WATER CHANGE

LAYMAN'S REPORT 2012

MEDIUM AND LONG TERM WATER RESOURCES MODELLING AS A TOOL FOR PLANNING AND GLOBAL CHANGE ADAPTATION.

APPLICATION TO THE LLOBREGAT RIVER BASIN

LIFE07 ENV/E/000845

WATER CHANGE

PROJECT TITLE:

Medium and long term water resources modelling as a tool for planning and global change adaptation. Application to the Llobregat Basin

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KEY MESSAGES:

The Water Change project developed a methodology and a tool to include Global Change impact analysis in water management plans. Its aim is to bring support to decision makers in choosing adaptation strategies for their long term planning, based on a cost benefit approach.

Outline

Presentation and objectives 03

Methodology and tool 04

DPSIR framework 05
Global Change scenario creation 06
Modelling system 07
Impact analysis 08
Definition of adaptation strategies 08
Cost benefit analysis for optimal adaptation 10

Case study 12

Presentation 13
Global Change scenarios 14
Impact analysis 14
Adaptation and cost benefit analysis 15

Dissemination 17

Water change workshops 18
Conference 18
Website, video and brochure 19

Conclusion and potential transfer 20

Impreso con papel ecológico

Presentation and objectives

PRESENTATION AND OBJECTIVES

In the context of Global Change water resources are under increasing pressure and more regions of the world are likely to suffer from water stress. The Water Change project developed a tool and methodology to support decision makers of the water sector in including Global Change impact assessments and adaptation strategies in their long term planning.

GLOBAL CHANGE

ALL ANTHROPOGENIC CHANGES AFFECTING DIRECTLY OR INDIRECTLY THE QUANTITY AND QUALITY OF WATER, INFLUENCING THE SUSTAINABLE MANAGEMENT OF WATER RESOURCES

OBJECTIVES:

- To develop a methodology for medium and long-term modelling of water resources in a river basin, taking into account future scenarios of climate, land uses and water demands, based on socio-economic evolution.
- To develop a modelling system capable of predicting the evolution of water resources within a river basin, by connecting input data, models and output data, and allowing the user to visualize and analyse the results.
- To apply the previous methodology and tool to a case study: the Llobregat river basin, which is highly affected by human activity.
- To assess the impacts of global change on water resources and associated infrastructures in the case of study, and to determine the vulnerabilities of different sectors. These two parameters will determine the final risk.
- To propose appropriate adaptation measures for the case studied, based on the evaluation of their benefits and costs (economic and environmental) in order to determine the most suitable ones, and value the repercussions on the investments required for their implementation and feasibility.

Methodology and tool

METHODOLOGY AND TOOL

DPSIR FRAMEWORK

In order to simulate Global Change impacts and, thereafter, develop strategies of adaptation, it is fundamental to understand the cause of the changes, and how they impact on the environment and the water resources. To do so, the methodology was structured according to the DPSIR framework. This approach stipulates: the Drivers of change generate Pressure on the environment, modifying its State, therefore causing some Impacts that could finally stimulate a Response from society. The DPSIR framework applied to the Water Change project is presented on **Figure 1** and includes the following steps: definition of Global Change scenarios, analysis of their impact through the integrated tool developed, and adaptation strategy comparison based on a cost benefit analysis.

