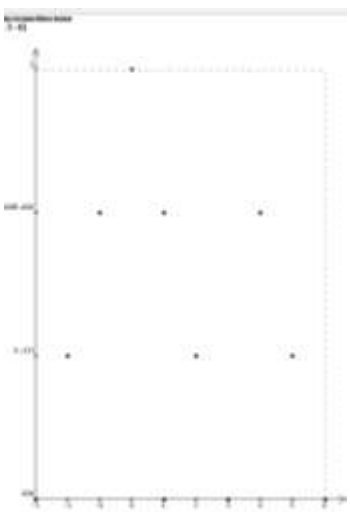</td></tr>
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SHARE RELATED IND.	/
COUNTRY CODE	FR
WFD HER	FRENCH WESTERN PRE-ALPS/FRENCH DAUPHINE
FIELD	**DATASOURCES**
DATA SOURCE	Alacayaga's morphological model (Alcayage 2012). Discharge data from BANQUEHYDRO.
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	FR717/FR714
NORMATIVE REFERENCE	LOCAL
NORMATIVE RELEVANCE	high
SHARE PILOT CASE STUDY	Arc-Isère

Attribution of weights

The Arc-Isère pilot case study has the specificity of being a large and heterogeneous watershed. Our objective in this project is partly to show how the SHARE methodology can be applied to such a large scale. The management priorities differ depending on the location in the watershed. This is why we decided to divide the basin into different reaches, and to use a different weighting scheme depending on the reach typology and management priorities. This section describes how the different reaches were selected and classified, how the weights were attributed, and how the results for all reaches are aggregated to have an overall ranking of the alternatives.

Different reaches with different management priorities

Selected reaches

7 reaches have been selected in order to perform the MCA. These reaches were distinguished by major confluences, or, in one case, by the presence of an important dam. They show different geographical characteristics, as well as different management priorities.
This level of detail was estimated to be relevant to watershed scale hydropower management. However, it is possible to run the application with more reaches (higher level of details) as well as less reaches (more aggregated results) in future applications.
The selected reaches are shown on figure 4.

