Guidance on water stress mitigation
Experiences and inspirations from the AquaStress Integrated Project

December 2008
Contributing partners:
University of Aachen (Germany),
University of Reading (United Kingdom),
NTUA (Greece),
CIHEAM-IAMB (Italy),
ALterra (The Netherlands),
Cemagref (France),
FEUP (Portugal),
Hydrocontrol (Sardinia),
INAT (Tunisia),
IAV (Morocco),
AEOLIKI Ltd (Cyprus),
CNR-IRSA (Italy),
etcetera, to be completed

Contributing authors:
H. Wolters1, D. Assimacopoulos2, M. Manez3, M. Dionnet4, G. Giuliano5 (eds.)

Chapter 1: D. Assimacopoulos, U. Alam6, A. Kassahun7
Z. Lili Chabaane9, Y. von Korff10, M. Blind1
Chapter 3: D. Rollin11, Y. von Korff, D. Assimacopoulos
Chapter 4: G. Giuliano, D. Assimacopoulos, M. Blind
Chapter 5: H. Wolters, K. Tarnacki12, G. Dimova13,14, C. Jacobs15, M. Bauer16,
H.Coelho16, C.Leduc16, A. Pollice17, M. Vurro17, P. Koundouri18,
Y.Kountouris18, T. Pantelides18, N.Pittis19, S. Schmidt, D.Ridder19
Chapter 6: M. Dionnet, K. Daniel10, D. Rollin, P. Koundouri, P. Bots20, Y. von Korff,
L.Vamvakeridou21, R. Giordano17, B. Bluemling22
Chapter 7: H. Wolters, U. Alam, D. Assimacopoulos, M. Manez

1 formerly RIZA; now Deltares, Utrecht, the Netherlands
2 NTUA, Athens, Greece
3 formerly USF; now Cemagref, Montpellier, France
4 formerly Cemagref; now Lisode, Montpellier, France
5 IRSA, Rome, Italy
6 Cranfield University, Cranfield, UK
7 WUR, Wageningen, the Netherlands
8 formerly USF; now Seecon, Osnabruceck, Germany
9 INAT, Tunisia
10 Cemagref, Montpellier, France
11 RWTH, Aachen University, Aachen, Germany
12 University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria
13 Alterra, Wageningen, the Netherlands
14 LUH, Hannover, Germany
15 Hidromod, Lisbon, Portugal
16 IRD, Montpellier, France
17 IRSA, Bari, Italy
18 University of Reading, UK
19 University of Piraeus, Greece
20 formerly Cemagref; now Technical University, Delft, the Netherlands
21 University of Exeter, UK
22 USF, Osnabruceck, Germany

Cover page photo: Guadiana river (Portugal)
Guidance on water stress mitigation

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## INTRODUCTION

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**SUMMARY**  

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Water stress is a global problem with far-reaching economic and social implications. Present trends in economic and rural development, sustainability demands and climate change will keep the issue on the agenda for years to come. This guidance offers a contribution to balanced and sustainable planning of water stress mitigation projects. It discusses the characterisation of water stress and different approaches and options to mitigate its effects.

**Who should read this document, and why?**
The target audience for this guidance are water managers responsible for planning and day-to-day management, typically on a regional to local scale. Presumably other audiences, such as policy developers, students, and water users, will find the presented topics and the suggested procedures relevant as well.

**What to expect, and what not to expect in this document**
Most of what this guidance has to contribute to existing literature is rooted in the experiences and lessons learned in the AquaStress project. AquaStress was carried out as an Integrated Project of the 6th Framework Programme of the European Commission. It ran from February 1st, 2005, to January 31st, 2009. We have limited our scope to the problems and solutions that were identified in this project. Thus, we have no pretences to deliver general descriptions of physical or sectoral aspects of water stress situations throughout Europe and Northern Africa. As an example, shipping and energy production are not addressed.

It is obvious that the results of the AquaStress project cannot be used as a blueprint for new projects. What is possible and useful though is to show the lessons that we learned. In fact, our main objective when writing this guidance is that water managers will find inspiration in the tools, methods and experiences that we describe here.

The other key deliverable of the AquaStress project for the same target audience is the Integrated Solution Support System, the I3S (pronounced I-triple-S). I3S is a collection of software utilities. Some of these utilities, such as numerical models, are stand-alone, whereas others, such as the various knowledge bases and the process support tool, are interconnected. You will find several references to I3S throughout this guidance. For more information, see appendix I and i3s.aquastress.net.
Due to the typical limitations of four-year projects, the full project cycle from incentive to implementation and ex-post evaluation could not be covered. As a consequence, we have not included chapters on implementation, operation or maintenance.

When reading this document, the reader may feel the need for additional and more detailed information. For such circumstances, we have included, at the end of each chapter, a number of references to existing literature and AquaStress reports. The latter are downloadable from the project website www.aquastress.net.

**Test sites and their function in the project**
The AquaStress project was designed to be stakeholder-driven and inclusive, i.e. we tried to combine expertise from all relevant disciplines in our approach and measures. This was accomplished by defining eight test sites, in which after the start of the project stakeholders were 1) organized under the AquaStress banner, 2) invited to co-define the problems related to water stress, and 3) invited to develop solutions in collaboration with the AquaStress researchers. The test site locations are shown on the map in Figure 1 and briefly presented in Table 1. Thorough descriptions can be found in the document ‘AquaStress booklet on Water Stress Mitigation Case Studies’, downloadable from www.aquastress.net.

![Figure 1. Geographical locations of the AquaStress test sites: 1=Guadiana, Portugal; 2=Flumendosa, Sardinia, Italy; 3=Vecht, the Netherlands; 4=Przemsza, Poland; 5=Iskar, Bulgaria; 6=Cyprus; 7=Merguellil, Tunisia; 8=Tadla, Morocco.](image-url)
Definitions of some frequently used terms

The glossary defines the terms and abbreviations that are used more than once in this document. We realise that different views and explanations may prevail in other references. The aim of the glossary is not to change that situation, but simply to make clear in which way the terms were used in the document.

We have defined water stress as: *Water stress occurs when the functions of water in the system do not reach the standards (of policies) and/or perceptions (of the population) in an appropriate quantity and quality, or at an appropriate scale.* It is important to note the difference between water stress and drought. Water stress is related to human water use, whereas drought is a feature of climate which can occur in virtually all climatic zones, with its characteristics varying significantly from one region to another. Hence a drought may cause water stress, but not necessarily so. It is important to note that water stress is about both facts and perceptions.

Reading guide

We have structured this guidance along the phases of a water stress mitigation project. These phases are reflected in the chapters of this guidance, and illustrated in Figure 2.

Chapter 1, ‘How to plan a water stress mitigation process’, addresses the planning approaches that can be followed in water stress mitigation processes in general. It explains in detail the steps that we identified and followed in the AquaStress case studies. In AquaStress we worked out the steps we could take in a lot of detail, but we could not address all these steps (notably those related to implementation are missing). The combination of the general and the AquaStress approach provides the background for the way in which we have arrived at Figure 2.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Country</th>
<th>Main sector(s) involved</th>
<th>Main problems defined</th>
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<tbody>
<tr>
<td>Guadiana</td>
<td>Portugal</td>
<td>agriculture, recreation</td>
<td>The use of water resources is inefficient, and there is a lack of integration between water use functions</td>
</tr>
<tr>
<td>Flumendosa, Sardinia</td>
<td>Italy</td>
<td>agriculture, nature</td>
<td>The competitiveness of farmers is below par, and protection of natural resources is required</td>
</tr>
<tr>
<td>Vecht</td>
<td>Netherlands</td>
<td>agriculture, nature</td>
<td>An optimal ground and surface water regime must be found for competing functions</td>
</tr>
<tr>
<td>Przemsza</td>
<td>Poland</td>
<td>industry, drinking water, nature</td>
<td>The water supply is endangered by pollution</td>
</tr>
<tr>
<td>Iskar</td>
<td>Bulgaria</td>
<td>industry, drinking water</td>
<td>Water resources are used in a non-rational way, the river is polluted</td>
</tr>
<tr>
<td>Akrotiri aquifer</td>
<td>Cyprus</td>
<td>agriculture</td>
<td>The groundwater resources are used in an unsustainable way, causing salt water intrusion</td>
</tr>
<tr>
<td>Merguellil</td>
<td>Tunisia</td>
<td>agriculture</td>
<td>Water resources are overexploited</td>
</tr>
<tr>
<td>Tadla</td>
<td>Morocco</td>
<td>agriculture</td>
<td>The groundwater resources are used in an unsustainable way, surface water is scarce</td>
</tr>
</tbody>
</table>

*Table 1  Overview of the main problems that were identified in the test sites*
Chapter 2, ‘How to identify water stress related problems’, highlights the identification of what is seen and felt as the problem to be solved. We devote a separate chapter to this step, because it is often found that different stakeholders (including the water manager) have different views, and ignoring the need for joint problem definition is bound to cause problems further down the line.

Chapter 3, ‘How to define the goals of the project’, follows the line of thought in Chapter 2 and addresses the ways to come to a joint and widely-supported definition of what the project is actually trying to achieve.

Chapter 4, ‘How to identify options’, addresses the methods and tools that can be used to identify options. The roles of water managers, experts and stakeholders are highlighted.

Chapter 5, ‘Selected options and measures for water stress mitigation’, presents an overview of the options that were actually elaborated in the AquaStress project. This chapter contains many experiences from the test sites, and includes the results of expert testing (in most cases using analytical models).

Figure 2  Phases of a water stress mitigation process and connected chapters
Chapter 6, ‘How to test and evaluate’, explains the most relevant criteria, methods and tools that are used in the procedures for testing and evaluation of the options of Chapter 5. In most cases, testing and evaluation has a pronounced participatory component.

In the final chapter, Chapter 7, ‘How to decide’, we have listed our observations on the decision-making procedures, where the water planner meets the decision makers.

Each of the chapters is edited in a colour according to the colours used in Figure 2. Colours are also used to distinguish between the examples that illustrate the text in the main body. These examples are presented in text boxes, the colour of which is green (for agriculture-related examples), orange (for industry-related examples), or blue (for domestic-related examples). Examples that do not fit in any of these categories, or that may relate to all of them, are placed in grey text boxes.
This chapter highlights the most relevant approaches for planning a water stress mitigation process, and outlines the process followed in the AquaStress case studies. The chapter is subdivided into three sections. The first section describes the theoretical framework that underlies current approaches in water management and planning, aiming to provide the reader with background information on the driving forces behind planning and decision making. The second section is dedicated to the ProST planning tool, a modelling tool supporting collaborative multidisciplinary processes, which has been developed by the AquaStress project. The third section briefly presents the AquaStress planning steps, as these were conceived and undertaken in the implementation of the project, and it provides an evaluation of the approach.

1.1 Planning approaches

Ensuring continuity of supply
Water managers are responsible for protecting their societies from the negative consequences of insufficient water. Though little can be done to prevent lower precipitation, a water manager can develop a plan of action to mitigate the effects society feels. It is worth noting that, in the past, these plans have generally been developed solely by water managers, but now, with support from the EU Water Framework Directive, a broader range of stakeholders are expected to be part of these processes.

Since a water system’s success is measured by its ability to ensure regular supply, and shield the end users from irregular supply, a mitigation plan is devised in order to safeguard supply. However, this plan needs to be able to adapt to the specific situation a society might face at a particular time. A water manager can be proactive in developing a mitigation plan with the other stakeholders by preparing one before the need arises. Or they can be reactive, and wait until they are facing a drought or other climatic phenomena to prepare one.

In preparing a plan to mitigate water stress, a key question to be answered is, ‘Whose water stress?’, as the response will differ. A farmer facing the loss of his irrigated crops due to insufficient water will require a different response to a householder whose domestic taps have run dry. To begin to frame these differing situations, needs and consequences, water managers can use different planning theories.
Planning theories
There are three main theories:
1. Rational Theory, which seeks to take complex situations and break them down into their constituent parts. Each part is then handled and managed separately but expected to fit together, rather like a jigsaw puzzle.
2. Deliberative Theory, which acknowledges there are different types and sources of knowledge, and seeks to establish a dialogue between them in order to get the different points of view, with the hope of leading to a common vision, rather like making a rope.
3. Political Theory, which, like Deliberative Theory, recognises there are multiple views, but does not seek to come to a consensus at the end of a discussion.

Whereas Rational Theory is still used in water management and planning, its limitations are that it does not take into account the social, cultural and political aspects of water. It is also criticised for overly simplifying a complex resource such as water. Water managers are attempting to encompass these issues by recognising the multiple types of knowledge and views. They can use two complementary tracks. Either organise stakeholder platforms within which to engage more views and thus enlarge the decision making base, or submit their own plans for public discussion. In both situations, preconceived ideas are likely to be contested and possibly modified, and even abandoned. The involvement of more voices in the decision-making process makes for a more chaotic process that struggles with the streamlined nature of most government projects with tight deadlines.

Further reading:
Experiences in Cyprus

Though the full planning process has not been enacted during the AquaStress project in any of the test sites, aspects of the process have been utilised in some places. In Cyprus, a severe drought and heavy drawdown on the Akrotiri aquifer in the greater Limassol area has pushed the Water Development Department to begin engaging with the local stakeholders in an attempt to develop a mitigation plan for the aquifer. As a new EU member state, Cyprus is subject to the obligations of the European Water Framework Directive including the involvement of the public in decision making. However, Cyprus does not have the same tradition of public participation as, for example, the Netherlands. Therefore, the process of eliciting stakeholder opinions has to overcome numerous obstacles including the public themselves. Water use in the area is also affected by issues such as the classifications given to land, and the government’s refusal to reclassify this land for non-agricultural uses. Nonetheless, the Water Development Department has started the process, moving away from a Rational Theory approach towards a Deliberative Theory. However, the interactions have not yet filtered into policy.

1.2 Planning tool: ProST

Planning a water stress mitigation project involves a team comprising water managers, researchers from various disciplines and stakeholders with diverse interests. Participants in such a team are engaged in a collaborative and iterative process that includes a number of discrete steps (see section 1.3). As these processes are quite complex, they gain in effectiveness when supported by project management tools, also known as workflow managers. Several tools exist to support planning. MSProject (Microsoft) is a well known example. However, project management tools frequently lack the ability to work in distributed participatory processes (many users at different places), or connections to knowledge bases (e.g. on information of water stress mitigation options). Hence an advanced tool called ProST has been developed in AquaStress. ProST uses scientific and technical guidance defined in the AquaStress process knowledge base.

The guidance specifies managed process steps on how to carry out various tasks to achieve reliable and reproducible results. ‘Managed’ means that tasks within a managed process can be scheduled and monitored using ProST. ProST distinguishes between different types of users, identifies their interests and information needs and allows multiple actors to share
their results. Using ProST involves the following three steps, depicted in Figure 1.1:

1. The project team collaboratively defines the water stress mitigation process – A process is a step-by-step description of what the team plans to do. The project team defines the process by breaking it down into steps, steps into tasks and tasks into activities and methods. Such a breakdown enables users to reuse parts of other process definitions at a step, task or activity level. The process describes any relevant information that can be of use in executing the tasks. For assistance in Step 1, the AquaStress team has developed a tool called the Knowledge Base Editor. This tool is described in more detail at i3s.aquastress.net.