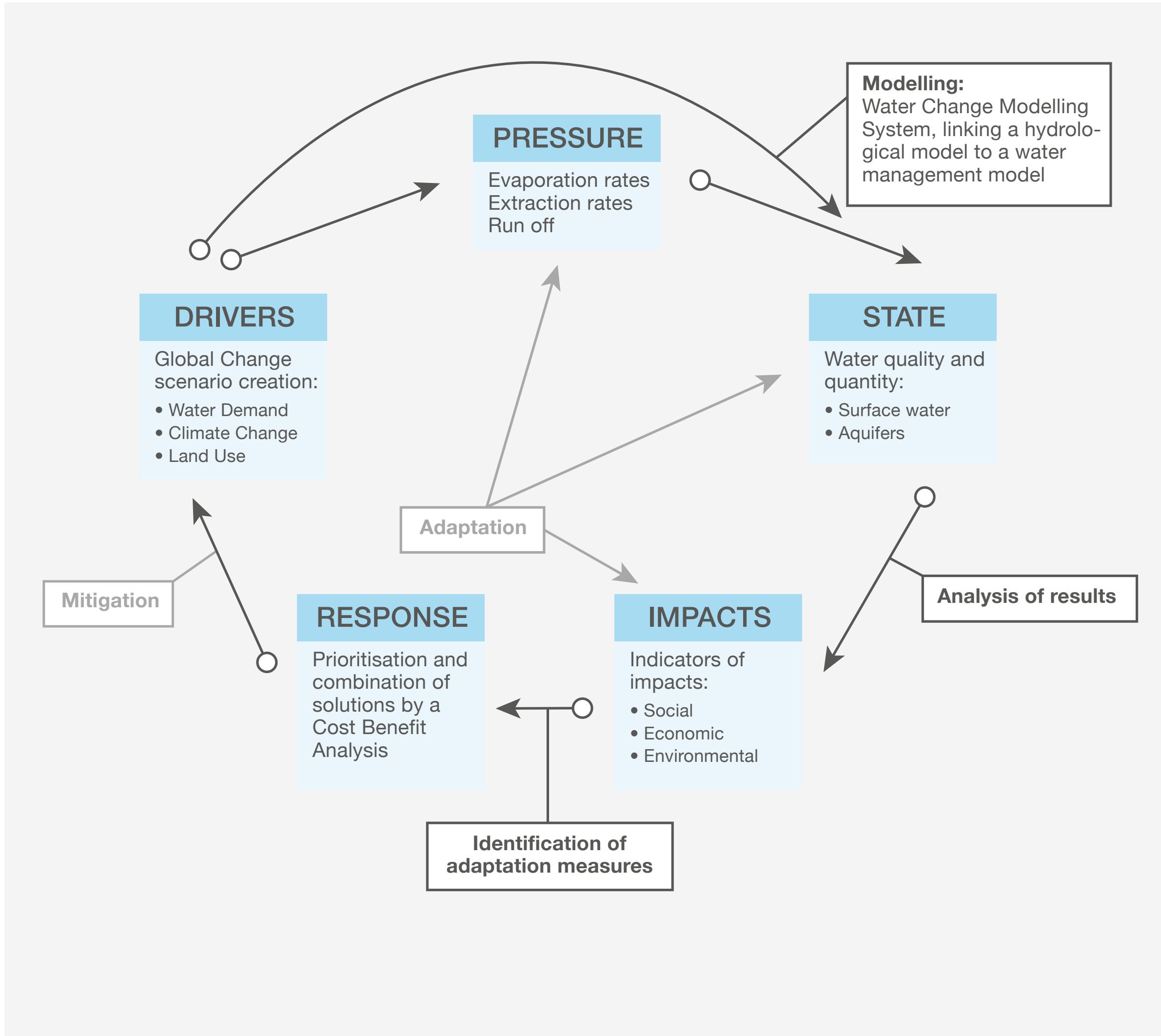


Figure 1: DPSIR framework applied to the Water Change project

METHODOLOGY AND TOOL

GLOBAL CHANGE SCENARIO CREATION

The drivers of Global Change taken into consideration are: climate change, land use, water demand (see box1). Studies of reference as well as results of existing projection models (climate models, land cover prediction tools) were used to assess the potential evolution of drivers and establish coherent hypothesis of change for different time horizons (**Table 1**).

GLOBAL CHANGE DRIVERS: BOX1

- Climate change: Precipitation patterns, temperatures and extreme events occurrence will be modified
- Land use: will be modified due to urbanisation, change in forest management and agricultural practices
- Water demand: Will be affected by demographic evolution, behaviour and climate change

	PROJECTIONS BASED ON MODEL'S RESULTS	FUTURE TENDENCIES FORM CURRENT STATE BASED ON EXPERT HYPOTHESIS
Demand	• Population projection models based on socio-economic evolution	• Local historical consumption rates modification • behavioral changes • climate change impact on demand
Climate	• General Circulation Model results • Downscaling • Correction	• Tendencies of mean precipitation and temperature • Increase of seasonal variability and drought
Land Use	• Land use projection model's results	• Observation of past tendencies • Local scale forest management

Water demand projections

Water availability projections

Table 1: Evolution of drivers

Scenarios of Global Change are used as inputs to the modelling system to simulate the hydrological response of the basin and evaluate the vulnerability of the water resource management system, under possible future conditions.

MODELLING SYSTEM

To address the interdependency between different issues of water resources management at the river basin scale (hydrology, quality, management) an integrated tool was developed linking several models of the water cycle. The tool developed, called Water Change Modelling System (WCMS) has the following characteristics:

1) Decision Support System (DSS) for long-term planning of water resources, which helps in the decision making process of water management,

2) Integrated tool coupling various models of the water cycle, such as hydrological, water management, and water quality models to simulate transversal processes affecting water availability and water use,

3) Generic tool that can be customized by the users for each application, and run with their own models.

The modelling system stores data from scenarios of Global Change and gives results in terms of impacts on water resources through a user-friendly graphical interface. Deficits in water supply for the different uses can be visualised and adaptation measures can be implemented to test their efficiency.