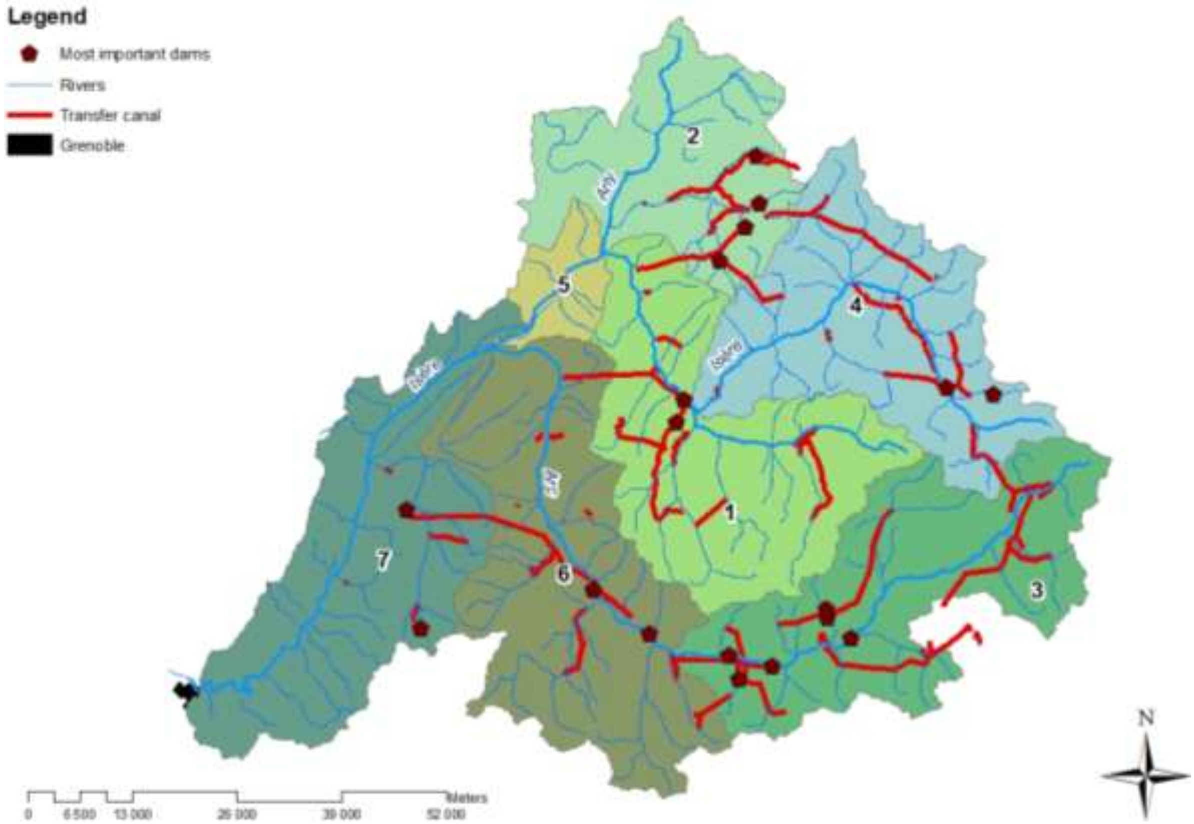

Figure 4: The Isère River basin, with selected reaches for MCA evaluation

Classification of reaches: altitude as a proxy for management priority

Reaches are classified into different typologies according to altitude. Indeed, altitude can be used as a proxy for several reach characteristics. Indeed, the issues at stake differ with altitude. Ecosystems of high torrential streams are richer and more vulnerable than those downstream. In contrast, flood risks are more important in the low basin, which is more densely populated. Altitude can also distinguish different types of streams, with different morphological mecanims. Lastly, the type of HP which can be built also changes with altitude. This is why a classification of reaches according to altitude seems relevant, even if it may be simplistic.

The reaches are thus classified into three classes depending on the median altitude of the river network (as defined by IGN). The classes are shown on table 1.

Table 1: Typology of reaches, using altitude as the basis for classification

Class name	Priority criterion	Altitudinal range (whole network)	Sub-watershed included in the class
Upper	River Ecosytem	>1500	3,4
Middle	Energy Production	[500;1500]	1,2,6
Lower	Flood Risk	<500	5,7

Weight attribution

The weights attributed to each criterion correspond to their importance in decision making. In Sesamo, weight determination is simplified by using a hierarchical approach. Weights are first attributed to macro-criteria, then to criteria, down to the indicators. As we are not ourselves managers of the basin, the weight may not reflect the actual management priorities of the basin. However we believe that this weighting scheme is realistic.
The weights of the macro criteria differ for each reach, reflecting management priorities. At the criteria, sub-criteria, and indicator level, weights are the same for all reaches.

Macro criteria level

As for macro-criteria, we assessed that the most important to decision making in the Arc-Isère River basin are: **RIVER ECOSYSTEM**, **ENERGY PRODUCTION**, and **FLOOD RISKS**. Environment is a management priority in the upper reaches, while Flood Risk is a management priority in the lower basin. Energy production, which we look to maximize at all altitudes, has by default the highest weight in the middle reaches, where the other criteria are not as essential. For each reach, the priority criterion has a weight which is twice the weight of the other 2 criteria (respectively 10 and 5). The other macro-criteria (**TOURISM**, **RIVER FRUITION**, **LANDSCAPE** and **OTHER STAKEHOLDERS**), are considered as less important; they have a weight of 1. The macro-criteria **ECONOMY** has a weight of 0, in order to avoid double counting (see discussion section).
The weighting scheme of the macro criteria is shown on table 2 (black: hierarchical weights, grey: normalized coefficient).

Table 2: Attribution of weights for macro criteria. (**X**: hierarchical weight, *X*: normalized coefficient)

Reach Macro-criteria	1	2	3	4	5	6	7
ENERGY PRODUCTION	**10**	**10**	**5**	**5**	**5**	**10**	**5**
	0.417	*0.417*	*0.208*	*0.208*	*0.208*	*0.417*	*0.208*
ECONOMY	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
	0	*0*	*0*	*0*	*0*	*0*	*0*
RIVER ECOSYSTEM	**5**	**5**	**10**	**10**	**5**	**5**	**5**
	0.208	*0.208*	*0.417*	*0.417*	*0.208*	*0.208*	*0.208*
TOURISM	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	0.042	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*
RIVER FRUITION	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	0.042	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*
LANDSCAPE	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	0.042	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*
OTHER STAKEHOLDERS	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	0.042	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*	*0.042*
FLOOD RISKS	**5**	**5**	**5**	**5**	**10**	**5**	**10**
	0.208	*0.208*	*0.208*	*0.208*	*0.417*	*0.208*	*0.417*

Criteria, sub-criteria and indicator level

Within the macro criteria, each sub-criteria has an equal weight. Within each sub-criteria, each leave has an equal weight, and within each leave, each indicator has an equal weight (and so on).