2. The project leader sets up the project. – To set up a project means to import the process in ProST, enlist users, define their roles and authorisations, establish deadlines and time requirements for each task and start the project.

3. Project team members use ProST. – After the initialisation, the project journal is sent to a central server from which it will be accessible to all project team members. The members of the team can use ProST to get guidance on how to execute their task, register what they have actually done and share the results with other project team members. In this way, besides enhancing collaboration among team members, ProST provides a comprehensive audit trail. Dependent on the role of the user, ProST can be used as a browser for water stress mitigation processes, as a tool to get insight about what is going to happen in the project, or in its full potential, as a means of collecting and sharing information about the activities for collaboration and participation, monitoring and auditing.

**Figure 1.1 Managing participatory processes using ProST**
1.3 Planning approaches in the AquaStress test sites

As an example of the application of a planning approach in water stress mitigation projects, we present the AquaStress experience. AquaStress was a research project, but it was firmly rooted in its test sites, hence we think our approach can be useful for practical water stress mitigation projects. Some evaluation comments on possible differences are included at the end of this section.

One of the most innovative elements of the AquaStress project is that the case studies that were worked out in the test sites were not predefined in the inception phase. The activities and objectives of the case studies were determined during the project lifetime in the eight test sites. Within the implementation of the project activities, the project partners and stakeholders have jointly defined and adapted the case study activities, as well as the concept of the case study in itself.

The definition of an AquaStress case study is: ‘An in-depth plan covering selected issues and also the regions that might be selected within the test site, by implementing specific options or combination of options in all or part of a test site, and offering integrated solutions together with technical, economic, institutional, educational and social assets.’

The planning of the water stress mitigation process followed in AquaStress has been implemented in nine discrete steps, also detailed in Figure 1.2:

1. Collection of data on the existing circumstances;
2. Stakeholder analysis and organisation of stakeholder bodies;
3. Quantification of water stress at the test sites;
4. Identification of water stress causes;
   - Using the DPSIR Framework;
   - Through interactive/participatory approaches - problem tree development;
5. Identification of water stress mitigation options;
   - Through interactive/participatory approaches - objectives tree development;
   - Investigation/research on types of options;
6. Selection of suitable and applicable options through stakeholder and expert consultations;
7. Implementation of options (virtual or real);
8. Evaluation and assessment of options;
   - Evaluation through the use of indicators;
   - Evaluation through a participatory process;
9. Refinement and reformulation of proposals (implementation plans and strategy formulation).
This nine-step process was adapted and refined through the continuous participation of stakeholders in the project. The alternation between research work (undertaken by the experts) and participatory activities, providing focus and setting the context of the case studies, has proven invaluable in the development of a mutually beneficial working relationship and the building of trust with participating stakeholders, as well as in the fine-tuning of the research approach.

**Step 1 – Data collection**
The first step of the process entailed the collection of data on:
- The characterisation of water stress, the description of the characteristics of the water stress experienced in each of the eight test sites;
- The water stress mitigation options and tools already applied in the test sites;
- The stakeholder groups available or active in each of the eight test sites.

In practice the data collection was not strictly the first step, but was intertwined with the following steps. Many data could only be collected with the cooperation of the stakeholders, moreover additional data were needed when the problems to be solved became clearer.

**Step 2 – Stakeholder analysis and stakeholder bodies**
An analysis of the local stakeholder groups was undertaken to identify key stakeholder groups and candidates for participation in the stakeholder bodies foreseen in the project, the Local Public Stakeholders Fora (LPSFs).

*Figure 1.2  Planning a water stress mitigation process – the AquaStress approach*
Those individuals were identified who could support and contribute to the full range of the project activities. The LPSFs, established in all test sites, were local councils composed by stakeholders active in the test site regions, with a profound interest in water management, either as end-users or as decision makers. The LPSFs were fully involved in the activities at the test site level. They have remained in direct collaboration with the project through meetings, workshops and continuing communication, in an effort to bring regional knowledge and experience into the project.

During the starting phase of AquaStress, it became clear that communication between the many researchers of the project and the partners in the test sites was problematic. In order to overcome these problems, Joint Work Teams (JWTs) were established in all test sites, comprising test site partners, AquaStress researchers and selected stakeholders. The establishment of the JWTs was a pivotal point in the implementation of the project, and greatly improved efficiency at the local level.

**Step 3 – Quantification of water stress**
Subsequent to the collection of data, the characterisation and quantification of water stress in the test sites was undertaken. In order to achieve the quantification of water stress, different approaches were used:

- The DPSIR framework, also used in subsequent steps, which are described in section 2.1.
- Individual indicators, used to describe the economic, environmental, social and/or institutional conditions of an area. These indicators (e.g. water use per capita) aim to summarise large amounts of measurements to a simple and understandable form in order to stress the main characteristics of a system.
- Integrated indices. The term ‘index’ refers to an aggregation of individual indicators. Indices also describe the complex characteristics of a system in simplified form; examples include the Water Stress Index (see section 2.2), the Water Exploitation Index and Water Availability Index.

**Step 4 – Identification of water stress causes**
Two separate groups undertook the identification of water stress causes in parallel:

- Researchers, through the analysis of the data collected in the test sites, using the DPSIR framework for the determination of the drivers and pressures causing water stress;
- Stakeholders, through interactive approaches in dedicated workshops to set up the problem trees. The problem trees aim at the identification and prioritisation of the underlying causes of water stress.

**Step 5 – Identification of water stress mitigation options**
Two groups undertook the identification of mitigation options in parallel. At the test site level, the stakeholders developed objective trees aimed to identify...
potential solutions to address the water stress causes that were identified in the previous step of the process. On the other hand, the researchers dedicated a significant part of the project effort and resources to this activity. They undertook the analysis and development of water stress mitigation options using a multi-disciplinary approach integrating technical and non-technical options.

**Step 6 – Selection of suitable and applicable options through stakeholder and expert consultations**

The selection of suitable options for implementation and evaluation in the test sites marked the definition of the case studies. The aim of the case studies was that they would serve as learning platforms to understand responses and impacts of different types and conditions of water stress.

In the test sites the JWT’s discussed and defined a goal and specific objectives. These goals and objectives were based on the perceptions of the local stakeholders on the problems and on acceptable solutions. This meant that there was an inherent bias in the criteria employed and in the selection of options, depending on the background and point of view of the participating stakeholders. This could not be avoided and, in fact, was expected in our stakeholder-driven approach. Nevertheless, reaching a consensus and hence achieving acceptance by the local stakeholders prior to the implementation of the selected options has enabled AquaStress to overcome one of the major obstacles in the implementation of projects in the field, where proposals put forward by experts often find strong resistance by the local society.

**Step 7 – Implementation of options (virtual or real);**

Three types of case studies were identified, in accordance with the type of implementation activities undertaken:

1. External case studies, in which the experiences and data from actual previous water stress mitigation option implementation or experiments undertaken in the past could be used as input for analysis;
2. Virtual implementation; undertaken through means such as computer simulations and workshops dedicated to role-playing exercises;
3. Field implementation, involving the actual implementation of mitigation options in the test site.

Given the time and budget limitations involved in the research process, the virtual implementation of options was selected in the majority of case studies.

**Step 8 – Evaluation and assessment of options**

The evaluation and assessment of the implemented water stress mitigation options was undertaken again in parallel by the experts and stakeholders, in a twofold process:

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AquaStress implementation was mainly virtual
• Evaluation through the use of indicators and indices; describing the efficiency and effectiveness of the employed options in mitigating the water stress circumstances faced in the case studies, and
• Evaluation through a participatory process undertaken by the JWTs (described in detail in chapter 6).

**Step 9 – Refinement and reformulation of proposals**

The final step in the AquaStress water stress mitigation process planning approach involves the formulation and refinement of proposals. This entails the development of Plans of Implementation for the selected options, within the framework of strategy formulation for the case studies. This process also involves a direct collaboration with the LPSF at each test site, towards the definition of the enabling environment and the establishment of a general consensus on an acceptable and suitable framework for the successful implementation of the plan.

**Evaluation of the AquaStress planning approach**

Throughout the implementation of the project, the partners and JWT members undertaking activities have encountered difficulties, faced setbacks, and identified weaknesses in the approach followed. The establishment of the JWTs was of key importance in the implementation of the project. It played a major role in overcoming the difficulties in communication that made themselves felt between the many project partners. The members of the JWT’s could dedicate themselves to clear tasks. They worked together close enough to learn about each other’s inputs in the process and appreciate them. The majority of option implementation activities have been undertaken in a virtual setting, because the actual implementation of water stress mitigation options was, for the most part, not feasible in the framework of an integrated project. Key steps of a real planning process, which could have significantly modified the decisions made, were therefore not integrated in the process: a financial analysis of the available options, the referral of proposals to decision-makers for a final approval, and of course the actual field implementation and subsequent evaluation of options. Furthermore, initiating the engagement and involvement of stakeholders has proven to be harder and more time consuming than anticipated, although once engaged the stakeholders can become enthusiastic participants and supporters of the process. Data collection has also presented some challenges, as the evaluation of an option’s effectiveness and applicability is highly dependent on the available data. A lack of relevant or reliable data can severely affect the evaluation process and compromise the significance of the derived results. Moreover the data collection was often not the first step of the process, as depicted in figure 1.2, but followed the steps of stakeholder analysis. A lot of the data was provided by the stakeholders.
At the same time, the AquaStress methodology has also been hailed as an innovative approach with significant advantages and offering new opportunities for improvements in the framework of water research. The enhanced role of stakeholders in the project, enabling their participation in the implementation activities not just as observers but instead as important decision makers whose input formed the basis for the case study development, has ensured a truly stakeholder-driven approach. The interaction with the stakeholders has been greatly improved through the virtual simulation of water stress mitigation options implementation, and the development of role-playing exercises. The simulations have highlighted the importance of adopting an integrated approach in the mitigation of water stress and the evaluation of available options, which have enabled a wider understanding of the issues at stake, providing increased awareness on water stress situations and perceptions to stakeholders and project participants alike.
2.1 Problem identification using the DPSIR approach

**The DPSIR approach**

Experts using a rational approach (see section 1.1) often characterise the aim of a problem definition process as defining the discrepancy between the desired and the existing situations. Even though there is a plethora of data and information available for describing the current state of water systems, expertise is required for combining data and relating it to objective descriptors of the present status. Furthermore, the desired future conditions represent the outcome of a strategy derived through a decision-making process that is based on expert judgement. Therefore, expert approaches in problem identification correspond to the gradual transformation of a set of conditions to problems, issues and relative questions that define the necessary action plan for analysing and solving the problem.

An example of such a formal transformation is the Driving forces-Pressure-State-Impact-Response (DPSIR) framework. The DPSIR framework has been developed to present the links between the origins and the impacts of environmental problems in a cause and effect chart (Figure 2.1). The DPSIR approach was initially proposed by the European Environmental Agency for reporting environmental problems, but, due to its relative ease of application and its usefulness, it has become popular and has been adopted by the majority of researchers in the field of natural resources.

![Figure 2.1 The DPSIR framework](image-url)
Each category in the DPSIR analysis is defined by a set of indicators. In the case of water resources management these are:

- **Driving Forces**: The driving forces are expressed through indicators on natural conditions affecting water conditions, human influences in the water resources of the region, social, demographic and economic developments.
- **Pressures**: Pressures describe developments in release of pollutants to the water bodies, the use of water resources and land. Pressures are described through indicators to measure the natural supply of water to a catchment area, the anthropogenic supply, water demand, and water pollution.
- **State**: The state of the environment in an area which is directly affected by the driving forces and pressures, and the indicators to assess it are those addressing water quantity and quality issues.
- **Impact**: The changes in the state of the environment often impact on the water resources, and the social and economic functions. Indicators to assess impacts are related to ecosystem integrity, water use value, and the socio-demographic consequences.
- **Responses**: Responses refer to attempts by individuals and groups in society, as well as governmental efforts, to prevent, compensate, ameliorate or adapt to changes in the state of the water resources and conditions.

Thus, the indicators used in DPSIR analysis provide information on water management and system performance, set priorities in policy making and support policy development, and monitor and evaluate effectiveness and efficiency of policy responses/instruments.

The DPSIR analysis has been very helpful in describing the link between human populations and the environment and presenting the current state of water systems. However, the main drawback is that its original design does not include economic aspects of the water system and therefore cannot depict the whole spectrum of sustainable water management issues. In addition, it often fails to take the entire system into consideration due to the subjectivity in understanding the categorisation of indicators as drivers, pressures, state, impacts, and responses. In some cases, isolated chains of indicators may not be enough to reproduce the complexity of systems, which tend to behave more like a network rather than a linear chain.

Taking into account the above constraints, the DPSIR approach was used in the AquaStress project and was applied in conjunction with the Log Frame Analysis, for identifying water stress-related problems.
The Log Frame Analysis is an analytical presentation and management tool that can assist in the design, implementation and evaluation of development projects. It provides a structured, logical approach to analysing existing problems and current situations, setting and prioritizing objectives, identifying potential risks in achieving the set objectives, determining the intended results and activities of a project, formulating a strategy and monitoring its implementation. Hence, LFA was not only used in the problem definition but also in the goal definition process, which is described in Chapter 3.

Experiences in the Limassol test site (Cyprus): DPSIR analysis and the dominant water management practices in the Limassol region

- **Driving Forces**
  - Low Local Rainfall
  - Population Growth
  - Seasonal Population
  - Agricultural Activities
  - Water works

- **Pressures**
  - Low water available
  - Seasonal Demand
  - Intensive use of fertilizers
  - Water exploitation patterns

- **State**
  - Demand higher than Supply
  - High salinity high nitrates in the aquifer
  - Drop of aquifer levels
  - Environmental threats on the local ecosystem

- **Impact**
  - Interrupted supply
  - Water quality deterioration
  - Reduced income
  - Direct use of recycled water

- **Responses**
  - Supply Enhancement
  - Demand Management
  - Socio-Economic Constraints
  - Institutional Political Context
  - Control of urbanisation
  - Sea intrusion monitoring
  - Conservation campaigns
  - Protected areas
  - Reduction of pumping
  - Code of Good Agricultural Practice

- **Impact**
  - Low Local Rainfall
  - Seasonal Demand
  - Agricultural Activities
  - Water works
HOW TO IDENTIFY WATER STRESS RELATED PROBLEMS

LFA is undertaken in four distinct steps: Situation analysis, Strategy analysis, Project planning matrix, and Plan implementation. The first step of the LFA is related to the problem definition process that, among others, aims at analysing the existing situation and identifying problems. More precisely, the problem analysis addresses the following questions:

- What is the main problem to be solved?
- What causes this problem?
- What are the consequences of the problem?
- Who is affected by the problem? Who ‘owns’ the problem?