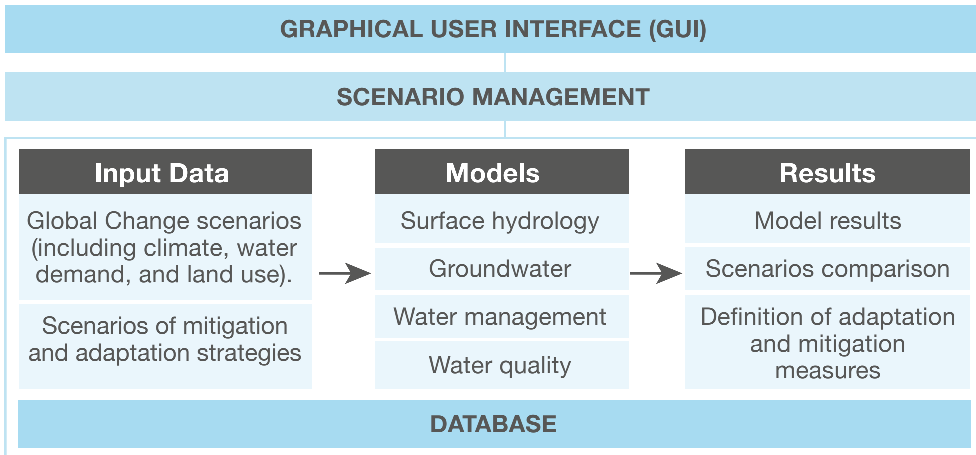


Figure 2: Modelling system overview

METHODOLOGY AND TOOL

IMPACT ANALYSIS

Indicators of impact are obtained from the simulations. Water deficits, supply reliability and intensity of deficit can be compared for all the scenarios simulated, and for the different water demands of the system (urban, agricultural and environmental demands). Each scenario leads to a different prediction of water deficit (**Figure 3**) which gives an overview of what can occur.

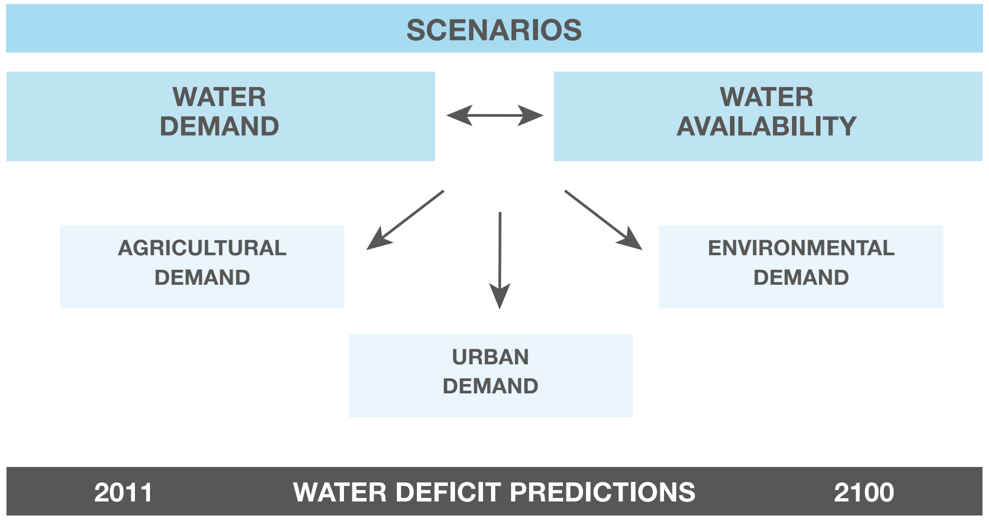


Figure 3: Water deficit prediction for different water demands

DEFINITION OF ADAPTATION STRATEGIES

Adaptation measures can be divided into "demand side" measures (reduction of demand), and "supply side" measures (increase in water availability). They can also be permanent (long-term solutions to avoid water shortages) or punctual (short-term solutions in case of water deficit). The impacts obtained in the previous step are the basis for defining different combinations of measures (referred to as adaptation strategies). New scenarios are developed and simulated including the adaptation strategies with the aim to solve different levels of water shortages. The impacts remaining after adaptation help for choosing the optimal adaptation strategy in terms of technical and economic efficiency. Depending on the case study the adaptation measures may vary and some propositions are given in **Figure 4**.