Two exception should be noted :

- in **ENERGY PRODUCTION** > **global** > **National energy improvement**, the indicators **Base Energy** and **High demand Energy** have a different weights, respectively 1 and 2. The reason is that High demand Energy is more valuable than base energy.
- in **FLOOD RISKS**, the **Maintenance cost for flood control structures** and the **New flood control structures** have a different weighting pattern (respectively 0,1 and 0,9). This corresponds to the proportion of money that is currently spent by the region for maintenance, and for the construction of new control structures.

Figure 5 shows the tree structure with the attributed weights for criteria, sub-criteria and indicators.

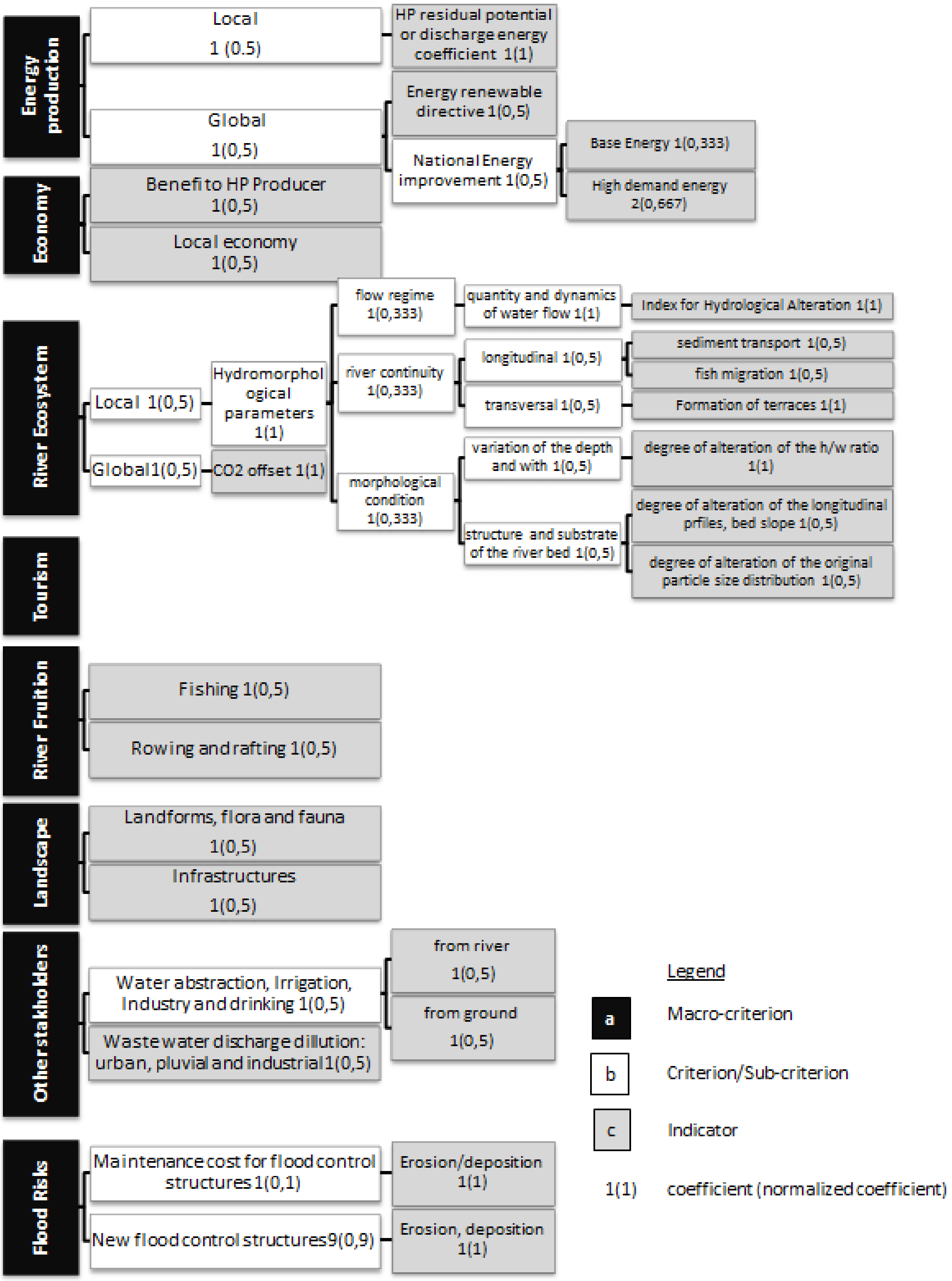

Figure 5: Weights attributed at the criteria, sub-criteria, and indicator level for the Arc-Isère pilot case study

Aggregation method

With the definition of reaches which have a different weight attribution, the alternatives will first be classified by SESAMO for each reach. In order to find which alternative has the best rating overall, the reach result are aggregated outside of the SESAMO software. The method of aggregation is an average of the results for each alternative, weighted by the length of each reach.

Evaluation of alternative performance: Results

Ranking of alternatives

Overall results

The following Table shows the overall ranking of alternative for each reach, and for the whole basin (average of reach score weighted by reach length)

Table 3: Alternative ranking for the Arc-Isère Case study (bold: highest score for each reach)

	Length (km)	**Alternative 1:** No hydroelectric equipment	**Alternative 2 :** Storage dams of the upper Arc and Isère basin	**Alternative 3:** Downstream run of a river dams, pump storage dams, and inter basin transfers	**Alternative 4:** All hydroelectric equipment