Experiences in the Przemsza test site (Poland):
Combined use of DPSIR and LFA in the Przemsza test site

- Groundwater resources
  - vulnerable to pollution
  - from ground and from surface waters (no isolation)
  - Abundance of mineral resources
  - High pollution background is soil, surface water and groundwater (lead, zinc, cadmium, iron, manganese)

- Urbanization
  - Mining development
  - Industry development
  - Chaotic land-use development
  - Morphological and geological deformation
  - Population growth (specially in 2nd half of XX century)
  - Prodigality in natural resources use (minerals, water, open space, forest) use, especially in 60-80 th of XX century
  - Post-mining and postindustrial waste generation
  - No effective environmental/water stress
  - Lack of public participation in water management

- Reduction of mining and industrial activity

- High pollution of surface waters
- Local shortage of water resources
- Illegal sewage connection to urban drainage
- Polluted runoff from non-point sources (derelict areas, highly urbanized areas, drainage from postindustrial dumping sites)
- Discharge of mine waters into rivers
- Pollution of groundwater aquifers resulting from hydrogeological phenomena (mining) as well from pollutant migration (disorder in sewage management and waste management)
Application of the combined DPSIR/LFA approach in the AquaStress project

The problem definition process in the AquaStress project was based on two premises:

1) The combined application of the DPSIR and Log Frame Analysis (LFA) for defining and describing the water problems, and

2) The identification of focal problems in relation to four major thematic areas:
   - environmental considerations (resource depletion and ecosystem degradation);
   - social considerations (including access to resources, water uses, and cost and its allocation to users);
   - development considerations (including strategies, master plans and social priorities); and
   - water deficit.

The combined use of DPSIR and LFA results in the construction of a tree diagram that represents the hierarchical relationship among causes and problems for each thematic area, and to a set of indicators for describing water systems.

Expert approaches such as the DPSIR/LFA approach on problem identification provide a valuable tool. The problem analysis must include the owners of the problem who are experiencing and who know the situation, and feed their inputs into the DPSIR/LFA approach. That is why a stakeholder-driven process was followed in the AquaStress project as described in section 2.4.

Further Reading


2.2 The Water Stress Framework (WSF)

Indicators have become a very important tool in the water sector. In particular, legislation such as the implementation of the EU Water Framework Directive has given prominence to indicators as management tools in the water sector. There are many other water indicators in use today. Most of these are single indicators of either water quantity or water quality, which for a long time have been the subject of water research. Some indicators have been combined as measures of various dimensions of water stress, including the widely used indicators relating the quantity of water available to the amount needed for certain activities. Two well known indicators are the ‘Water availability per capita per year’ and ‘Water withdrawals’. The ‘Water availability per capita per year’ indicator defines specific thresholds relating to water shortages: 1700 m³/capita/year or less indicates water stress, 1000 m³/capita/year or less indicates water scarcity. The ‘Water withdrawals’ indicator indicates the degree of stress in a location, but does not take into account water transferred from trans-boundary rivers or international inter-basin transfers.

With the Water Stress Framework (WSF) the AquaStress project tried to create a framework for indicators of water stress that would cover all water consuming sectors. The aim is to ease the management of water stress by providing a tool for a first assessment of the integral effect of measures taken by different sectors to combat water stress. The focus is to:

• characterise the water system,
• describe the water stress situation in the different water sectors,
• recognise the water stressors and
• act appropriately with bundle mitigation options against water stress.

As a first step to identify water stress, a common definition for water stress was adopted that would include all expected aspects of stress: ‘Water stress occurs when the functions of water in the system do not reach the standards (of policies) and/or perceptions (of the population) on an appropriate quantity and quality or at an appropriate scale’.

A water management tool, the WSF, emerged that can assess the complex issues in potentially water-stressed areas. This tool has been developed, along with a related index (Inter Sectoral Water Stress Index - ISWSI). The purpose of building and using the WSF is to define:

• the ability of the water system to exist in some preferred state,
• its ability to continue to deliver its services over time, while
• rapidly identifying the possible stressors.

The WSF is a composite of indicators. The matrix of indicators combines five water-consuming sectors and five categories (see Figure 2.2). The WSF is generated through a combination of two parts: the Integrated Sectoral Water Stress Index (ISWSI), which captures the level of water

\[
\text{WSF} = \text{ISWSI} + \text{PM}
\]
stress in the different sectors, and the Potential Margin (PM), which is an assessment of the available water resource supply.

For regional assessments, comparability across sites needs to be ensured. For this purpose, a limited number of core indicators belonging to the five different categories was selected (compare Figure 2.2 and Table 2.1). The most important selection criteria for the core indicators were data availability and the sensitivity of the indicator to water stress. It is important to know from the beginning what the objective of the ISWSI calculations is. For example, if the indicators are adapted to a particular bio-geographic region depending on the local conditions, the regional comparison should only be limited to those particular bio-geographic regions around the world. In such a case, for instance, the Mediterranean subtropics with its particularities would be comparable around the world.

During the case study application process, autocorrelation between the indicators was also tested which further reduced the final number of indicators to be used. For any indicator which was not available at the test site, a replacement was made. Where possible, the selection was made in consultation with the stakeholders at the site. When doing so it was realised that a prerequisite for site-specific evaluation is the selection of the required indicators in consultation with stakeholders. It should be noted that this should be seen as an iterative process, with refinement of this structure achievable if needed during the site process. If there are significant data gaps at a site, proxy values can be provided using expert opinion, until such time as an appropriate specific indicator becomes available.

**Figure 2.2 Water Stress Framework**
First the data for the core indicators are collected (compare Table 2.1). Alternative indicators may be identified in close cooperation with stakeholder if needed. Each indicator is normalised to values between 0 and 1 and then aggregated to form a sectoral water stress index or a composite index of the corresponding category. The results are shown in a spider graph. The five branches of the spider web represent the summarized water stress indicators either from the five water-consuming sectors, e.g. domestic and agricultural sector, or from the five categories, e.g. quantity and quality issues. The summarized results might be based on different time steps or for different sectors. Regarding the determination of the weightings for the calculation of the WSF, since those are a political issue and must be regarded as such, weighting should be done in consultation with stakeholders. Alternatively, weights could be based on the economic relevance or on the water consumption of a sector. This choice will also depend on the priorities of the user. As it is important to ensure transparency in the interpretation of the results, in general it is recommended not to use weights (i.e. all weights are set to 1) for the first calculations.

The WSF can be used in two different forms, but in the project it was only used in two forms:

- Intertemporal comparison of water stress for a particular test site. As can be seen in Figure 2.3, the WSF is able to show changes in water availability and changes in water stress depending on the different times of the year. Figure 2.3 refers to the Flumendosa test site in Sardinia. The higher the value, the higher the inferred stress. In figure 2.3 we can see how water stress affects the different sectors during the whole year while in summer the agricultural sector is particularly affected. As a result mitigation options for water stress should be discussed for the agricultural sector. Furthermore if these options address the summer period the effect on the water stress situation is even higher. The majority of the data for the Sardinian case study comes from the databases of the Italian statistical office and of the European Union.

<table>
<thead>
<tr>
<th>DOMESTIC</th>
<th>AGRICULTURE</th>
<th>INDUSTRY (PRODUCTION)</th>
<th>INDUSTRY (TOURISM)</th>
<th>ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity Issues</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Drinking water</td>
<td>Irrigation dependability</td>
<td>Water quality</td>
<td>Water use intensity</td>
<td>Deviance from natural flow</td>
</tr>
<tr>
<td>Quality Issues</td>
<td>Quality norms</td>
<td>Salinity</td>
<td>Water treatment</td>
<td>Wastewater polluted load</td>
</tr>
<tr>
<td>Institutional and adaptive capacity</td>
<td>Water regulation</td>
<td>Water saving technologies</td>
<td>Recycling</td>
<td>Protected areas</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Supply interruptions</td>
<td>Supply dependability</td>
<td>Supply interruptions</td>
<td>Water treatment</td>
</tr>
<tr>
<td>Social and economic equity</td>
<td>Economy of water suppliers</td>
<td>Farm size dispersion</td>
<td>Labour-related water intensity</td>
<td>Nature protection</td>
</tr>
</tbody>
</table>

*Table 2.1 Example of the core indicators of the ISWSI*
• Intersectoral comparison. As shown in Figure 2.4, the WSF shows particular sectorial water stress affecting some sectors more than others. This is helpful to identify the type of mitigation option. In the Moroccan case study the list of indicators was discussed with local stakeholder and local data is used. We can see that while the main stressors in the agricultural sector are in the category of ‘society and equity’ and ‘institutional and adaptive capacity’, in the domestic sector the category of ‘infrastructure’ embodies the main deficiencies. On first glance these results appear to be easy to achieve. But often discussing solutions is easier if a common
view of the problem is given. This is supported by the WSF as it represents a more ‘external’ view on causes of water stress based on data. The third and fourth types of potential application of the WSF are inter-basin comparisons and the characterisation of different basins and the use of the tool for foresight results on water stress.

To support the calculation of sectoral water stress indicators and the ISWSI a stand-alone tool has been developed to support the process. The tool can support the discussion on appropriate sectoral indicators, and allows weighted combination of all indicators to ISWSI. It can be found on i3s.aquastress.net.

Further reading
2.3 A tool for water stress identification in agriculture: Remote Sensing

For planning and management of water resources, water managers, and specifically irrigation engineers, need to have temporal and spatial values of actual evapotranspiration ($ET_a$) for various land uses. Accurate estimations of $ET_a$ give insight in water consumption, crop water stress, and production levels of crops. The use of Remote Sensing (RS) data is a powerful tool to estimate $ET_a$ for large areas.

Experiences in the Tadla test site (Morocco):
Crop water stress detection using RS

Within AquaStress a new algorithm has been developed (SSEBI-2) to derive daily actual and potential evapotranspiration maps from Remote Sensing. The approach allows a quick temporal and spatial assessment of seasonal water consumption for large river basins or irrigation systems, with a minimum amount of input data required.

For the Tadla area, a number of 26 low resolution MODIS images of 2006 were used in combination with meteorological data to derive actual and potential evapotranspiration on a daily basis. Findings:
- SSEBI-2 appears understandable and reproducible by non-remote sensing experts.
- SSEBI-2 revealed the occurrence of water stress at specific moments in the irrigation season of 2006. This information can be used to improve irrigation strategies and to propose alternative cropping calendars.

The water stress characterisation from RS was further used as a reference scenario for water-saving scenarios simulated with a hydrological model (Hydrosplash).

Further Reading:

Experiences in the Merguellil test site (Tunisia): RS and Spatial Modelling assessing the agriculture water need and use in the Kairouan Plain

The use of remote sensing data joined with simulation models of crop water requirements has resulted in maps of water requirements at a monthly or annual scale and thus gives useful information to improve agricultural water management.

The methodology is applied on the Kairouan plain in central Tunisia. The potential use of remote sensing data was tested, using various processing and classification methods. The eCognition software was applied, joined with spatial analysis using multiple dates and multiple sources data (multiple dates ASTER and SPOT 5 images).

The methodology is used with other data in a GIS database. This makes the use of a simulation model for crop water requirements (the CRIWAR model) useful, because it allows for the evaluation of agricultural water needs at several temporal scales (week, month or year). The calculated water requirements of the public irrigated area are compared with the water consumption data as given by the authority in charge of agricultural water management. Results show that water consumption and water requirements for these areas are almost the same (the differences range between 2 % to 9 %).

So at the regional scale, the calculated agricultural water requirement is approximately equal to the measured agricultural water consumption. The private irrigated areas, for which no measured water consumption data are available, account for more than 75 % of the calculated total water consumption.

Further Reading:


2.4 Problem identification with participatory approaches

Using ‘participatory approaches’ means that those actors who are affected by the problem (or its potential solution) or who are interested in it take part in identifying the water stress issues. Such processes can be organized in many ways. Stakeholders can be involved either individually or collectively. They can be briefly contacted to obtain their views on a particular issue (‘consultation’ in the WFD) or there can be a series of workshops with them to discuss or model the relevant issues (‘active involvement’ in the WFD).

Often it is a water authority who will provide an initial formulation of the water stress problem – usually from its own perspective. In the European context this usually is the drawing up of a water management plan that is supposed to meet the WFD requirements. Within the drawing up a water management plan falls the requirement to consider the needs of the stakeholders who see the water management issues from their own, often very different, perspectives. They will usually have specific water use needs (for example to use a certain quantity of water from an aquifer). These needs tend to lead to conflicts between various user groups; typically between ecologists and farmers but also, for example, between water authorities who have the task to protect the quality and quantity of water bodies and industrial use that may lead to pollution.

Because there are many potential stakeholders with many potentially divergent opinions on how the specific water situation is supposed to be managed, and also because it is likely that there are groups of stakeholders who already have a history of conflict over these issues with each other, it is usually necessary to conduct a stakeholder analysis. This typically leads to the setting up of stakeholder bodies such as advisory councils, citizen juries, dialogue forums and others. In the AquaStress project, the LPSFs were set up for this purpose (see section 1.3).

This stakeholder analysis will:
- Simultaneously identify stakeholders and potential issues
- Analyse the interests of specific stakeholders on a given issue
- Determine the level of participation stakeholders will want (information, consultation, active involvement, negotiation…)
- Select participation mechanisms that fit to the levels of participation (e.g. newsletters for information; open houses for information and consultation; workshops for active involvement; shuttle diplomacy – between different stakeholder groups – for negotiation)
- Analyse existing levels of conflict around the issues to be discussed
- Prepare an issue management plan (meaning that for each issue the designer should consider what kind of preparatory work is needed before
the issue can be discussed with the stakeholders - for example, technical studies or decisions to be taken).

**How to develop a participatory process**

There are many hands-on guidelines for how to conduct stakeholder analysis. In terms of methods it usually means a mix of traditional survey approaches (contacting individual stakeholders using semi-structured interviews) with some form of group modelling techniques. Stakeholder analysis in this form typically takes place in the first ‘problem situation and formulation’ stages of participatory modelling exercises. The methods that are used then are methods such as cognitive mapping, the soft systems methodology or simpler techniques such as questioning key stakeholders individually or in small group for eliciting relevant information. Performing stakeholder analysis in a truly participatory manner typically allows greater coverage of potentially important stakeholders for the problem being studied and starts to gather agreement on the structure of the problem to be treated. This is a key step for the later participatory development of alternative options to solve the problem, model building and alternative evaluation, as will be further outlined in the later chapters of this book.

**When should such a process be used?**

It is clear that truly involving stakeholders in decision making requires time, money and considerable skills - such as being able to understand complex relationships between a great number of actors as well as between these actors and the physical system they impact. Therefore, this costly work should only be undertaken when a few pre-conditions are satisfied:

- The responsible decision maker (usually the water authority but of course this can differ) seriously expects benefits from stakeholder involvement that go beyond the idea that legal obligations (such as defined by the WFD) have to be met. These benefits could be widely supported solutions, using locally available information for the solution, overcoming of conflicts and building of trust, empowering local communities, creating more widespread ecological consciousness and other benefits.
- Other relevant decision makers – such as municipal mayors, or more senior authorities on a regional or ministerial level, also agree with the proposed participatory decision-making process (in case this does not happen, the process may very soon find itself blocked, as in the example from Cyprus described below).
- The other stakeholders, such as local farmers, nature protection agencies, even the wider public, are motivated enough to become involved in the issue and in the way foreseen by the planned participation process. If you are planning monthly working group meetings about the state of a local aquifer with 30 experts from administration, lobbying groups and NGOs but these people tell you they only want to see the finished aquifer diagnosis, you should think about your planned process again.
HOW TO IDENTIFY WATER STRESS RELATED PROBLEMS

- There is no extreme conflict among some of the central stakeholders to the extent that they do not want to talk to each other. If that is the case, the only possible way forward would be to go through the courts.
- A decision maker does not want to use the participation process to ‘sell’ a preconceived solution. This would be very dangerous not only for the decision maker but also for participation processes in general. Once stakeholders perceive that they are about to be manipulated – and usually people are very alert to this – making progress will become extremely difficult and much will be lost, especially in terms of trust and the possibility to cooperate in the future.