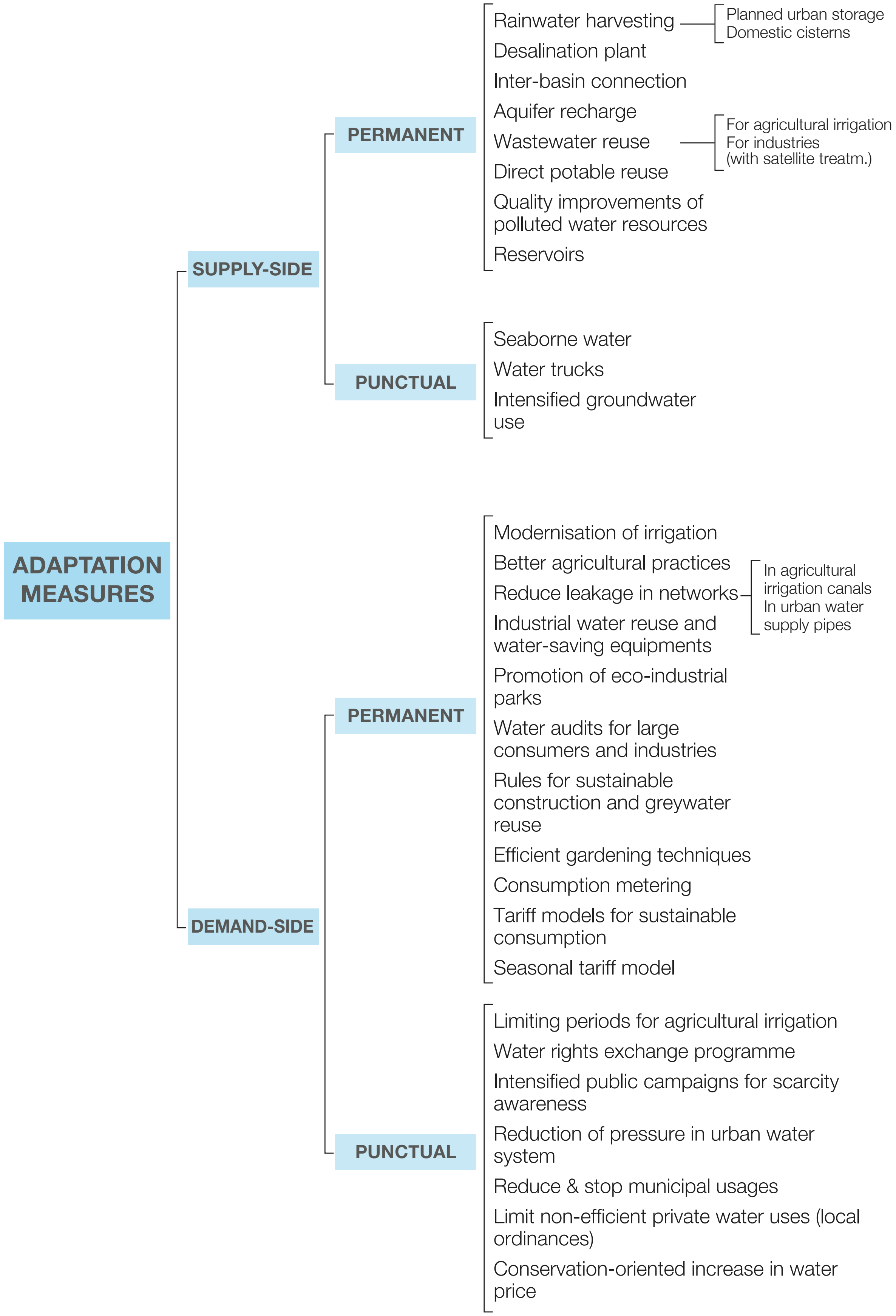


Figure 4: Adaptation measures classification

METHODOLOGY AND TOOL

COST BENEFIT ANALYSIS FOR OPTIMAL ADAPTATION

Adaptation strategies should be feasible solutions to avoid deficit in the basin and optimise the investments and costs. The cost-benefit analysis addresses this issue by comparing the costs of implementing alternative sets of measures/policies to the benefits obtained from their application as a response to the expected water shortages over the 30-year period simulated (**Figure 5**). The benefits of adaptation refer to the avoided costs of Global Change impacts, that is, the economic damage of droughts on the different water uses –agricultural, industrial and domestic– in a basin in case no adaptation is undertaken. Water deficits have several consequences that affect negatively the welfare of society, and the aim here is precisely to quantify this loss of welfare. The methodologies considered to quantify the impacts in economic terms address direct, indirect and intangible costs of the drought.

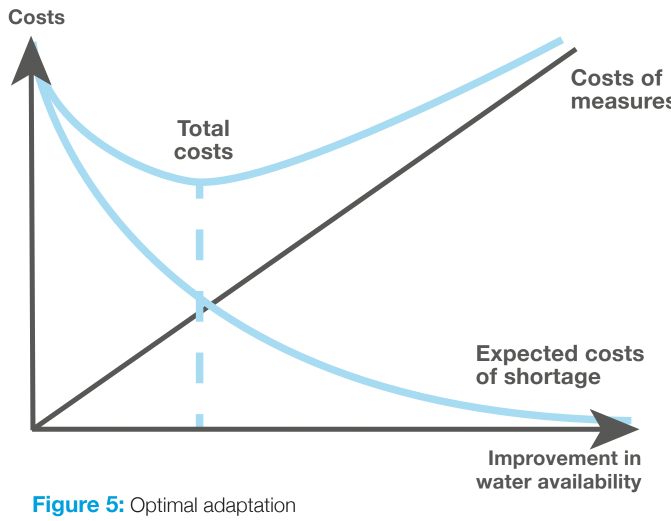


Figure 5: Optimal adaptation

COSTS OF ADAPTATION =

Explicit cost of the measures

BENEFITS OF ADAPTATION =

Valuation of impacts without adaptation - valuation of residual impacts after adaptation

Direct and indirect costs of drought (also referred to as market effects) are calculated for industrial and agricultural water demands using a regional economic input-output model (IO), where losses are measured through changes in the gross value added. According to the monthly water supply deficits obtained from the simulation, the IO model quantifies both costs for each economic sector due to disturbances in the intermediate inputs and production. The more intense is the drought, the longer it takes for the economy to completely recover. On the other hand, intangible costs for domestic demands (also referred to as non-market costs) are addressed by adapting existing results from the AquaMoney project, which quantified into monetary terms the non-market effects of a drought in several cases.