Reach 1	290	0,427	**0,655**	0,241	0,488
Reach 2	207	0,531	0,543	0,531	**0,562**
Reach 3	263	0,531	0,522	0,357	**0,539**
Reach 4	277	**0,536**	0,516	0,207	0,41
Reach 5	76	**0,63**	0,135	0,293	0,258
Reach 6	354	0,427	**0,534**	0,19	0,476
Reach 7	373	**0,641**	0,482	0,393	0,403
TOTAL		0,522	**0,523**	0,308	0,463

For the whole Isère river basin, the **Alternative 2** is ranked as the best alternative by the SESMO software. This alternative consists of Storage dams in the upper Arc and Isère basin, by no inter-basin transfer of run-of-a-river dams in the low basin.
At the individual reach scale, this alternative is the best for reach 1 and reach 6. These two reaches are middle basin reaches, were hydroelectric installations are present, and where **ENERGY PRODUCTION** was granted an important weight.
The second best alternative, which has almost the same overall score, is the **Alternative 1**. This alternative consists of no hydroelectric equipment. Indeed, this alternative scores very high for both flood risks, and river ecosystem, despite the absence of energy production. This alternative ranks best for reach 4, an upper basin reach, and reaches 5 and 7, the lower basin reaches that emphasize the importance of Flood risks.
The worse alternative is **Alternative 3**, that is the hydroelectric equipment of the lower basin.

Detailed results for representative reaches

REACH 4: Upper Basin

Reach 4 is an example of an upper basin reach, were **RIVER ECOSYSTEM** is granted the greatest weight. For this reach, **Alternative 1** ranks first (No hydroelectric equipment). The results for this reach, at the macro-criteria level, are presented on figure 6.