All these conditions should be met before starting a participation process. If there are indications to the contrary and a participatory water management plan still has to be drawn up it may be better to restrict the participatory work to the extreme minimum and to explain fully why this is so.

Experiences in the Akrotiri test site (Cyprus): Involving stakeholders

In the Cyprus test site, a water authority wanted to study, with the help of the AquaStress project, how treated effluent from a wastewater could be stored in a local aquifer. In this way, the authority hoped the threatening seawater intrusion to the aquifer could be stopped and water could be made available in the summer months for irrigation.

However, there had been a history of difficult relationships between the water authority and local decision makers. The AquaStress project failed to see this clearly when it invited local mayors to a workshop on the question of effluent storage in the aquifer. While other factors may also have played a role, it is likely that because of this lack of clarity on existing relationships, and also because of the specific way that the problem was framed (not from a stakeholder perspective), most mayors from the concerned municipalities were not keen to cooperate.
Problem tree development

The participatory construction of the problem tree aims at reaching consensus between experts and the local population on the focal problem and its underlying causes. If the panel reaches agreement on the main problems to be solved, agreement is also expected for its solution, in terms of mitigation options that can be implemented. The problem tree is constructed through a brainstorming process, where, in equal terms, experts and stakeholders describe the causes and effects of the main problem and then link them in order of sequence. Therefore, the problem tree is a graphic representation of the series of actions that led to the problem realization.

The problem analysis is undertaken in five steps:

1) Identification of existing problems, based on the available information;
2) Ranking of problems and selection of the main problem for the analysis;
3) Identification of the important direct causes. This step answers the question ‘why is this problem happening?’ The answers can be problem statements by themselves and become the Level 1 causes. The process of cause identification is therefore iterative; this means that the question

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**Figure 2.5 Construction of the problem tree**
is repeated for each level cause, and answers are written down as second, third etc. level causes;

4) Identification of important and direct effects of the focal problem. This step is similar to the identification of major causes. However, instead of asking 'why?' a problem exists, the question is ‘what does this problem lead to?’;

5) Review of the entire problem tree. In the final step, the entire tree is reviewed to ensure that it is valid and complete. The tree should ‘read’ like a logical sequence of cause and effect relationships (Figure 2.5).
An example of the outcome of the participatory problem analysis process is given for the Iskar Case Study.

Further reading:
Usually a project is initiated because there is an issue which people want to address or there is an opportunity to exploit. For example, a water board needs to regulate ground water levels which different users find contentious. Alternatively, a national authority subsidises the purchase of drip irrigation equipment for small-scale farmers who join together to benefit from this. However, starting a water stress project is not easy because the inherent problems are usually complex. Not only is there is a physical system to be understood, including the effect of potential water stress mitigation technologies on this system, but also a human system that is supposed to apply and use these solutions. The ecological, technical and social systems have to be taken into account when defining project goals. Obviously there is a need here for experts as their initial understanding of the various systems may help predefine what the realistic and desirable goals are. At the same time, a participatory process, which starts within this predefined framework and is open to the evolution of project objectives, may lead to a reformulation of these goals and go beyond the expected solutions.

3.1 Expert approaches

Objective-oriented planning

According to the definition of Novartis Foundation for Sustainable Development (2005), ‘an objective is the intended physical, financial, institutional, social, environmental or other goals which a programme / project is expected to achieve and which lies in its own sphere of influence’. Objective-oriented planning has been developed as a tool for assisting in the planning of a project and therefore can be applied in any management process, such as a water stress mitigation process. It is part of the Log Frame Analysis (LFA) and, when combined with the DPSIR analysis, can result in a set of indicators which describe each element of the LFA analysis. Objective-oriented planning is used for defining the goals and the necessary means for achieving the desired situation and/or for solving problems. Its main advantage is that it provides the user with the ability to integrate the

Outputs: Immediate results from activities
Purpose: Immediate objectives
Objectives: Desired situation

Figure 3.1 Objective analysis (adapted from Örtengren, 2004)
various aspects of the problem resolution and the flexibility to present them in a logical and easily understandable form, i.e. the objective tree. The objective tree graphically links the three levels of objectives that are set during the water stress mitigation process, as illustrated in Figure 3.1:

- **Overall objectives**, which state the desired direction of the process;
- **Process purpose** that describes the prevailing situation if the ‘solutions’ are successfully implemented; and
- **Outputs** from the activities that will be implemented during the mitigation process.

Complex problems can be solved with the contribution of expertise from different fields, where the expected results can be fully described from a variety of mitigation options. However, since the solutions will not be implemented by experts but by those who are experiencing the problem, the objective tree should ideally be developed through a participatory process with representatives of key stakeholder groups. This way a shared understanding of the options and the means for achieving the goals will be accomplished and the successful implementation of the solutions will more likely be guaranteed.

**Development of the objective tree**

The objective tree is a reversed representation of the problem tree, described in section 2.4. A tree diagram is developed where each cause has been replaced by its solution, in order to achieve the main objective.

![Figure 3.2 Construction of an objective tree](image-url)
As each cause has a different degree of impact on the problem, and may be either minor or major, one-off or permanent, it follows that the relevance of and the difficulty in addressing certain causes is also variable. Certain ‘solutions’ may be entirely implausible or simply beyond the scope of the analysis, and therefore these can be ignored, or removed from the tree. What remains is a set of ‘solutions’, potentially available for implementation in order to resolve the focal problems and achieve the desired situation. The process of developing the objective tree is similar to that of the problem tree, as illustrated in Figure 3.2. The analysis could also result in a set of indicators that describe or define the ‘solutions’ presented in the tree.

An example of the outcome of the participatory objective analysis process is given in Figure 3.3 for the Vecht Case Study.

**Figure 3.3  Schematic representation of the objective tree in the Vecht Case Study**

**Further Reading**


### 3.2 Interactive approaches

In an ‘ideal interactive case’ the stakeholders are consulted on their identified water-related issues (as described in section 2.4) and the goals of the project are adjusted based on their perceived needs and interests. The goal would then not only become a widely-supported water management plan but also, for example, ensure economic sustainability of camp sites that use high quality water from a local aquifer, ensure drinking water services for various municipalities (who are also pumping into this aquifer), and give a more broadly developed ecological knowledge of swimming pool owners (who have wells) etc.

Practically speaking, it is important to take time for goal definition with stakeholders and to remain open throughout the project regarding the possible development of these goals. In several AquaStress case studies, entire meetings (of a half day or a day) were devoted to elaborate on what the project should focus. In Portugal, for example, researchers and local stakeholders held a day-long meeting on possible joint projects which were eventually proposed by the stakeholders after having listened to the expertise offered by the researchers. Several of these smaller projects were then jointly defined in more detail afterwards.

As has already been discussed, there are several challenges and pitfalls when defining a project goal together in a participatory way. These can also be formulated as trade-offs:

- **The needs of the initiators versus the needs of the participants:** To ask the stakeholders about their point of view regarding the project goals creates a problem for the initiators. If they do everything the participants want to do, the project may become too large or may not focus any longer on the needs of the initiating water authority. On the other hand, if the needs of the stakeholders are not taken into account, there is a risk that the stakeholders might be lost altogether and that they might possibly realise that they do not agree with the results after the work has been carried out(!). The art then is to accommodate the needs of the stakeholders but at the same time draw realistic boundaries of what the project can and cannot do. It should also be noted that the involvement of certain stakeholders (for example from a higher political level) can mean that there will be more resources available to finance possible solutions.

- **Say of stakeholders in the process definition vs. limitations of initiators’ resources.** Openness with regard to project goals usually entails an expectation by participating stakeholders that they have some influence on how things are done in the project. Giving them a say in the process creates trust and ‘buy-in’. On the other hand, making concessions on how things are done may entail new costs for the initiators (for example, because additional consultations are requested or meeting facilitators...
HOW TO DEFINE THE GOALS OF A PROJECT

need to be employed). Again the art is to open up but also to delineate limits. This usually needs to be done early in the process.

- **Time:** A participatory approach costs time for consultation, for meetings, and for the analysis of all input from the participants. An expert solution is quicker – at least at the beginning. The question to consider is whether it is possible to implement the decision without the contributions and buy-in of the stakeholders.

- **Skills:** A participatory approach requires considerable skill regarding the handling of the strategic questions that arise (e.g. on what level to involve stakeholders, which decision-makers to consider, how to frame the main issues etc.) as well as skill in group facilitation for assuring high-quality interactive meetings and workshops. A more traditional expert-driven approach needs less socio-psychological knowledge but may fail on the stakeholder involvement aspects. Also, with regard to this point it is important to know if involving stakeholders is required or not.

**Further reading**


**Experiences in the Guadiana test site (Portugal)**

A participatory approach for defining the project goals was applied here. Researchers and potential stakeholders met to define a project together. An evaluation questionnaire filled in by five stakeholders after the workshop resulted in the following table.

<table>
<thead>
<tr>
<th>Has the workshop allowed you to assess:</th>
<th>Not at all</th>
<th>Slightly</th>
<th>Moderately</th>
<th>A lot</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expertise, methods and tools offered by AQS partners</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An area for collaboration</td>
<td></td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The implications and responsibilities of each one within the project</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
**Introduction**

In this chapter we show how a water manager can proceed when identifying water stress mitigation options. The option identification and selection procedure is usually a combination of the inputs provided by water managers, experts, and stakeholders. It is also partly a creative process. The total number of options may be limited, but the number of combinations of content and context variables on the one hand, and options and measures to solve the problems on the other hand, is large. Section 4.2 provides some sources of inspiration to start from, while section 4.3 presents a tool that can be used in the identification process.

It is useful to keep in mind what we defined as options and measures. Options are groups of measures which target comparable water stress mitigation goals. Measures are well-specified activities which are planned and implemented to reach a desired situation. Alternative measures make up options. In most cases, the measures that have been developed are site-specific.

### 4.1 Overview of the mitigation options

**Characterisation of options**

We have distinguished options in three categories: technical options, economic options and institutional options. The technical options are further divided into options to manage water supply and options to manage water demand. Economic options aim at water demand management by economic incentives. Institutional options address the ways in which people co-operate and organise themselves informally or formally, in order to better cope with water stress. Technical measures are often designed to reduce communities’ susceptibility to risks, whereas non-technical measures focus on reducing their vulnerability to risks.

The definition of the options that we have elaborated, tested and evaluated has gradually developed in the course of the project. This was a result of the interactions between the experts and the stakeholders. In some instances, such as desalination, we dropped the option because the test sites expressed no interest. In other instances, such as integrated surface/groundwater management, we re-adjusted the focus of the option as a result of specific demands from the test sites. We learned from these experiences that a flexible approach by experts is essential in order to avoid the pitfall of imposing solutions to problems that do not exist.
The options that were investigated mainly refer to the sectors of agriculture and industry. Some options refer to domestic use, nature and recreation. Some sectors with a stake in water stress, such as power production and shipping, are not included in this list, because they were not of key importance in our test sites.

**Rationale of the approach to option research**

During the project, we accumulated extensive knowledge on a wide variety of mitigation options from scientific backgrounds, recent advances of research, achievements of management projects, and implementation experiences in various field situations.

The AquaStress project aimed to select the water stress mitigation options within the contexts of the test sites, rooted in the local problems that had been identified. We performed this work by analysing the potential contribution offered by existing and new developed measures. We analysed both technical options (engineering and technology), aimed at utilising and optimising water sector solutions, and non-technical options, focusing on economic tools, administrative arrangements, participatory processes and education initiatives.

We recognised improvements in technical measures which are far from being fully exploited and which offer a substantial margin for increasing water availability or reducing water demand. We investigated innovations to increase option performance, as well as integration aspects for selected technical options, such as competing water demands, water quality requirements, and compensation potential in combinative use.

On the other hand, rendering non-technical measures operational is not common practice, due to their complexity and the accompanying need to change behaviour. Specification of non-technical instruments for achieving reliable application of technical options was another objective of the analysis.

The complete set of options considered in the portfolio is given in Chapter 5. We assessed the technical options with reference to functional and operational features (such as conditions, scale, time frame, data requirements) and to impact (water balance, environmental and societal issues, economics). The results of these assessments are summarised in the descriptions of the options in Chapter 5. They formed a background for interactions between experts, water managers and stakeholders to select, test and evaluate mitigation options. These integrated, stakeholder-driven types of assessments are the subject of Chapter 6.
4.2 General criteria for the identification and selection of options

The selection of options is based on a consultation process, where each participant plays their specific roles:

- **Experts** provide a wide range of options for mitigating water stress, according to the available scientific knowledge and the international experience;
- **Water managers** represent the administrative offices that are usually responsible for financing and supervising the implementation of mitigation options;
- **Stakeholders** are usually the owners of the problem to be solved through coordinated actions. Otherwise, they may be the ones affected by the solutions that are proposed, either in a positive or a negative sense. Among the stakeholders there are often those who will implement the proposed mitigation options. Thus, they contribute to the process with their knowledge of the local conditions and their experience from past implementation efforts.

The formulation of a commonly-agreed action depends on the level of flexibility of each participant in the consultation. More precisely, the list of mitigation options is gradually reduced to account for the perceptions and priorities of the interested parties, as illustrated in Figure 4.1. The aim is to identify options through a participatory process rather than a negotiation process or personal communication. The advantage of this approach is that it can lead to consensus on the actions to be taken, without one party feeling neglected or undermined.

A variety of participatory methods are available for enhancing the interaction among experts and stakeholders (e.g. focus groups, brainstorming groups, workshops, game simulations etc), although experts should also be

![Figure 4.1: The process of reducing the list of available options](image-url)
considered as a stakeholder body. In the AquaStress project, the integration of their knowledge was achieved through:

- The formation of working groups, in which researchers and the local stakeholder forums joined forces in the process to identify the options; and
- The organisation of workshops on option identification. The workshops aimed at information exchange. The selection of options was done in accordance with the objective tree (section 3.1). An example of the results of these workshops in the Flumendosa catchment is given in the box below.

**Experiences in the Flumendosa case study (Sardinia, Italy): Proposed and accepted measures**

In the Flumendosa case study, experts proposed a number of measures, as listed in both columns below.

The stakeholders only accepted the measures in the right column. They rejected the ones in the left column.