The value of the cost the population perceives when there is a water supply restriction is equivalent to the value they are willing to pay in order to avoid this situation. Each time there is deficit in domestic water demand, an annual cost can be assigned to the impact.

Regarding the costs of adaptation, carrying out a cost-effectiveness analysis of a set of measures helps to rank and prioritise the different options. Each measure consists in an explicit cost function (fixed and variable cost) and an effectiveness indicator (the incremental water resources mobilised or saved). They can be plotted according to their minimum unit cost, which is usually achieved when the measure operates at its full capacity. It is then possible to decide the most efficient strategy to achieve a certain adaptation target, that is, a given volume that needs to be added to current available water resources to face water deficit (**Figure 6**).

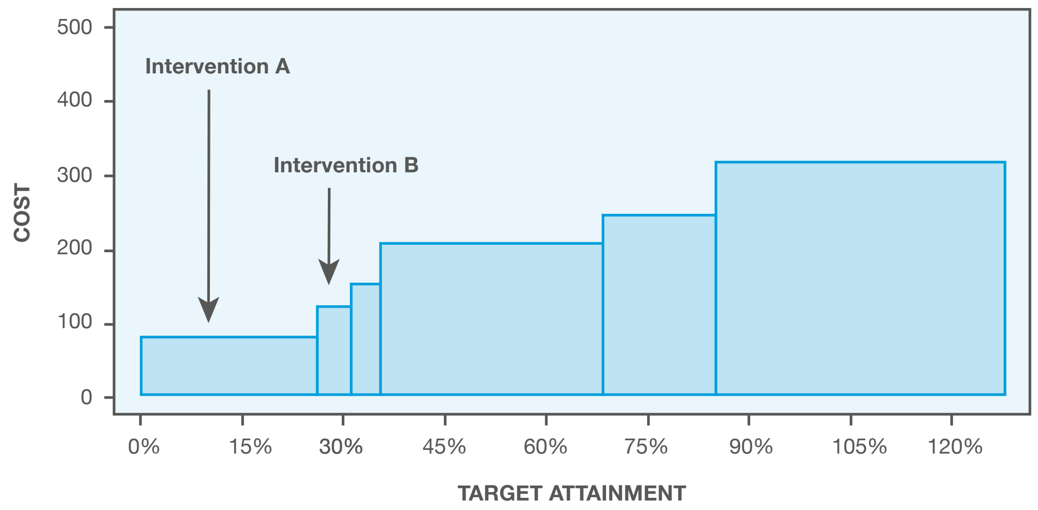


Figure 6: Water availability cost curve

Finally, the aggregation of CBA results consists in designing several adaptation strategies that are tested in the water management tool for a number of future climate scenarios. It provides data on the costs incurred by measures and the avoided damages of drought on society, and allows comparing them. These results provide insight for decision-makers about how much adaptation is needed with respect to the uncertainty of future global change scenarios.

Case study

CASE STUDY: THE LLOBREGAT RIVER BASIN

PRESENTATION

The Llobregat river basin is located in Catalonia, northeast of Spain. Together with the Ter and other small basins, the Llobregat supplies a densely populated area (Barcelona region with over 5 million inhabitants).
Average annual rainfall reaches 700 mm and the hydrological regime is largely dependent on the seasonality of precipitation. 20% of the total rainfall goes to the river system. Due to the high seasonal variation of precipitation. Only a fraction of the precipitation can be used for demands and the supply is highly dependent on the quantity of water stored in the dams upstream.

LLOBREGAT RIVER BASIN:

- TOTAL AREA ~ 5000 KM^2
- RIVER LENGTH ~ 170 KM
- RESERVOIR CAPACITY ~ 220 HM^3

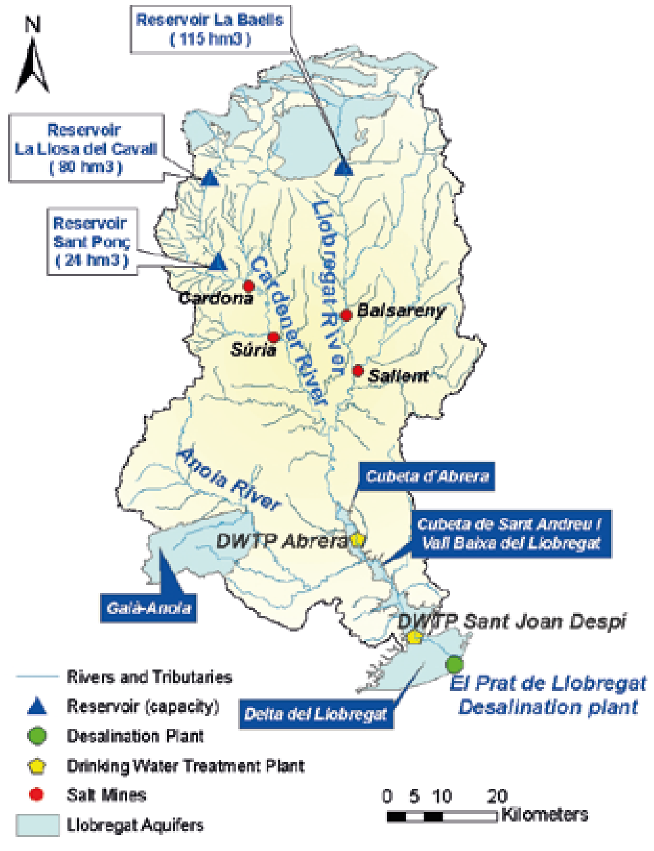


Figure 7: Llobregat River basin

CASE STUDY: THE LLOBREGAT RIVER BASIN

GLOBAL CHANGE SCENARIOS

A total of 65 scenarios were established for the case study, linking the different factors of influence, and matching future water availability scenarios to water demand projections. For each time horizon, a set of several scenarios were obtained based either on projection models or plausible hypothesis of change (**Table 2**).
In Table 2 the minimum and maximum variations obtained for the different scenarios are given.

	WATER DEMAND			WATER AVAILABILITY	
FACTORS*	**CC[1]**	**Demagraphy[2]**	**Behaviour[3]**	**CC[1]**	**Land use[4]**
2027	0 to +1%	+6% to +24%	0 to -10%	+1% to -15%	0 to -4%
2050	0 to +5%	+7% to +42%	0 to -10%	-5% to -15%	0 to -4%
2100	5% to +12%	+10% to +45%	0 to -10%	-10% to -40%	0 to -4%

[1]CC= Climate change impact on mean water availability and mean water demand
[2]Demography = Increase of demography with respect to 2007 data
[3]Behaviour= Impact of behavioural changes on mean domestic water demand
[4]Land use= Impact of land use change on water availability
* The data were obtained from ACA, IDESCAT, F. Gallart 2001 and 2003, IPCC climate scenarios, SMC, AEMET.

Table 2: Predicted range of change for scenario creation – Llobregat basin

IMPACT ANALYSIS

Simulations were run for the 65 scenarios. The mean yearly water demand divided in amount supplied (light blue) and deficit (dark blue) (sum of all demands of the Llobregat-Ter basin) is presented on **Figure 8**, for each scenario.

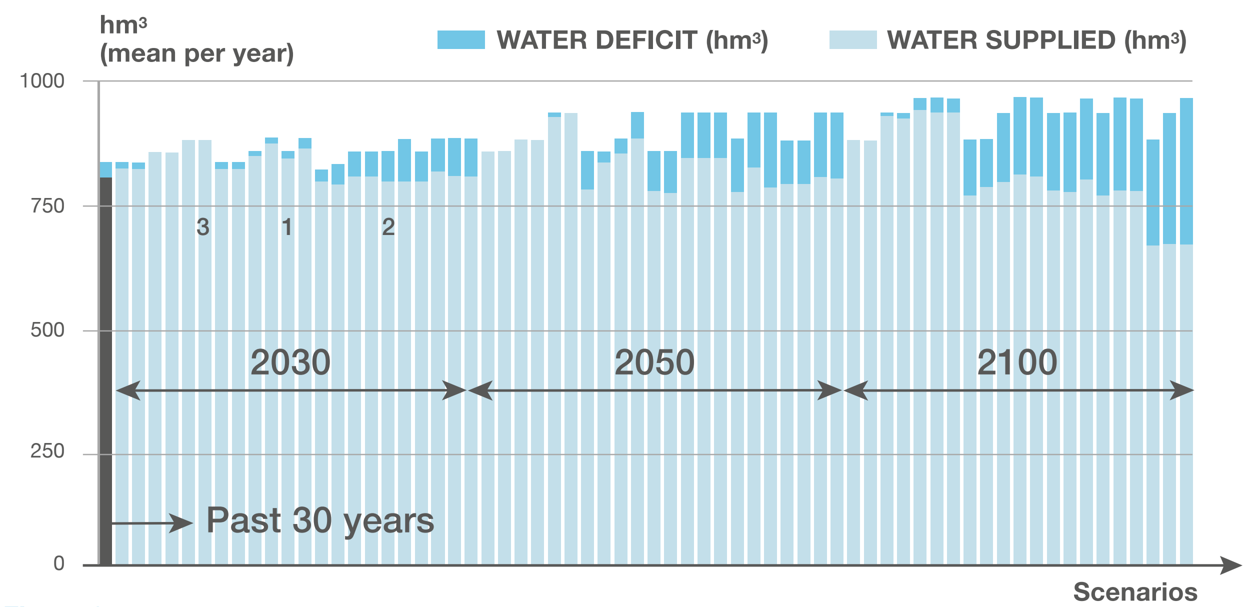


Figure 8: Future water deficits – simulation results for the 65 scenarios

The results show the range of impacts increases with time. There are more scenarios with important deficit in the future. In 2030, according to these projections the deficit may reach 10% of the demand while in 2100 the deficit could go up to 30% of the demand.