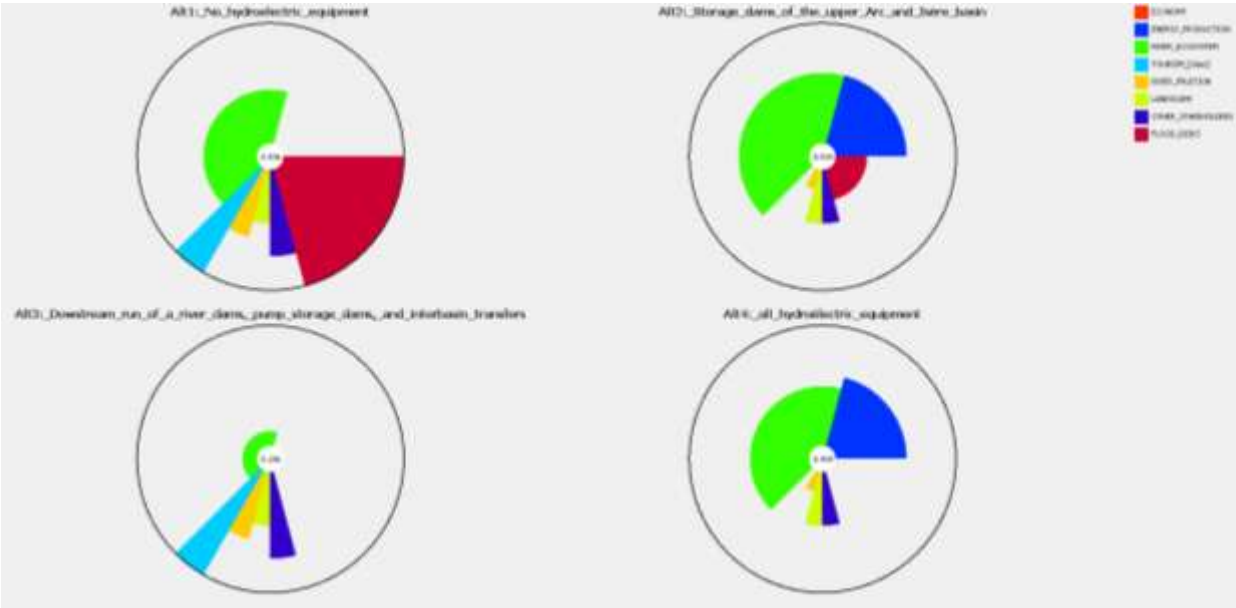

Figure 6: Pie graph of the results for reach 4, Arc-Isère case study, macro-criteria

The figure shows that Alternative 1 ranks high for **FLOOD RISKS** and **RIVER ECOSYSTEM**, which compensates the absence of **ENERGY PRODUCTION**. The other macro-criteria also vary, but they do not have a decisive weight.

REACH 6: Middle Basin

Reach 6 is an example of a middle basin reach, where **ENERGY** is granted the greatest weight. In this reach, **Alternative 2** ranks first, that is hydroelectric equipment of the upper Arc and Isère River. The results for this reach, at the macro-criteria level, are presented on figure 7.

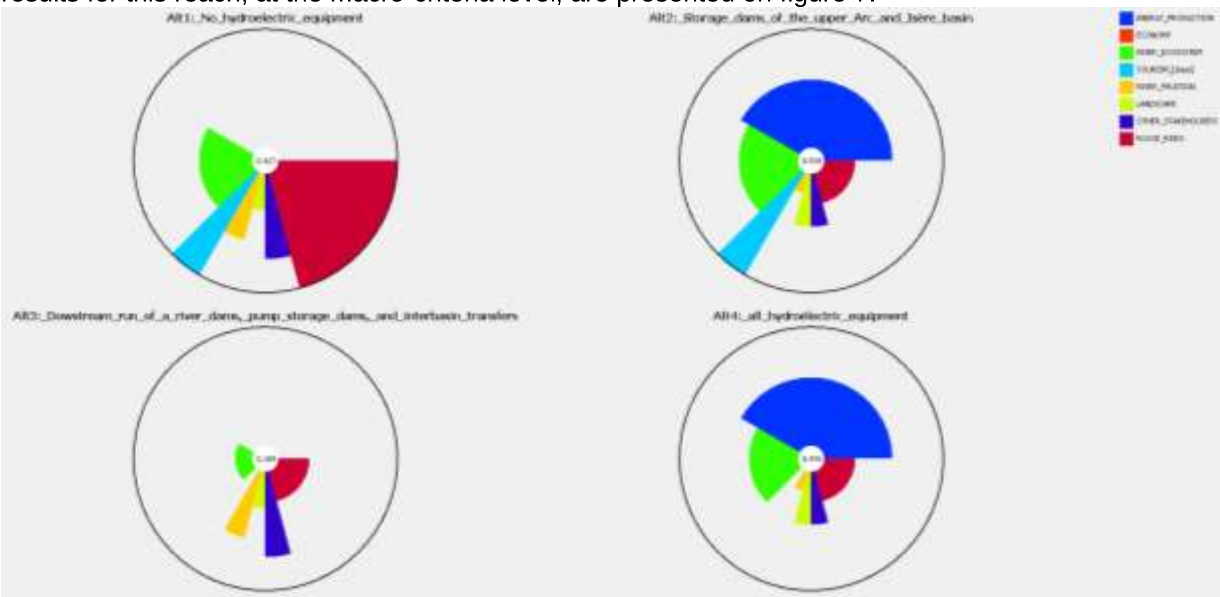

Figure 7: Pie graph of the results for reach 6, Arc-Isère case study, macro-criteria

This figure shows that for **Alternative 2**, the low score on **RIVER ECOSYSTEM** and **FLOOD RISKS** is compensated by a very high score of **ENERGY PRODUCTION** (a lot of energy produced + a lot of weight).
Alternative 3 has a very low score in the reach: the inter-basin transfers have a strong morphological impact, yet the energy resulting from this transfer is not produced in this reach. Thus the score is low on all key macro-criteria that are considered.