<table>
<thead>
<tr>
<th>List of rejected measures</th>
<th>List of accepted measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Re-use of water</td>
<td>• Introduction of rapeseed and sunflower</td>
</tr>
<tr>
<td>• Introduction of sugar beet as bio fuel</td>
<td>• Removal of undergrowth</td>
</tr>
<tr>
<td>• Introduction of a new crop: sweet corn (Zea mays rugosa)</td>
<td>• Adapt crop locations to soil profiles for a better use of rainfall</td>
</tr>
<tr>
<td>• Artichoke &amp; sweet maize rotation to save water</td>
<td>• Irrigation scheduling on the basis of historical data of rainfall and evapo-transpiration (water saving)</td>
</tr>
<tr>
<td>• Rotation with sweet corn in place of barley to save water</td>
<td>• Reduce fertilizer</td>
</tr>
<tr>
<td>• Change planting time of sugar beet to save water</td>
<td>• Enhanced reservoir operation for maintaining VMF (Vital Minimum Flow)</td>
</tr>
<tr>
<td>• Change planting time of vegetables to save water</td>
<td></td>
</tr>
<tr>
<td>• Regulated Deficit Irrigation for orchard trees (peach, citrus)</td>
<td></td>
</tr>
</tbody>
</table>
4.3 A tool for the identification of options

Case-based Reasoning Tool
Case-based reasoning, also known as learning by analogy, is a scientific field that aims to organise knowledge in such a way that one can find cases similar to one’s own. For example: ‘where can I find an area similar to the Vecht?’

The critical factor of success for such a system is the appropriateness of the criteria used to find similar sites. For water stress, one of the first criterion is the physical environment, but further detailing of a search of similar sites can be achieved by looking into cultural backgrounds (e.g. is the attitude towards water management similar?) or applied options (e.g. is drip irrigation already implemented?). In the I3S, a case-based reasoning tool is included which allows finding similar areas based on readily available European maps. This tool can be used to make a first selection of potential similar areas. In a second iteration one can manually search the site knowledge base to find the most appropriate area similar to one’s own. When new sites or cases are uploaded to the I3S the ability to work on case-based reasoning increases.
Introduction

In this chapter we present the options that we elaborated, and partly tested and evaluated, in the AquaStress project. The practical experiences in the test sites are frequently highlighted. The options’ suitability for solving the problems in the specific context is assessed. The effects of the options and measures are in many cases quantified with the aid of mathematical model tools. Chapter 6 continues with some key examples of the subsequent full examination of options and their combinations, together with stakeholders.

In reality, the distinction between the mathematical quantification of effects of an option and a subsequent interactive full test and evaluation procedure, is not so clear. Often the mathematical assessments and the interactive assessments converge to preferred options and measures in a cyclic way. Whereas the definitions of economic and technical options are more or less clear, the term ‘institution’ is, even among experts understood differently. In the chapter on institutional options a nowadays widely accepted definition is provided that understands institutions not only as formal laws and organisations determining the interaction of sectors and administrative levels to implement plans and measures, but also as informal rules, norms and behaviour that generally structure human interaction.
5.1 Overview of the selected options and measures in AquaStress

As explained in Chapter 4, we distinguish between technical, economic and institutional options. Technical options are further divided into water demand and water supply management options. Tables 5.1, 5.2 and 5.3 present the measures, tools and methods which we elaborated or developed under the header of these options.

### Technical options

<table>
<thead>
<tr>
<th>Option family</th>
<th>Option</th>
<th>AquaStress activities were focused on development of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water demand management (section 5.2)</td>
<td>1. Industrial water saving</td>
<td>measure Modernize technical subsystems (Iskar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Optimize the operation of pump aggregates (Iskar)</td>
</tr>
<tr>
<td></td>
<td>2. Minimizing losses in agriculture</td>
<td>measure Increase the area under drip irrigation (Tadla)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Improve hydraulic management of irrigation canals (Tadla)</td>
</tr>
<tr>
<td></td>
<td>3. Tailoring cropping patterns</td>
<td>measure Improve the match between crop rooting depth and soil profile (Flumendosa, Merguellil)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Develop feasible, alternative cropping patterns and cropping calendars to reduce water demand (Tadla, Merguellil, Guadiana)</td>
</tr>
<tr>
<td>Water supply management (section 5.3)</td>
<td>4. Reducing pollution from industrial users</td>
<td>method Methodology for mitigation of water stress due to industrial pollution (Przemsza)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Apply chemical treatment of waste water (Iskar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Optimize the performance of radial settlers (Iskar)</td>
</tr>
<tr>
<td></td>
<td>5. Enhanced reservoir operation</td>
<td>measure Set Vital Minimum Flow as lower limit to dam release (Flumendosa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Improve operation modes for a reservoir (Guadiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Plan dam releases in Spring (Merguellil)</td>
</tr>
<tr>
<td></td>
<td>6. Surface water control</td>
<td>tool Calibrated model to simulate water quality inflow to reservoirs (Guadiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Reduce use of fertilizer (Flumendosa, Merguellil)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Remove upstream tanks to increase water inflow (Merguellil)</td>
</tr>
<tr>
<td></td>
<td>7. Rainfall harvesting</td>
<td>measure Adapt water release thresholds of reservoirs, construct small dams (Merguellil)</td>
</tr>
<tr>
<td></td>
<td>8. Groundwater protection and management</td>
<td>measure Adopt more responsible farming practices to reduce leaching of nutrients (Guadiana)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure Infiltrate treated wastewater in the aquifer (Cyprus)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tool Monitoring and management tool (Tadla)</td>
</tr>
</tbody>
</table>

Table 5.1 Overview of technical options and related measures, methods and activities

### Economic options

<table>
<thead>
<tr>
<th>Option family</th>
<th>Option</th>
<th>AquaStress activities were focused on development of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water demand management (section 5.4)</td>
<td>9. Water pricing</td>
<td>measure water pricing for agricultural use (Merguellil, Guadiana, Cyprus)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>method choice experiment, willingness-to-pay analysis (Merguellil, Guadiana, Cyprus, Przemsza)</td>
</tr>
</tbody>
</table>

Table 5.2 Overview of economic options and related measures, methods and activities
### Institutional options

<table>
<thead>
<tr>
<th>Option family</th>
<th>Option</th>
<th>AquaStress activities were focused on development of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both water demand and supply management (section 5.5)</td>
<td>10. Change institutions in irrigation management</td>
<td>measure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>method</td>
</tr>
<tr>
<td></td>
<td>11. Change patterns of water use</td>
<td>method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>method</td>
</tr>
<tr>
<td></td>
<td>12. Effective implementation of legal regulations</td>
<td>measure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure</td>
</tr>
<tr>
<td></td>
<td>13. Reorganisation of water service</td>
<td>measure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>method</td>
</tr>
<tr>
<td></td>
<td>14. Participation of stakeholders in surface water control</td>
<td>measure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>measure</td>
</tr>
</tbody>
</table>

### Table 5.3 Overview of institutional options and related measures, methods and activities

### 5.2 Technical water demand management options

**Option 1: Industrial water saving**

Industrial water use has a significant impact on the water resources in many European river basins. Water-intensive industrial processes (using a lot of water, using a large fraction of the available water, impacting heavily on hydrology, and/or causing deterioration of the water quality) contribute to water stress.

Considering the complexity of the industrial water systems, extremely detailed preliminary work is necessary for clarification of the interconnections between different water resources, the technological processes and the units within a process. A good starting point for certain industries which are listed in Annex I of the Integrated Pollution Prevention and Control (IPPC) Directive is the comparison with the Best Available Techniques (BAT) and with the corresponding BAT Reference Documents (BREFs). It should be noted that the data from the BREFs should be carefully analysed in terms of the conditions in which they have been obtained and to what extent they are relevant to the local situation. Another useful identification tool is the method of water balancing which provides a background for water efficiency.
analyses and further development of system dynamics modelling. Water consumption is often linked to energy consumption and so, whenever possible, this relation has to be clarified before the final selection of the appropriate solutions.

In the AquaStress project, the option industrial water saving has been investigated in two case studies: in the Przemsza test site (Poland) at a river basin scale and in the Iskar case study (Bulgaria) within the biggest industrial water consumer in the region – the Kremikovtzi metallurgical plant. The main steps and achievements of these two case studies are presented below.

**Option 1: Industrial water saving**  
**Experiences in the Iskar test site (Bulgaria)**

**Problem:**  
The Upper Iskar faces permanent water stress with more severe conditions in years when there is more drought. The water resources are currently shared mainly between industries (45%) and households (55%). Due to the high water consumption by both users, there is no water available for agricultural needs. Water distribution, therefore, causes conflict among the users and action is required to share it more wisely. The Kremikovtzi metallurgical plant is the dominant industrial water user in the region. The fresh industrial water consumption of the plant amounts to 50 to 60 million m$^3$/y, which is comparable with the water needs of a town with around 600 000 inhabitants.
SELECTED OPTIONS AND MEASURES FOR WATER STRESS MITIGATION

**Proposed measures:**

1) Several improvements in the technological processes were suggested and summarised in a program of measures, in order to reduce the fresh water consumption:
   1.1. Modernization of the industrial cooling systems
   1.2. Modernization of the high pressure pumps at the hot rolling mill plant – the pumps are one of the biggest water and power consumers ($H=150\text{bar}; \; Q=1600\text{m}^3/\text{h}$). Several alternatives were considered: frequency control of the engines; specific treatment and recycle of the used water (e.g. micro filtration); installation of new piston pumps and utilization of turnover waters;
   1.3. Implementation of a system for condensed water utilization – such a system may cover about 10-15% of the fresh industrial water needs; however there are some logistic and operational restrictions, which need to be evaluated in a preliminary study.
   1.4. Optimization of the operation of pump aggregates – replacement of the over-dimensioned pump aggregates with smaller and more effective ones; automated operation.

2) Development of System Dynamics Modelling (SDM) for the Kremikovtsi water supply system for generating alternative scenarios, exploring factors, policies and impacts, aiming at supporting the decision-making process. The use of SDM will be discussed in more detail in Chapter 5.

**Findings**

- The modernization of the industrial cooling systems (measure 1.1) would bring significant effects in terms of fresh water consumption; however, in the scope of this study it was impossible to specify the exact values due to lack of data on the fresh water addition, although there are reliable indirect clues (increased turnover water flows and increased fresh water consumption compared to the design values).
- Although any of the proposed solutions would positively affect the industrial water consumption, measure 1.2 appears to have the highest impact, both in terms of water and energy saving. If frequency control is applied, the expected savings are around 60% of the energy consumption and up to 50% water consumption for the pumps, which results in a 12% saving of fresh industrial water.
Option 2: Minimising loss in agriculture

Water stress can be counteracted by the improvement of irrigation efficiency. Average loss of irrigation water in the Mediterranean is 55%, so only 45% of the water that is diverted or pumped up, actually reaches the crops. The first measure under this option focuses on a reduction of loss from irrigation. Loss occurs from, for example, a poor conveyance, or from a mismatch between water demand and water supply (over-irrigation). Loss depends largely on the water application method and the condition of the irrigation system. As a side note, it is important to realise that loss from irrigation is not loss on the scale of a basin. What percolates as excess irrigation gift will partially be recovered downstream.

Option 2: Minimising loss in agriculture
Experiences in the Tadla test site (Morocco)

Problem:
In Tadla high loss of irrigation water occurs due to improper (antiquated) irrigation techniques. The government is currently encouraging the adoption of more efficient irrigation methods through subsidies.

Proposed measure:
Increase the area under drip irrigation. Effects are simulated using a hydrological model.

Findings:
The study demonstrates that the introduction of efficient irrigation techniques, such as drip irrigation, is promising. These techniques go in tandem with a different cropping pattern to the traditional one. Some 15-20% of irrigation water can be saved. Care should be taken, however, with a large scale introduction of drip irrigation. Groundwater tables
might drop if surface water savings are applied elsewhere. The question which should be addressed is what will be done with the ‘saved’ water. If the ‘saved’ water is used to increase the agricultural area, the net saving effects are zero. A better policy would be to maintain the original cropped area and surface water supply, and reduce the groundwater withdrawals. In absolute terms, groundwater mining would go down from 23 million m$^3$ in the reference situation to 14 million m$^3$ for the alternative drip scenario which is considered helpful. Care should be taken with respect to the higher actual evapotranspiration as a result of the cultivation of other crops as this water consumed is an irrecoverable loss. The difference between the higher evapotranspiration loss and the lower groundwater mining is made up by lower drainage loss, being a consequence of applying drip irrigation, but this adversely affects downstream water availability in the river basin.

As a second measure under the option ‘minimising losses in agriculture’, we considered technical improvements in the allocation of water at irrigation system level and in the operation of irrigation canals.

**Option 2: Minimising losses in agriculture**

**Experiences in the Tadla test site (Morocco)**

**Problem:**
Poor management at the main canal level in Tadla leads to inefficient water distribution and increased water shortages at field level.

*Mixed gates in main canal, Tadla (picture Xavier Litrico Cemagref)*
Proposed measure: Improved canal operation and maintenance by means of adaptations to hydraulic structures.

Findings: A study on the hydraulic behaviour of the Tadla main canals showed that water delivery in Tadla to the secondary canals is hampered by the hydraulic behaviour of the main canals. The bottlenecks that prevented a good hydraulic management of the main canals were identified: the installation of a new structure interfering with the existing regulating structures in the main canals, and oscillations due to the hydraulic interaction between pools. Technical improvements of the hydraulic structures were formulated.

Option 3: Tailoring cropping patterns
The option ‘tailoring cropping patterns’ investigates how changes in cropping patterns and timing of crops can help to reduce water demand in agriculture and thus help to optimise the use of the available water. Water demand for different crop types, taking into account the different soil types, is determined to avoid crop stress in order to get profitable yields.

Option 3: Tailoring cropping patterns
Experiences in the Flumendosa test site (Sardinia, Italy)

Problem: Crop locations and soil types do not always match. Deep-rooting crops, such as wheat, are grown on shallow soils. As a consequence, crops are limited in their vertical root growth and they do not benefit from precipitation excess in the winter. The figure below shows all locations in the study area where mismatches between soil profile depths and crop rooting depths may occur. The red zones indicate places where deep rooting crops may be restricted in their vertical development and where water savings could be realised.

Proposed measure: Match the rooting characteristics of the crops better with the soil profile. Effects are simulated using a hydrological model.
Results:
Model results indicate a clear relation between crop performance in terms of relative evapotranspiration (\(ET_{rel}\), the ratio of actual and potential evapotranspiration: \(ET_{rel} = \frac{ET_{act}}{ET_{pot}}\)) and the depth of the soil profile. The actual evapotranspiration is considered as an indicator for crop yield. Plotting this depth against the \(ET_{rel}\) for wheat shows an unambiguous correlation with the deeper profiles giving the highest \(ET_{rel}\) values (figure).

Relative ET as a function of the depth of the soil profile

It appeared that a better match between crop rooting characteristics and accompanying soil profiles can be found, allowing farmers to save on one or more irrigation gifts for their irrigated crops.

The current exercise presents some alternative ideas on where to look for when water savings are necessary. Models can help to further identify potential options, but can primarily help in quantifying the effects of such options. It is recommended that the findings as described here are further validated with detailed, physically-based, field scale simulation models.