ADAPTATION AND COST BENEFIT ANALYSIS

Specific adaptation measures were selected to be applied to the Llobregat river basin. Each measure was studied in detail and the amount of water gained from its application and the price of implementation were identified. Different sets of adaptation measures were identified for three scenarios for 2030 (economic projections not being reliable enough for long term scenarios) with the aim to avoid water deficit at the lowest costs. The three scenarios selected (scenarios 1, 2 and 3) are chosen in order to be representative of the future possible conditions: 1% and 7% deficit in total for scenarios 1 and 2 respectively and no deficit for scenario 3 (**Figure 8**). The third scenario, not predicting any deficit is used to assess the cost incurred by adapting unnecessarily. The strategies (see **Figure 9**) are: a high adaptation strategy (AM1) covering 70% of the monthly deficits of all 65 scenarios, a medium adaptation strategy (AM2) covering 50% and a low adaptation strategy (AM3) covering only 30% of the monthly deficits.

AM1: (high)

- Desalination plant
- Irrigation modernisation
- Seasonal tariff
- Anoia river quality restoration
- Rhone river transfer

AM2: (medium)

- Desalination plant
- Irrigation modernisation
- Seasonal tariff
- Anoia river quality restoration
- Water reuse in metropolitan Barcelona
- Aquifer recharge
- Seawater intrusion barrier
- Promotion of local sustainable construction
- Subsidies for adoption of water-efficient domestic appliances
- Direct potable water reuse

AM3: (low)

- Desalination plant
- Irrigation modernisation
- Anoia river quality restoration
- Water reuse in metropolitan Barcelona

Figure 9: Strategies of adaptation

CASE STUDY: THE LLOBREGAT RIVER BASIN

Each of these strategies are tested for the three scenarios with the aim to know which part of the drought damage has been effectively avoided and which cost (investment and operation of the measures) should be assumed. Therefore, the inclusion of these alternatives into the tool and the calculation of their costs and benefits provide insight for decision-makers about how much adaptation is needed with respect to the uncertainty of future global change scenarios.

The decision can be based upon a similar matrix as the one below (**Table 3**). This matrix shows the net results (benefits – costs) in present values for the case study for a simulated period of 30 years (2011-2030). A first determining conclusion arises: benefits are significantly higher than costs and thus adaptation to Global Change is desirable in the cases considered (except for the no-deficit scenarios). Regarding which strategy should be chosen, the decision-maker can apply different selection criteria, combining the economic values with other indicators of impact. It is recommended to complete these results with further information such as the fact that some strategies may not avoid 100% of the drought in all the scenarios and thus society should cope with remaining drought impacts, which may be still significant.

	SCENARIO 1* (LOW DEFICIT)	SCENARIO 2** (MEDIUM DEFICIT)	SCENARIO 3*** (NO DEFICIT)
High adaptation (AM1)	13.369,05	80.829,96	-1.775,27
Medium adaptation (AM2)	14.293,01	89.513,98	-887,05
Low adaptation (AM3)	14.756,70	77.315,41	-490,58

* Scenario 1 = 20% increase in domestic water demand, 5% decrease in water availability
** Scenario 2 = 10% increase in domestic water demand, SMCA2 climate scenario
*** Scenario 3 = Any scenario not predicting any water deficit as of 2027

Table 3: Accumulated net result (benefits minus costs) for each scenario and strategy, in present values (million €)

Dissemination

DISSEMINATION

The project has used different channels to disseminate its activities:

WATER CHANGE WORKSHOPS:

The project team organized 2 workshops to present the project activities and debate with stakeholders. A first workshop was held in Barcelona on November 18th, 2010. The Final Workshop took place in Barcelona on February 23rd, 2012.

CONFERENCES:

The Water Change project was presented in several Conferences:

- April 2009: EGU Conference in Vienna
- September 2009: 11th Plinius Conference on Mediterranean storms in Barcelona
- October 2009: Etiages-secheresses-canicules et leurs impacts sur les usages de l'eau, in Lyon
- January 2010, LIFE Climate change seminar in Helsinki
- May 2010, EGU Conference in Vienna
- September 2010, Hydropredict Conference in Prague
- December 2010, SCARCE 1st Conference in Girona
- June 2011, WATERMATEX Conference in San Sebastián
- October 2011, Jornadas de Ingeniería del Agua in Barcelona
- November 2011, SCARCE 2nd Conference in Madrid
- May 2012, Water Innovation Europe Conference in Brussels

The project was also presented during the Imprints Workshop in June 2010 and CUADLL Workshop in November 2011.