REACH 7: Lower basin

Reach 7 is an example of a lower basin reach, were **FLOOD RISKS** is granted the greatest weight, due to a high density of inhabitants. For this reach, **Alternative 1** ranks first (No hydroelectric equipment). The results for this reach, at the macro-criteria level, are presented on figure 8.

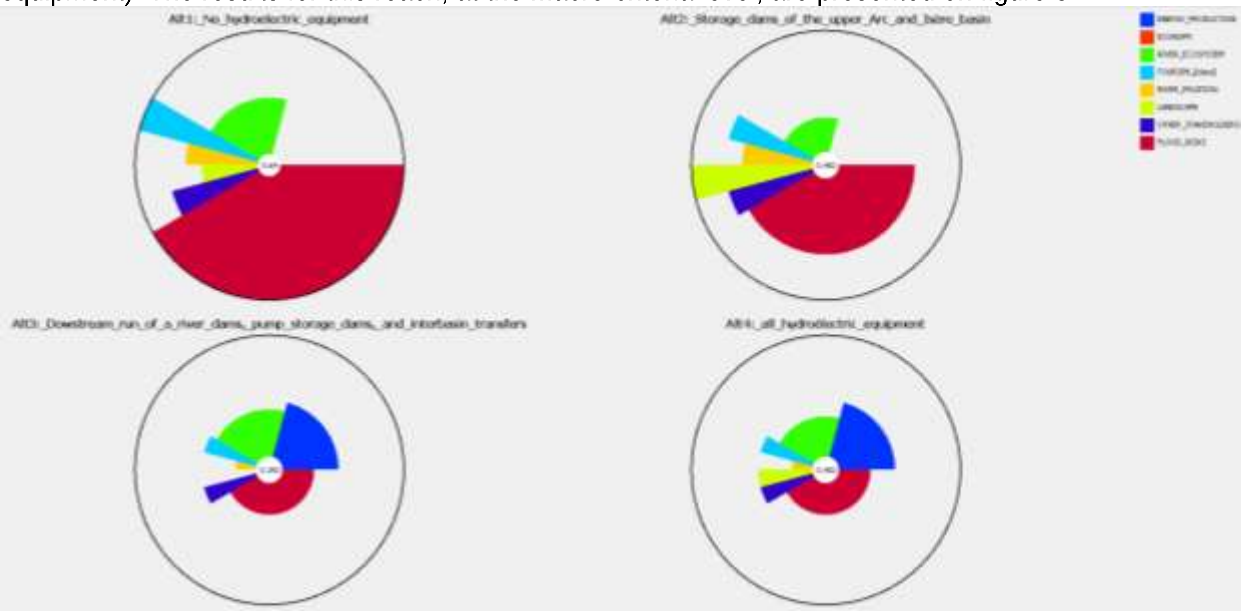

Figure 8: Pie graph of the results for reach 6, Arc-Isère case study, macro-criteria

This figure indicates that **FLOOD RISKS** is the determinant factor in the alternative ranking. In comparison, the other macro-criteria change very little. This results from the high weight granted to flood risks, but also from the fact the any type of hydroelectric equipment strongly influences the morphology of the channel by eroding the bed, which has important consequences on the cost of flood control structures.

Sensitivity Analysis

Sensitivity analysis is necessary because of the uncertainties present on the decision-maker preferences. Indeed, the translation of preferences into weights is not necessarily intuitive, partly arbitrary, and may lead to important error. In this case study, this analysis was performed for each reach, on the macro-criteria weights (because they are the ones to which most attention was paid in the methodology application). The results were considered as robust when the preferred alternative remained the same unless the order of macro-criteria importance had to be changed. The sensitivity analysis of the overall results was not realized, because it could not be automatized in the software.