Further comments apply to the general applicability of this option other than increasing farmers’ awareness on these issues. Crop choice principally depends on profitability of the product and is therefore market-dictated. The physical environment is consequently of lesser concern. However, when conditions become limiting with respect to production factors (with water often being the most important one), both water demand options and options related to a better management of available resources come into view and should be further explored.
**Option 3: Tailoring cropping patterns**  
*Experiences in the Guadiana test site (Portugal)*

**Problem:**  
With the increasing water supply and demand due to the new irrigation infrastructures in the left bank of the Guadiana River, agricultural surface and land use are expected to change significantly in the following years.

**Proposed measure:**  
This option aims at evaluating the effect of possible scenarios of land use, taking into account its effects on water demand, namely:  
1. Current agricultural water use in the Guadiana River left bank according to present land use; and  
2. Future water demand scenarios, representing different crop distribution options, under the hypothesis of an area of 30000 ha of potentially irrigated crops, made available by the Ardila irrigation scheme.

**Findings:**  
Three scenarios were tested regarding several possibilities of crop development and compared to current water demand, as seen on the following figure.

- The first scenario supposes a specialization in irrigated olive due to its strategic importance in the current Portuguese primary sector. This scenario comprises an increase in water demand to over 200-250 million m³/year.
- Another scenario supposes an increase of irrigated cereals and forages, namely due to: the increasing interest in biofuel production (maize, sorghum, sunflower among others); raise of cereal prices in the international market. This hypothesis would increase water demand even more than the olive crop as these crops are also more water demanding – expected water demand would be in the order of 225-270 million m³/year.
- A third scenario supposes an increasing competition in the olive sector, namely due to new production countries such as Latin-America. In this case, part of the irrigated surface would be used for cereals, vineyards and arboriculture, thus reducing water demand comparatively to the former scenarios to 150-225 million m³/year.
According to these results, water demand is expected to increase significantly in the following years implying the use of modern irrigation technologies, namely drip irrigation systems. This context raises a clear need for technical training and development of extension support services that can aid farmers in implementing and operating their irrigation systems and avoid water losses due to the inefficacy of most current ones.

Option 3: Tailoring cropping patterns
Experiences in the Tadla test site (Morocco)

Problem:
In Tadla, a large area is cultivated with high water-demanding crops such as alfalfa.

Proposed solution:
Investigate feasible, alternative cropping patterns and cropping calendars to reduce water demand.

Findings:
Modelling results showed that substantial water savings are achieved with alternative crops or changed planting dates. Explanation of crop calendar and water demand: the crop water requirement varies largely with the time of planting in the year, due to climatic variations. An example for sugarbeet is shown in the figure below.
For Tadla, solutions in the area are to be found in a reduction of evaporative demand, in combination with more efficient irrigation techniques. It was demonstrated that a replacement of the high water-demanding crops in favour of less water-demanding crops can save water, especially when crops are timed in such a way that high peak temperatures are avoided. Further investigations are warranted into crop and irrigation method diversions to limit consumptive use during the summer months with sparse rainfall.

The choice for alternative cropping patterns largely follows profitability for farmers, within limits set by the irrigation department. With the crops that have been traditionally cultivated in Tadla, the scope for water savings might appear limited. However, as world market prices are showing drastic change, in particular for grain, other transitions could also be explored, again within local economic constraints and water savings opportunities.

### 5.3 Technical water supply management options

**Option 4: Reducing pollution from industrial users**

Industrial pollution may have a long-lasting adverse impact on a whole catchment, preventing surface and groundwater utilisation downstream and thus causing water stress. This option is often closely linked to the option ‘Industrial water saving’ and the considerations described there apply here as well. The application of this option demands an extensive water quality database which will allow reliable evaluation of the wastewater quality of the industrial user. Often such data is either not available or it is scarce, which necessitates a water quality monitoring program to be developed in advance. The monitored parameters and the frequency of sampling depend on the type of the manufacturing process. A good starting point is to refer to the list of priority substances according to the Water Framework Directive, as well as the guidance for industrial water quality of certain industries in BREFs.

In the framework of the AquaStress project, the option ‘Reducing pollution from industrial waters’ has been investigated in two case studies: in the Przemsza test site at river basin scale and in the Iskar case study within the Kremikovtzi metallurgical plant. The main steps and achievements of these two case studies are presented below.
Option 4: Reducing pollution from industrial users  
Experiences from the Przemsza test site (Poland)

Problem:  
The water resources in the Przemsza test site are impacted by the industrial water use and high population density. The limited water resources are additionally decreased by poor water quality and industrial discharges have been identified as major pressure on the aquatic environment. There is a strong need for more sustainable, integrated and adaptive water management in this region.

The Przemsza river

Proposed approach:  
• Develop and apply a methodology to support the mitigation of water stress due to the industrial sector on catchment level. The methodology consists of: water quantity and quality balance models for the sub-catchment, analytical analysis of priority and hazardous priority substances, and use of EC BREF documents to compare standards  
• Apply BAT standards to industrial plants in the test site.

Findings:  
The case study demonstrates the applicability of the suggested methodology to support the mitigation of water stress caused by the industrial sector; however, precise recommendations can not be made at this point. The water quality and quantity model and the water quality
Schematic representation of the proposed methodology

Analysis revealed bottlenecks and narrowed down the general water management problem to hot spots (focus contaminants, major water polluters, etc). The application of suggested BAT standards in the BREF documents (e.g. precipitation of heavy metals, biological treatment of coke wastewater) can lead to improved wastewater quality from some industrial users in highly polluted parts of the basin but still needs further investigation such as pilot studies and close collaboration with industrial plants before testing and actual implementation.

Lessons learnt:
A lot of time has been spent on the analysis of the situation and the determination of specific water management problems since the general status of the water resources was known. However, the water management bottlenecks were not clearly defined. To support the application of the suggested methodology it is necessary to enhance a monitoring network. The popularization of the balance model and the application of BAT standards are recommended to mitigate water stress in highly industrialized river basins. Limitations of this methodology are the availability of reliable data and the necessity of close collaboration with industrial water users in the test site to be able to work out tailor-made solutions.
Option 4: Reducing pollution from industrial users
Experiences from the Iskar test site (Bulgaria)

Problem:
The Kremikovtzi plant has been considered to be the biggest environment polluter in Sofia, the capital of Bulgaria. The environmental impact of Kremikovtzi is often juxtaposed with its economical and social benefits – an issue that recently polarises the public concerning the future of the plant. Kremikovtzi has four wastewater discharging points into the Lesnovska River, three of which are industrial waste water flows. Although in certain technological processes there are several local industrial wastewater treatment facilities (settlers) and a common waste water treatment plant for industrial and rain water, the water quality downstream in the Lesnovska River shows the presence of industrial pollutants.

Proposed measures:
1) Chemical treatment of the excessive waters of the dirty cycle at the hot rolling mill plant - at present due to low effect of removal of the suspended solids in the radial settlers, the dirty cycle turnover water is diluted either with clean cycle turnover water or with fresh water.
2) Optimization of the performance of the local settlers in certain technological processes – improvement in the construction and technological operation. Expected results are better water quality, reflecting in higher recirculation ratios.