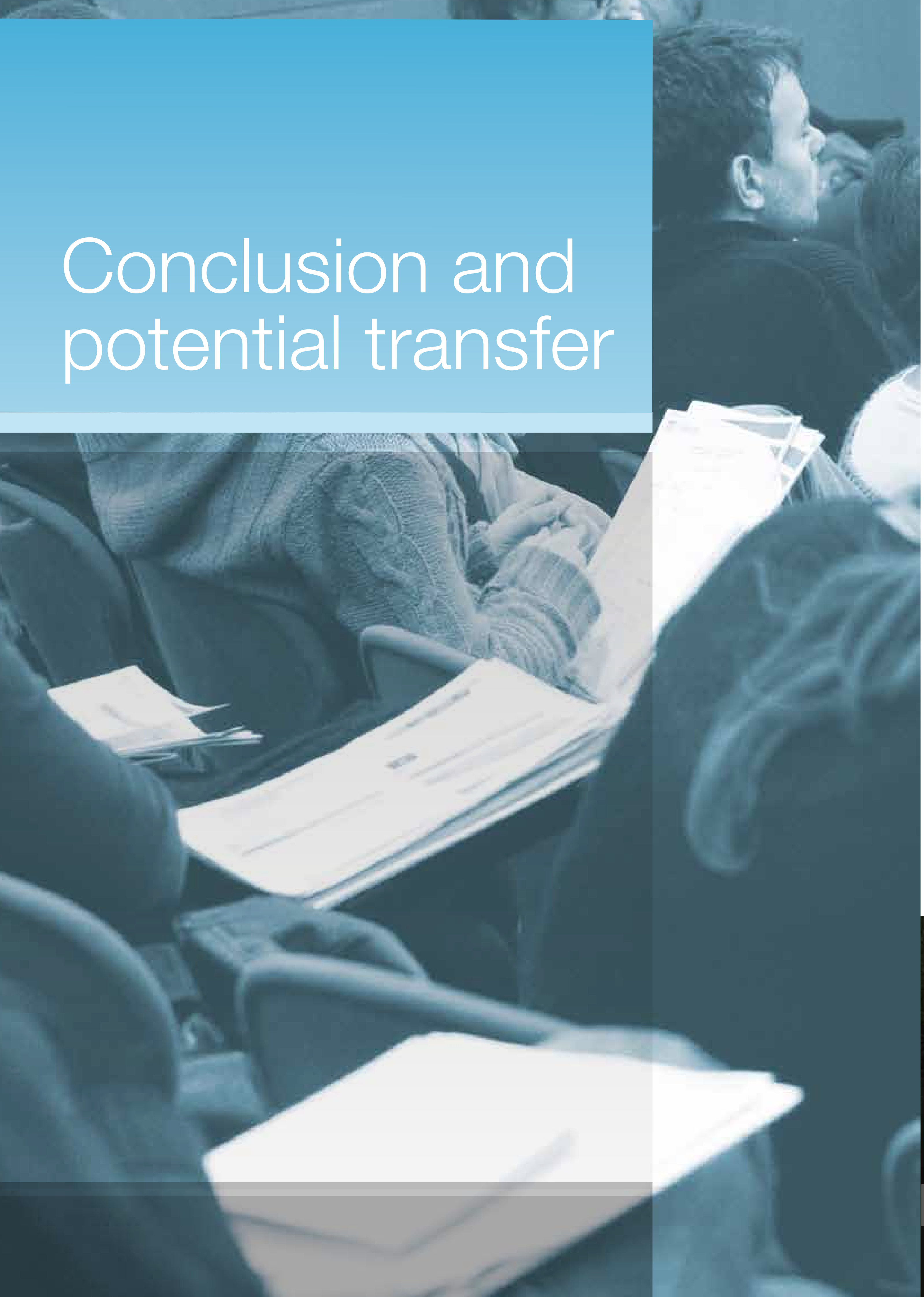
WEBSITE, VIDEO AND BROCHURE

A website for the project was developed as well as a video, which is downloadable from the internet. Two brochures were created, one for the preliminary results and another with the final results and conclusions of the study.

See: **http://www.life-waterchange.eu/**

PUBLICATIONS:

Publications for different scientific journals are being prepared and will be available on the project's website.



Conclusion and potential transfer

CONCLUSION AND POTENTIAL TRANSFER

In conclusion, the methodology and tool developed in the Water Change Project facilitate the study of the possible impacts of Global Change on water resources. This is particularly useful for river basin agencies and water companies to develop long term planning in compliance with future scenarios of climate, land use, and water demand.

Specific recommendations are given to establish Global Change scenarios tailored to the issue studied, representative of the entire range of possible futures, adapted to the models of the water cycle used for the simulations and combined in a coherent way.

The modelling approach selected to simulate Global Change impacts is the integration of existing users' models inside a modelling platform. The tool created during the project, the Water Change Modelling System, allows such integration. Other functionalities of the WCMS are the storage of the models input and output files in a central data base, the user interface and the scenarios' comparison via graphics and tables, or visualised in a dynamic map of the river basin.

Finally the project shows how to combine the results of the simulations with a cost-benefit analysis. In this sense, this evaluation supports the decision-making regarding which strategy is the most efficient in terms of avoided drought costs and financial resources needed for its implementation.

The Llobregat case study is used as a support to develop and test the project methodology. Results show the importance of considering Global Change in long term planning, since deficit in water demand could be significantly greater then today and socio economic impact could be very important.

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