Of the 7 considered reaches, 4 show sensitive results: 2,3, 4 and 6. For these reaches, the preferred alternative changes if the weight difference between the most important criteria and the second/third most important criteria changes, or if we weight differently the second and third most important criteria (that we chose to give the same weight in the present analysis). For three of these sensitive reaches (2,3 and 6), small changes in the weight distribution switch the preferred alternative to alternative 1 (No hydroelectric equipment).

For the three other reaches, that is 1, 5 and 7, the results seem to be robust. For these reaches, a significant change in the weighting scheme, as well as a change in the order of preferences, is necessary to change the outcome.

As for the aggregated, basin scale result, no sensitivity analysis was done, since it was impossible to do in the framework of the SESAMO software. However, we note that **Alternative 1** and **Alternative 2** have very close overall scores (0,522 and 0,523 respectively). Moreover, we have seen that the non-robust reaches tend to have **Alternative 1** as the second best alternative. As a result, we can't say that **Alternative 2** is the best, but rather than alternative 1 and 2 are equivalent.

Concluding remarks on results

We have seen that the results can be sensitive to different weight attributions. Moreover, it is overall quite difficult to understand which factor has which influence on the final result. Despite a good knowledge of the method used and of the influence of the alternative of the relevant criteria, it is important to analyze the results carefully, as well as the contribution of each criteria to the final ranking of the alternative, in order to make a sound and informed decision. The MCA method implemented in the SESAMO software can help make sound decisions, but it cannot take the decision in the mind and place of the decision-maker, considering the complex structure and the consequences of the decisions to be made.
Another important point to note is the fact that this pilot case study was realized by university workers, not in contact with real decision-makers. Moreover, the setting of the decision does not correspond to a current issue. Thus, these results are illustrative of the implemented method, but they have no value for actual, real decision making.

Discussion

This section aims at raising a few points that we reflected upon as we completed this pilot case study. First, the underlying assumptions of the proposed methodology are stated. Then, criteria selection for Arc-Isère is briefly discussed, as well as the weighting scheme. The issue of uncertainties and time scales are tackled.

MCA methodology proposed in the SESAMO software : underlying assumptions

Many Multicriteria Decision Aid Methods are proposed in the literature (Malczewski, 2006) (Belton & Stewart, 2002) (Ben Mena, 2000) (Roy, 1985), and used in concrete cases. The SESAMO method is thus one among many existing methods. A review of this methods have helped us understanding the underlying assumptions of the method proposes by SHARE.
This method is said to be a method of total aggregation, which means that indicator scores are compiled into a unique function, defined by the preferences of the decision maker, expressed by a weighting scheme. This implies that criteria and indicators are commensurable, and comparable.

Moreover, this method does not allow for hesitations/indifference (unlike outranking methods), nor for pre-defined management goals (such as the obtainment of ecological *good status*), since no minimum threshold value is set for the macro-criteria. The main advantage of this method is the explicit accounting of compromises made in the decision-making process. Moreover, the results are clear and readily understood, and the method relies on robust mathematical bases.

Criteria selection

A criterion is a judgment factor, on the basis of which an action is evaluated. In the context of MCA, Criteria are tools that allow the comparison between different alternatives. The family of chosen criteria must have the following characteristics (Bouyssou, 1990):

- legibility: sufficiently small number of criteria so as to be a discussion basis allowing the analyst to assess inter-criteria information necessary for the implementation of an aggregation procedure,
- operationality: considered as a sound basis for the continuation of the decision aid study
- It should also be:
- exhaustive: contain every important point of view
- minimal: no unnecessary criteria
- non redundant: no functional relationship beween two criteria, so that no criteria is "double counted"

Moreover, the criteria must be measurable, and data must be available to evaluate them.