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<tr>
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Measured suspended solids in the blast furnace water
```
Findings:
The most problematic parameter of the industrial wastewaters in Kremikovtzi is the suspended solids. The performance of most of the local radial settlers is unsatisfactory, the effect of removal is inconsistent and the concentration of suspended solids at the outlet is much higher than the norms. The analyses have shown that radial settlers, where dirty cycle turnover water is chemically treated, show significantly better performance. If the modernisation of the high pressure pumps is realised (as suggested in the option ‘Industrial water saving’) it will result in significant water saving and will decrease the load of the radial settlers at the hot rolling mill plant. The other technological processes in the hot rolling mill plant may save up to 300 m³/h water as a consequence of a better treatment of turnover waters (e.g. coagulation and settling).

In normal conditions, the average concentration of suspended solids at the inlet of the WWTP of Kremikovtzi is around 60-70 mg/l, while the concentration at the outlet varies between 20-30 mg/l, which corresponds to treatment efficiency in the range of 65%-70% and complies with the norms for the protection of the receiving water body. However, hourly excessive peaks of suspended solids (200-350 mg/l) often occur. It was proven that when the concentration of suspended solids at the inlet does not exceed 150 mg/l, the outlet concentrations are below the norm of 50 mg/l. A better performance of the radial settlers at the technological plants will significantly relieve the operation of the WWTP.

Dissolved forms of cadmium, nickel, cobalt and mercury were not detected in any of the investigated technological flows. The other heavy metals were either not detected or their concentrations were very low. More monitoring of data is necessary for the evaluation of wastewater quality in terms of heavy metals and other hazardous substances.

Further reading
**Option 5: Enhanced Reservoir Operation**

The option ‘Enhanced reservoir operation’ focuses on the adaptation of reservoir operation schedules according to water quality and quantity aspects. The option can be designed in different ways according to the site specifications of the respective case. Basically, it implies an adaptation of rules for impoundment and releases of dams and reservoirs according to defined boundary conditions, for example relevant water quality parameters, inflowing pollution loads or downstream water demands. Within the AquaStress project two different option designs were investigated: the Sardinian case study focusing on the maintenance of environmental flow by adapting reservoir release patterns, and the improvement of the reservoir water quality state on the Portuguese site and thereby the increase of the usability of available water resources. Therefore the AquaStress project provides a methodology which is feasible to be combined with other technical options (Surface Water Control) and provides at the very least real-life support in the decision-making process.

**Option 5: Enhanced reservoir operation**

**Experiences in the Flumendosa test site (Sardinia, Italy)**

**Problem:**
The Flumendosa is a temporary river, in that it becomes dry during the summer period. Due to the construction of dams the natural river flow is cut by nearly 90%, amplifying water supply shortfalls of the connected areas. Regional requests to provide water downriver for supplying water distribution facilities, as well as planned recreational facilities, necessitates knowledge of the water volume required to fulfil these demands. This is called the vital minimum flow (VMF).

*Flumendosa reservoir*
**Proposed measure:**
Modification of time and volume of releases from the reservoir, in order to fulfil VMF requirements. The existing demands for drinking and agricultural water supply are taken into account.

**Tools and methods:**
A quantification of VMF was made using model tools and analytical methods.

**Findings:**
The study determines that an annual water volume of 48 million m³ (1.52 m³/s), equal to 12% of MAR (natural mean annual run-off), has to be provided in order to maintain the VMF. This requirement was retrospectively embedded into the reservoir release schedule of the main three dams in 2004, giving monthly release volumes.

**Original and enhanced release schedules**

Care should be taken with the forecasts for a 'real-life' implementation of this option, as according to the regional stakeholder ENAS (Ente acqua della Sardegna), it is still being hampered by a lack of guidelines to establish operational rules which may be different for the different basins at the regional administration.
Option 5: Enhanced reservoir operation
Experiences in the Guadiana test site (Portugal)

Problem:
Insufficient available resources in the Ardila irrigation system, even under normal conditions, and crucial water deficits in dry periods. There is an existing lack of capacity for an optimal use of the available resources. The Enxoé dam provides the urban water supply for the Serpa and Mértola region but its resources are highly polluted. The main polluters are agro-industrial and agricultural users, causing high levels of nitrates, sulphates etc. in irrigation water, and municipal and industrial wastewater discharges. This pollution results in significant water quality problems, such as reservoir eutrophication. These problems in connection with drought characteristics of the region result in heavy water supply shortfalls of the main water supply facilities. The lack of alternative water sources makes the region highly vulnerable, aggravated by the lack of institutional and water management strategies to face drought situations.

Proposed measure:
A combined application with option ‘Surface Water Control’ resulted in the development of four alternative operation modes for the Enxoé reservoir.

Tools and methods:
The four alternatives were developed together with the local decision-makers and stakeholders. These alternatives were evaluated considering stakeholders decisions. Virtual tests (simulations) were used to propose the most promising alternative.
Findings:
The simple fact that stakeholders have been made aware of alternatives for present practice is the first important result of the study. The study provides a reservoir operation alternative, which not only considers water volumes but which also targets on the necessary water quality demanded in the region. One of the main results of the simulation is a matrix, indicating the consistency between the simulated alternatives, the potential for improving the water quality and the related ranking. The most promising alternative reservoir operation is the ‘Diverting’, which includes the diversion of polluted water inflow connected with a compensation of the water volume by the Alqueva or Laje reservoir. This alternative also receives the highest ranking according to the stakeholders’ evaluation.

The option ‘Enhanced reservoir operation’ can also be aimed at improving the use of aquifer capacities for storing and sharing water, in order to increase the amount of the exploitable resources in water-scarce areas. In this setting, the measure not only addresses dam operation, but also includes the prediction of changes in both groundwater quantity and quality. This is achieved by combining hydrodynamic observation, geochemical sampling and numerical modelling.

Option 5: Enhanced reservoir operation
Experiences in the Merguellil test site (Tunisia)

Problem:
In central Tunisia, the large Kairouan plain aquifer is overexploited. A more dynamic policy could increase the groundwater resource and partially help to limit the continuous water-table decline.

Proposed measure:
To plan dam releases in the Spring in order to (1) decrease evaporation loss of the dam water and (2) increase groundwater recharge.

Findings:
Evaporation of the reservoir results in an increased mineralisation of first the surface water and then the groundwater. A hydrochemical study demonstrates that water infiltrated since the dam construction in 1989 is significant only in the first 7 km of the aquifer downstream of the dam, confirming the slow motion of groundwater and the limited proportion of recent recharge compared with the large volume of groundwater stored in the Kairouan aquifer.
Because of the rainfall variability, the present functioning of the dam, aimed at keeping some water for just one irrigation scheme, is not able to reach its objective. A proactive management would release water in the Spring before the summer evaporation peak and use that water to recharge the Kairouan aquifer. The conditions of release (duration, flow) could be optimised for a maximum groundwater recharge. A numerical simulation showed that 24 million m$^3$ could have been saved in this way over the last 20 years. This figure is higher than the mean annual groundwater inflow to the Kairouan plain aquifer, averaged over the same period.

**Option 6: Surface Water Control**

The option ‘Surface water control’ has the objective of improving the availability of water of sufficient quality at catchment scale. One measure to achieve this relates to reservoir management. In order to make this measure operational, a methodology was developed to simulate water quality processes occurring in the water body of reservoirs. It is closely linked to option 5, ‘Enhanced reservoir operation’. The methodology used consists of the advancement and application of various simulation models. With the improved simulation models, virtual tests of several management alternatives are set up. A vast amount of water quality models presently exist but usually they do not fit the specific purpose and conditions prevailing in semi-arid regions. Here, the AquaStress project provides a methodology which has the potential to be transferred to other areas of similar conditions, thereby contributing to other technical options and at least supporting real-life decision-making processes.

**Option 6: Surface water control**

**Experiences in the Guadiana test site, Portugal**

**Problem:**

For implementing a water quality model for the Enxoé reservoir, upstream boundary conditions are needed. Due to the lack of appropriate data of reservoir inflow (quality and quantity) the application of a standard methodology (e.g. OSPAR Guidelines) together with a run-off model is not applicable.

**Tools and methods:**

Reservoir inflow records were developed using the simulation model MOHID. Data analysis for the purpose needed, and the corresponding correlation between the available reservoir data and simulated inflow loads were developed. As no measurements on nutrient levels exist,
those concentrations were estimated based on the number of citizens and common values for equal-inhabitant concentrations. A conceptual model was set up focusing on reservoir processes regarding the most relevant water quality parameters. An inverse reservoir model for calculating inflowing nutrient loads from upstream areas was implemented. The reservoir water quality processes were simulated with a modified version of the model CE-QUAL-W2 (Version 3.2).

Findings:
A comparison between the time series of simulated concentrations of phosphate, nitrate, total phosphorus and chlorophyll-a in the Enxoé reservoir shows a considerable conformity, particularly against the background of a lack of river flow and reservoir inflow data. This proof of data consistency represents the main result of the study as it serves as essential input information to the option ‘Enhanced reservoir operation’ and the linked evaluation of the reservoir operation alternatives described by stakeholders’ opinions.

Another group of measures under the option ‘Surface water control’ addresses the schemes of land use patterns and management. The effects of these schemes are assessed with a modelling framework. This framework is designed to assess sustainability of land uses in water-limited environments and to formulate a list of alternative land uses allowing the attainment of water quality goals discussed and decided with stakeholders.
Option 6: Surface water control  
Experiences in the Flumendosa test site (Sardinia, Italy)

**Problem:**
In Sardinia agriculture uses large amounts of the available water resources. Return flows from cultivated areas drive considerable nutrient, pesticide and sediment loads to the river net, impairing further use of such surface resources.

**Proposed measure:**
Consider different agricultural management / crop rotations: 1) reduction of applied fertilizer, 2) Introduction of rapeseed and sunflower. The effects are simulated using a hydrological model.

**Findings:**
The study demonstrates that a reduction of 20% in the application of fertilizers can result in a decrease of nutrient and sediment loss (ranging from 6% of total N and sediment to 15% of total P) with a trade-off of very limited reduction (if any) in the expected crop yields (not more than 7%). The economic analysis of cost/revenues associated with this option showed that it is economically viable for most of the crops. The introduction of rapeseed and sunflower cannot be sustained without fiscal support.

Option 6: Surface water control  
Experiences in the Merguellil test site (Tunisia)

**Problem:**
In the Merguellil basin agricultural practices and a number of small reservoirs impact quantity and quantity of water stored in the large reservoir downstream. This reservoir plays a major hydrological role in providing water for irrigation and aquifer recharge (later used for drinking water and irrigation).

**Proposed measure:**
Reduction of applied fertilizer and removal of a number of upstream tanks. The effects are simulated with a hydrological model.

**Results:**
The 20% reduction of applied fertilizers resulted in a decrease of nutrient and sediment load ranging from 3% (N) to 16% (P) without any calculated reduction in crop yield. The simulated removal of a limited
number of upstream tanks seems to be rather questionable since it resulted in an increase of surface runoff and in water inflow in the dam of around 2.2 million m$^3$/yr with a trade-off of an increase in sediment load of 141 t/day.

**Option 7: Rainfall harvesting**
The option ‘Rainfall harvesting’ focuses on the hydrological consequences of different water harvesting and soil conservation practices in rural areas, evaluates the impacts on-site and downstream, and estimates the agronomic and socio-economic effects. This approach helps with the development of appropriate modelling tools to support decision making.

**Option 7: Rainfall harvesting**
*Experiences in the Merguellil test site (Tunisia)*

**Problem:**
The limited and fragile Merguellil water resources face an increasing demand. In the upstream catchment, water and soil conservation works significantly reduce the river flow, by turning a part of blue water into green water. The lower discharge to the basin outlet induces a decrease in the groundwater recharge. Benefits and losses of water and soil conservation works are broadly discussed.

**Proposed measure:**
assessment of the effects of water and soil conservation works by:
- identification of changes in physical processes and in farmers activities induced by new water and soil conservation works;
- representation of their impacts on different scales (local, catchment)
- comparison of the different physical approaches while incorporating socio-economic dimensions.

**Tools and methods:**
Field surveys, system dynamics model

**Findings:**
The local impact of water and soil conservation works depends on the age and maintenance of the works, with a frequent loss of efficiency after a few years. Individual water budgets of areas with water and soil conservation works vary enormously and the new resource created locally is very uncertain in time. At the basin scale, models show the fundamental role of water and soil conservation works in the reduction of the Merguellil flow downstream during the last two decades. Five
different scenarios simulate changes in climate conditions, in the number and efficiency of water and soil conservation works, and in rules for the management of large and small dams. The real exploitation of the Merguellil limited water resources depends on farmers decisions at the local scale (upstream), closely linked with the probability of failure in the water supply. Downstream, the regional decrease in the river flow and in the groundwater recharge affects all irrigating farmers. Economic efficiency, which is higher downstream, may oppose social equity, because people are poorer upstream. This conflict exposes contradictory decisions that were taken at a higher level.

Option 8: Groundwater protection and management

The option ‘Groundwater protection and management’ focuses on building a methodology, based on the use of simulation models, to evaluate the effects of anthropogenic and natural pollutants and to develop approaches for their mitigation. We used the simulation models to evaluate the variations of nutrient content (nitrates, in particular) in groundwater. These variations are expected as a result of the forecast agricultural changes. We put emphasis on areas where the groundwater is particularly threatened and we have incorporated the existing regulations for the concentrations of these substances in groundwater.

The proposed methodology is summarized by the following steps:

• to examine present conditions to learn about the main problems impairing groundwater.

• to interview the stakeholders to adjust Best Management Practice (BMP) scenarios to solve the problems they feel are most significant. In this participatory approach decision makers and stakeholders are involved in the decision-making process. In section 6.3 we describe the participatory approach.

• simulate the BMP scenarios adjusted (basically consisting of changing agricultural land uses) assessing the consequences of their application on groundwater and also considering soil type, lithology, geology and aquifer characteristics.

For natural pollutants we built methodologies (based on simulation models) to evaluate the effects of plans to increase groundwater volume and to push back seawater intrusion. A mathematical model was implemented in order to quantify the volume of groundwater which can be restored by applying the measure. Further model simulations have been applied to estimate the sustainable withdrawals for domestic and irrigation uses.
Option 8: Groundwater protection and management
Experiences in the Guadiana test site (Portugal)

Problem:
Until recently, the area was characterized by traditional rain-fed extensive agriculture practices. This practice was supposed not to create particular problems to surface and groundwater quality. In recent years, the expected increase in water availability (due to the construction of many reservoirs) has caused a shift from traditional agriculture towards irrigated and modern intensive agriculture practices. These practices increase the risk of groundwater pollution from diffuse sources, leading to the presence of high contents of nitrates, sulfates and related chemicals in water bodies, causing groundwater quality deterioration.

Tool:
The GLEAMS model was used to simulate nitrate leaching as well as to evaluate the potential groundwater pollution risk.

Proposed measures:
A strategy was created with the intention to reduce the impact of irrigated agriculture on groundwater quality.
The adoption of a more ‘responsible’ type of farming was stimulated by setting up Best Management Practices scenarios. This means planting crops that cause less leaching of nitrates on the areas with more permeable soils. In the preparation of these scenarios different land uses (winter wheat growing and traditional, modern and super intensive olive tree groves) together with the corresponding irrigation water consumptions were taken into account.

Findings:
The study shows that under the simulated conditions, the super intensive olive grove produces lower nitrate concentrations and load in the leachate than the traditional olive grove, thus causing a lower potential impact on water quality, translated in less pollution. This result can be explained by the fact that the intensive kind of olive tree cropping is responsible for much higher N uptakes and greater potential yield.
The study also shows that the most suitable among the simulated Best Management Practice scenarios is the one that entails the most polluting olive groves grown on the less permeable soils and the less polluting super intensive olive grove grown on the more permeable soils. This scenario is the most suitable not only from the point of view of nitrates leaching, but also taking into account water consumption.
The use of models allows forecasting the consequences on water bodies of land use changes and different BMP scenarios, well before their implementation. These land use changes could be the consequence of the large Ardila irrigation system which will come into operation soon. The study has resulted in a clear idea of the areas that, more than others, put at risk the quality of water bodies in their proximity. These findings are of great importance for decision makers in order to allocate the often scarce funds on those areas where they are more required (critical areas).

**Option 8: Groundwater protection and management Experiences in Cyprus**

**Problem:**
Akrotiri is the third largest aquifer in Cyprus. Here, the dramatic reduction in the natural recharge resulted in a serious deficit in the water balance of the aquifer. In the last few years the general water table level in the plain has stabilised at below sea level. As a result, the inland progression of the fresh water/sea water interface has greatly increased.

**Proposed measure:**
Artificial recharge of treated wastewater through injecting wells and infiltrating pounds. This will have significant effects on the water balance of the aquifer. This in turn will affect irrigated agriculture as well as the general environmental conditions in the surrounding area. Specifically, aquifer recharge will sustain current water availability for irrigation, will prevent seawater intrusion and thus maintain current irrigation water quality while the continuation of agricultural activities will prevent desertification in the surrounding area and maintain current environmental conditions. Furthermore, the policy will prevent the loss of jobs in the agricultural sector.
A mathematical model was implemented in order to quantify the volume of groundwater, which can be restored by applying the measure. Further model simulations have been applied to estimate the sustainable withdrawals for domestic and irrigation uses from the aquifer. The groundwater flow and seawater intrusion model was calibrated with data from 30 boreholes (with water table measurements for 2006). At the outset a decision support system was applied in order to define the optimal artificial recharge technique (i.e. wells, ponds, etc.). Thus several model simulations determined the sustainable annual withdrawals for domestic and irrigation uses, under different scenarios summarised in eight AquaStress integrated actions.
**Findings:**
The model results made it possible to define:
1) the sustainable annual withdrawals for domestic and irrigation uses from the Akrotiri (Limassol) aquifer, under different scenarios. The minimum sustainable annual pumping was estimated at 5.6 million m$^3$/y. It can be increased to 6.4 million m$^3$/y by injecting treated effluents in ponds located in the upper part of the domain during winter, or to 7.6 million m$^3$/y, by using the artificial barrier that is constituted by the injecting wells. A return flow of 0.4 million m$^3$/y, due to the increase of the irrigation volume by considering irrigation water reuse, may further increase the groundwater sustainable volume up to 8 million m$^3$/y.
2) the position of the artificial barrier of 3 wells, able to increase water availability of 2 million m$^3$/y, by injecting 0.8 million m$^3$/y of treated municipal effluents during winter (in 3 months/y).

**Option 8: Groundwater protection and management**
**Experiences in the Tadla test site (Morocco)**

**Problem:**
Excessive water table fluctuations, due to irrigation return and uncontrolled groundwater pumping, produce water scarcity conditions in the irrigated perimeter of Tadla; monitoring activities do not produce the desired change in management due to the absence of a suitable decision-support system.

**Tool:**
We developed a tool integrating monitoring data and a groundwater model. This tool can help in producing scenarios for the different management options and in decision making.

**Findings:**
A customised tool has been implemented consisting of a ground water flow model developed with MODFLOW, which is encapsulated within an ArcGIS 9.2 environment. This tool easily analyses the large amount of piezometric data coming from the monitoring network activities, individualises the critical situation (e.g. where the water table exceeds defined thresholds) and simulates the evolution of the piezometric levels due to different management options with regard to:
- variations of the volumes of surface waters in the irrigation network and/or the rate of ground waters abstractions inside and outside the irrigated perimeter;
• variations of the crop pattern and/or of the irrigation technique.

The tool has been proposed to water managers, but up to now no feedback has been received.

5.4 Economic options

A key purpose of economic policy relating to resources management, and especially to water resources management, is to achieve economic efficiency. This implies that the social marginal benefit derived from the utilisation of the resource should be equal to the social marginal cost of the resource. That is to say that the social benefit from one extra unit of the water resource should be equal to the social cost of producing this unit. It is important to note that social economic efficiency differs from what could be called private economic efficiency which would relate to private firms. To achieve social economic efficiency, all costs and benefits derived from the utilisation of the resource should be taken into account. On the expenditure side, external costs including the environmental and ecological impacts of water abstraction and water pollution should be accounted and compensated for.