Criteria of the Arc-Isère Pilot case study

We found it difficult to respect the requirement of exhaustivity as well as the requirement of minimality. It is also very difficult to have an exhaustive list of criteria which can also be measurable, and for which sufficient data exist.
In the Arc-Isere Pilot case study, exhaustivity was preferred, to the detriment of legibility. Indeed, 8 macro-criteria are defined, declined into 28 indicators! Moreover, the tree structure is complex, especially for the **RVIER ECOSYSTEM** macro-criteria. Thus, the family of criteria is quite exhaustive, but the tree structure is maybe too complex to be the basis of actual discussions and decisions. This choice was made in part because no real decision rests on this case study. As consequence, the relevance of obtained results is not a real constraint. Moreover, it may be more important to base a decision on approximate, but exhaustive results, rather than on exact computations that forget essential factors (Roy, 1985).
Another issue is that of redundancy. Indeed, the macro-criteria **ENERGY PRODUCTION** and **ECONOMY** are on the same level. Yet, part of **ECONOMY** is the benefit that results from **ENERGY PRODUCTION**. The other part relate to revenues due to tourism, river fruition, or landscape, other factors that are macro-criteria. Thus, there are clear functional relations linked to the **ECONOMY** macro-criteria. Especially, the production of energy double counted. We kept this macro-criteria in the tree for homogeneization purposes, yet it has a weight of 0.
That said, it is interesting to not that this structure is similar to other studies concerned with water basin management (e.g (Prato, 2003; Hämäläinen, et al., 2001))

Weighting scheme

In the Arc-Isère Basin case study, we used different weights for different reaches. This choice is to us legitimate, because it allows taking into account explicitly the heterogeneity of the water basin. Yet, it raises new questions: on what basis shall we classify the reaches? We chose altitude, because we consider it to be a relevant proxy for many reach characteristics, yet this choice could be discussed. Moreover, the definition of altitude thresholds is partly arbitrary.
This choice also raises interpretation issues. The final result is an aggregation of an already aggregated result. This makes it more difficult to analyze and interpret the final result.

Uncertainties

Three types of uncertainties exist in the context of MCA : uncertainties linked to the preferences of the decision-maker, uncertainties linked to indicator evaluation, and uncertainties is the sense of semantic imprecisions (Mendoza & Martins, 2006).
The uncertainties linked to the decision-maker preferences are taken into account in the sensitivity analysis. The uncertainties about the indicator evaluation are not taken into account in the Sesamo

software. The only way to deal with this type of uncertainty in the software is to classify the impacts of each alternative from the best to the worse, without quantifying these impacts, if the quantification is too unreliable. However, this does not allow the integration of the uncertainties to the final result. This type of uncertainty could be taken into account using a probabilistic approach: the indicator evaluation is not a number but rather a distribution, which is used in computations. Lastly, the uncertainties related to imprecision are not taken into account in the SESAMO software. These are treated in fuzzy logic models (Mendoza & Martins, 2006; Ma, et al., 2010).
The non-treatment of uncertainties in the SESAMO software is, to us, an important limitation of its application.

Time scales

In the decision tree, criteria that will be immediately impacted by the alternatives and criteria which will be impacted on longer time scales coexist. For example, if we decide to build a dam, energy production will increase right away, while hydro-morphological impacts will show months or years later, and continue to evolve for a long period of time.
This raises two types of questions: first, is it important in the decision making process? As sooner benefits better? Should the future be discounted? And second, how could we take into account the fact that the criteria evaluation will evolve with time? The fact that a decision be taken and analyzed in a punctual fashion can raise questions, since the impacts evolve with time, as well as our knowledge about these impacts. In the Arc-Isère Pilot Case study, we are dependent upon the developed morphological model (Alcayaga, et al., 2012), which considers an initial and a final equilibrium state. Thus, the entered morphological impacts correspond to the impacts that will show in an unknown amount of time, from 10 to 30 years. This may have an impact on the final decision, and must therefore be explicated.

Conclusion

Thus the application of the SHARE MCA method to the Arc-Isère basin has been explained in this report. Especially, all used indicators were described in detail. Several important methodological choices have been made. First, concerning the chosen alternatives, we decided to do *a posteriori* evaluation of the installations that are already present in the basin. Second for the structure of the decision tree, we somewhat privileged the exhaustivity of criteria, as opposed to the practical possibility to evaluate them and to get easily interpretable results. We also focused on the taking into account of the morphological impacts of dams, which were evaluated using an expert model realized in parallel. For the weight attribution, we decided to give a different weighting scheme to different river reaches which had distinct management priorities, and to then aggregate the reach results. This allowed us to account for the heterogeneity of the Basin. Lastly, the results were not clear cut. They pointed almost equally towards two different alternatives: No hydroelectric equipment, and hydroelectric equipment of the upper basin (storage dams). Lastly, it seemed important to touch the issue of uncertainties and time scales: it would be interesting to take these aspect into account more explicitly in future applications of the method.

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