We investigated the economic options that we present here in close connection with technical and institutional options. As a result, it is not always possible to present the results of the studies in purely economic terms. Instead, we describe the economic findings together with the preferred technical or institutional options. We arrived at these results by intensive consultation with local stakeholders. Therefore the assessment results are less of an expert-based nature than those of the preceding sections.

Option 9: optimal water pricing

This section presents an essential economic instrument that can be used to facilitate the optimal management of water resources under conditions of water stress. Several economic instruments were proposed in the test sites, but only one was accepted by the stakeholders. This is the utilisation of optimal pricing mechanisms as a means of promoting economic efficiency. This instrument is not universal in its application. Instead it should be utilised based on the existing circumstances of each particular application.

Water pricing is the instrument that can be manipulated so that the social cost of the resource is recovered from those that enjoy the benefits of the resource and those that cause negative external economies due to their use of the resource. In order to achieve equality between marginal social cost, optimal water pricing is crucial. Overpricing the resource will result in suboptimal use of the resource while underpricing the resource will lead to
excess consumption of the resource. In order to identify the benefits and accordingly set the optimal price, we use the Choice Experiment Method.

**Method used in optimal water pricing studies: the Choice Experiment Method**

The AquaStress case studies have attempted to provide indications for the optimal pricing of water. For this exploration the Choice Experiment Method (CEM) was primarily used. In a CEM application the water resource is broken down into a number of its constituent characteristics. For example a water resource can be characterised by its availability relating to its quantity, its quality, its environmental impacts and its price. Members of the relevant population are asked to make pair wise choices profiles of the characteristics defined at different levels. Using these comparisons, a measure of the value for each of the characteristics is then derived in the form of the Marginal Willingness to Pay (MWTP). The MWTP as a characteristic defines how much the public values one extra unit of the provision of the characteristic in question. More detailed information about the use of CEM is provided in section 5.3.

The valuations for the various characteristics aggregated over the relevant population represent the social benefit derived from each of the characteristics. These valuations can then provide guidance for water managers and policy makers as to the level of investment that would be optimally undertaken for each of the characteristics. Similarly the valuations can be used when deriving the optimal unit price of water. The experiences from the AquaStress case studies are presented below.

**Option 9: Water pricing**

**Experiences in the Merguellil test site (Tunisia)**

**Problem:**
- **underlying hydrological problem:** water table drawdown due to uncontrolled extraction of groundwater
- **economic problem:** estimate the effects of measures to counteract groundwater depletion, with a focus on the introduction of a charge for groundwater.
- **institutional problem:** estimate the effects of measures to counteract groundwater depletion, with a focus on improving the transparency of the irrigation system.

**Proposed economic measure:**
water pricing, combined with metering
Tools and methods used:
A choice experiment is implemented by asking whether farmers are willing to join a collective organisation which is run by farmers themselves and set to stabilize the groundwater table level by metering and charging water use. The empirical results show that farmers are willing to make a change to the current water management by joining this new type of organisation. Restrictions on the area of land to be irrigated are not recommended as it was found to be of no use in terms of saving water, since it is common to lay some land fallow each year in the local region.

The results suggest that larger farmers value future benefits more and are therefore more willing to participate. The results indicate that the wealthier farmers are reluctant to adopt changes in policy. This may be because the wealthiest farmers are also those who benefit most from the current situation and can still afford to continue pumping deeper even with increasing pumping costs.

Findings:
A major priority for Tunisian water managers in the Merguellil Valley is to find ways to stop the continuous decline of the water table. A water pricing policy is accepted as providing incentives for farmers to save water. However, the effective implementation of this policy requires the setting up of an institution which ensures good enforcement and monitoring of this system. In particular, in order to elicit farmers’ collective action in saving water, hidden actions should be avoided by setting up a strong mechanism of self-monitoring. Publicizing water use frequently, together with naming and shaming, are valued highly among the farmers and should be tried and set up as a rule. In addition, independent monitoring by a third party (preferably the central government) is an important factor determining the success of the management of the public goods valued by the farmers. Therefore, it is strongly recommended that monitoring from outside should be introduced into the current regime.

Restrictions on the area of land to be irrigated are not recommended as it was found of no much use in terms of saving water, since it is common to fallow some land each year in the local region.

The results suggest that larger farmers value future benefits more and are therefore are more willing to participate. The results indicate that the wealthier farmers are reluctant to a policy change. This may be because the wealthiest farmers are also those who benefit most from the current situation and can still afford to continue pumping deeper even with increasing pumping costs.
**Option 9: Water pricing**

**Experiences in the Guadiana test site (Portugal)**

**Problem:**
The area suffers from irrigation water shortages. The Ardila irrigation subsystem scheme that is being built and implemented, will allow not only to extend irrigation from typical rain-fed agricultural lands or small scale groundwater use to large scale surface water irrigation system, but will also bring changes to crop structure and to agriculture intensity, productivity and total water requirement. Therefore, a water pricing policy is going to be implemented, and the price level is yet to be established.

**Proposed economic measure:**
water pricing, as a function of: (i) water supply with or without pressure; (ii) reliability of water supply, and; (iii) nitrate concentration of the supplied water.

**Methods and tools:**
A choice experiment was implemented. This consisted in presenting several policy scenarios to farmers in order to understand their preferences over the new water supply scheme. The following attributes were evaluated: water reliability (hours per day provided with water), water quality (nitrate concentration), water supply type (water pressure) and water price (volumetric price in cents/m³). Additionally, simulations were performed on policy alternatives for water price schemes and the effect on water resource use and crop structure change.

**Findings:**
The most important attribute for farmers regarding public water supply service is water pressure, followed by reliability and nitrate concentration. The analysis results show that current irrigators are only willing to accept public water if it is provided with pressure while farmers who are currently undertaking dry-land farming are more willing to accept a public water irrigation scheme even without pressure. More concretely, farmers are willing to pay 14.9 cents/m³ more for water with pressure relative to water without pressure, no matter what size of farmers. Regarding reliability water services, and in average, farmers are willing to pay 0.68 cents/m³ for one more hour of water supply per day, and this number will be higher for larger farmers. Nitrate concentration is the least important factor valued by the farmers. They do prefer water with lower nitrate concentration, but at a low level of willingness to pay, even though the current local level is higher than the recommended maximum level set by Portuguese Environmental Ministry.

The policy simulation reveals that when provided with public water supply...
under the currently proposed price (8 cents/m$^3$), some farmers show a preference to change the crop structure, mainly from non-irrigated crops to olive yard, or by planting more olive trees. As the proposed water price increases, fewer farmers would accept the policy and change crop structure. In particular, farmers of whom land covers more than 40% of the sample area indicated their preferences over crop structure change under the price of 8 cents/m$^3$. Many farmers will switch to irrigate olive yards or plant more olive trees once provided with water under the price proposed in the survey of 10 cents/m$^3$. In fact, the provision of better irrigation facilities at low prices will bloom olive production in the region resulting in increased water demand.

Using pumping cost as substitute for water price, the empirical analysis shows that the price elasticity estimated from the cross-sectional data is about -0.45, which means that for a 1% increase in water price, farmers will decrease water use by 0.45%. Moreover, small farmers are more elastic than big farmers. In other words, small farmers will decrease more than big farmers in response to a same increase in water price. Based on this estimation, water demand under different price is predicted and it is found that at least 10 cents/m$^3$ is required to have total demand fall below the current level.

**Option 9: Water pricing**  
**Experiences in the Akrotiri test site, Cyprus**

**Problem:**
- underlying hydrological problem: reduced water availability and deteriorating water quality in the aquifer
- economic problem: estimate the effects of the proposed policy of aquifer recharge with treated wastewater, from the perspective of local farmers and local public, and with focus on the value of water quality, water quantity and general environmental conditions.

**Proposed measures:**
- hydrological measures: replenishment of the Akrotiri aquifer with treated wastewater from Limassol and nearby villages
- economic measures: water pricing

**Tools and methods:**
A choice experiment was implemented to understand farmers’ preferences over the proposed hydrological measure.
Findings:
There are positive economic gains from the application of the policy. Specifically farmers are willing to pay an additional €0.027 per m$^3$ of water to maintain current water quality. They are willing to pay an additional €0.055 per m$^3$ to maintain current water quantity. Finally they are willing to pay an additional €0.0004 per m$^3$ to maintain an additional job in the agricultural sector.

The general public also derive significant economic benefits from the aquifer recharge. Specifically the public is willing to pay an additional €0.128 per m$^3$ to maintain current water quality, €0.053 per m$^3$ to maintain current environmental conditions while they are willing to pay €0.0008 per m$^3$ to maintain an extra job in the agricultural sector.

This study can assist with the derivation of policy recommendations. Most importantly, this study concludes that the aquifer recharge policy is considered to be useful and desirable by both farmers and the general public in the Akrotiri region. The extra values derived from individuals in the area through aquifer recharge can justify the increase in water rates. This would help achieve the economically efficient allocation of water resources by limiting consumption.

Discussion:
The recharge of the aquifer with treated wastewater comes out as a feasible measure from the study that we present here, but it is controversial. The findings from the stakeholder analysis that we presented in section 2.4 were different. Causes may be found in differences between the groups that were interviewed or consulted (specific stakeholders and their representatives in section 2.4, vs. surveys with samples of 150 and 300 individuals that were designed to elicit preferences). The study presented here is concerned with social welfare, and it concludes that social welfare will increase from the recharge. Hence from an economic perspective the recharge is desired, independent of the opinions of local stakeholders.

Option 9: Water pricing; willingness to pay for water stress mitigation

Experiences in the Przemsza test site (Poland)

Problem:
Evaluate the preferences of the public in terms of willingness to pay for flood control, biodiversity and recreational access to riverbanks.
**Proposed measure:**
An economic analysis was conducted to evaluate the importance and the goals of the flood control policies.

**Method:**
a choice experiment application was used. This particular application is explained in more detail in section 5.2.

**Findings:**
The analysis indicated that respondents derive significant economic values from flood risk reduction, recreational access to rivers and biodiversity conservation. Specifically, the respondents declared they were willing to pay additional local taxes of €6.207 per month in order to decrease flood risk, €2.49 to improve recreational access to rivers and €1.37 per month to improve local biodiversity. The average amount of local tax per month at the time of the survey was €51.95.

The implementation of flood control measures appears to be of major importance to the local population. To some extent it could be financed by increased local taxation. Survey respondents appeared to have a positive stance towards local taxation for the creation of flood control measures. Simultaneously however, the general public indicated that they are willing to pay increased tax rates for the visual and recreational amenities that will result from improving the current conditions of river banks. While the economic analysis indicates that the aforementioned impacts are those of critical importance for the local population, there also appear to be economic values derived from the maintenance of the biodiversity riches in the region.

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**5.5 Institutional options**

In the AquaStress project institutional options were examined alongside technical and economic options. Due to the characteristic of institutional options, discussions about institutional options were initiated together with local partners and stakeholders.
In the project, the term ‘institutions’ is defined according to North (1990) stating that institutional options cover all ‘humanly devised constraints that structure human interaction. They are made up of formal constraints (rules, laws, constitutions), informal constraints (norms of behaviour, conventions and self-imposed codes of conduct), and their enforcement characteristics’. On the one hand, this definition allows looking at institutional options in terms of changing behaviour to support e.g. the implementation of economic or technical options. On the other hand it enables the examination of organisational changes that may facilitate the implementation of economic and or technical options.

In brief, institutional options refer to the range of choices available to actors when they have to make a decision which is linked to both formal (e.g. laws) and informal (e.g. norms, rules) institutional factors that determine decision-making practices. In practice the range of choices is limited as institutional options require a very sophisticated implementation. They often address a number of actors and tackle the power and influence of a particular stakeholder or stakeholder groups. Moreover, they are based on the acceptance and agreement of stakeholder and show their effect in the long term. Additionally, institutional options are scale-dependent: certain problems in water management may raise the question of making decentralised sectoral ministries responsible, or rather local governments; other issues may require a behavioural change of one specific water user group in a community. Furthermore, institutional options sometimes force stakeholders to discuss technical options, e.g. in order to fulfil new legal requirements, or even to implement technical options. This shows that the discussion about implementing institutional options may incorporate two discussion levels at the same time and thus may become more complex than just the discussion about implementing a technical option. This is the reason why the AquaStress project took the chance to initiate discussions about the type and the way in which institutional options could be adapted in the test sites. In the following, three examples are given to show the range of methods and the different results on the sites.

**Option 10: Change institutions in irrigation management**

**Experiences in the Tadla test site (Morocco)**

**Problem:** The National Water Saving Program in Morocco - the major strategy for water stress mitigation - consists mainly of the conversion from surface to drip irrigation through financial subsidies. Essentially, large-scale farmers have benefited as they are able to bear the investment charge of these projects, while some social and organisational constraints of...
small-scale farmers in combination with low know-how prevent them from benefiting from these projects.

**Proposed measure:**
Collective organisation of farmers

**Methods and Tools:**
Dialogue facilitation, role playing games, integrated modelling and capacity building.

**Findings:**
Some more details about the general testing approach in the Tadla site are presented in section 6.3. The specific objective for institutional options was to assess whether the organisation of farmers is relevant regarding the introduction of water saving technologies. Although no clear positive results can be provided yet as to which extent the organisation helps to mitigate water stress, the creation of a water user association by local farmers shows that farmers can effectively be involved in water management. Collective irrigation projects are seen as crucial for small scale farmers as they will allow them to benefit from the same irrigation technology as the bigger ones, while increasing their organisational capacity. Additionally the study shows that the introduction of technological options goes hand in hand with institutional options.

**Example of the integrated modelling approach including institutional settings and socio-economic context**
The case study of Tadla is a good example of the linking of technical and institutional options. Additionally, it shows that the research project formed the basis from which an adaptation process started which will continue over the next years.

In contrast, the Przemsza case study (Poland) represents institutional options including disseminating information and changing public awareness to prepare a discussion about water stress problems. The hypotheses behind these kind of activities e.g. increasing awareness, is that eventually they also lead to more sustainable behaviour. A desired change of behaviour represents a typical form of an informal institution. Currently the discussion focuses on technical solutions, disregarding the fact that other types of mitigation options might be relevant. The objective of the activity in this case is to prepare the start of a discussion about non-technical issues.

**Option 12: Effective implementation of legal regulations**

**Experiences in the Przemsza test site (Poland)**

**Problem:**
The problems in the Przemsza basin are twofold: first, the region comprises large towns and intensive mining industry leading to the contamination of surface water as well as groundwater pollution. As a consequence most water bodies are failing to meet the objectives of the Water Framework Directive. At the same time clean mine water is used in a system supplying water to the citizens, a system that is endangered by constrained mining activity. Together with an anticipated rise of the underground water-table, social conflicts can be expected in the future. Secondly, all these regional problems are aggravated by a lack of tradition in public participation. The public perception of water-oriented problems and water stress is weak, resulting in an inability for the inhabitants to become active partners in the integrated water management.

**Proposed measure:**
Establishment of effective social consultation procedures

**Methods and Tools:**
Workshops, dissemination events, brain-storming panels and summer school.

**Findings:**
The testing of the option ‘Strengthening of public understanding of water stress and building a capacity for the integrated water management’
in the Przemsza case study presented a typical institutional option to increase awareness and eventually lead to changed—more sustainable—atmosphere in regard to water consumption. This institutional option is indirectly called for by the expressed need for public participation according to the WFD. A first step in the participatory processes is information as conducted by the above mentioned institutional option. Nevertheless, the implementation of this option in the Przemsza basin was not rated successfully. It was argued that society is not always prepared for making full use of new regulations and instruments although such tools would provide them with the opportunity to become a more visible and audible partner in decision-making processes. Certainly, it could be also argued that, maybe, the implementation of this institutional option was not conducted well enough. Hence, what can be drawn as a conclusion is that the implementation of even ‘easy-looking’ institutional options bear more problems than generally envisaged because their complexity is underestimated.

The close institutional stakeholder collaboration is a strong aspect of the Guadiana case study. Not only do the stakeholders show their interest by sharing information and contributing to the case study development but they are also interested in active participation regarding technical development.

**Option 10: Change institutions in irrigation management**

**Experiences in the Guadiana test site (Portugal)**

**Problem:**
There is a lack of capacity for optimum use of existing water resources among the various sectors (agriculture, households and environment). The major water stress issues that have been identified are related to the inefficient use of resources. Moreover, no clear characterization of point and diffuse pollution sources exists, and there is no comprehensive contingency plan to tackle drought and water stress situations.

**Proposed measure:**
Development of ‘best usage’ of shared water resources through institutional stakeholder collaboration

**Methods and Tools:**
Participatory modelling, agent-based models and role playing games

**Findings:**
Institutional changes were induced by the collaboration between
the various partners and the regional stakeholders that developed since the beginning of the project. The process was further enhanced through workshop sessions and meetings in order to improve concept and scenario development. The facilitation of the decision and co-decision process, considering the consultation of experts, has become a subject of participatory modelling activities. More details about the interactive testing and evaluation process are presented in section 6.3.

According to the broad definition of ‘institution’, the examples of the initiation and implementation show a wide range of institutional options. It becomes clear that institutional options such as technical options need to be identified for each case study on their own. However, even if the institutional option is identified, it is often necessary to agree upon the way of implementing and refining the option. Furthermore, even if a particular option was successful in one example this is often not automatically applicable for another test site because the institutional context needs to be taken into account as well as the natural characteristics of the test site. We can often observe that after e.g. the introduction of a new environmental emission standard (a formal institutional option) a new technological option to achieve the new standard is required. Occasionally it could be the other way round which can be seen in the example of Tadla. It may not always be indispensable in such a case to adapt institutions but it may become a complementing and supportive measure. Finally, the interaction of institutional and economic options should not be forgotten. Here, feedback mechanisms exist too. One typical example is that water user organizations confronting a water provider certainly have more negotiation power in regard to water prizing than individual users.

Further reading:

M. Manez, B. Blümling, M. Hare, and D. Günther: Report on perceptions of water stress from stakeholders over different sectors in the case study areas, Deliverable 2.2-1 of the Aquastress project, 2006


6.1 Introduction

As defined in chapters 2 and 3, participatory approaches can be used to identify water stress-related problems and project goals in order to mitigate the problems. This chapter takes the process further by looking at the participatory testing and evaluation at two levels: mitigation options and specific measures (as specified in Chapter 5). These measures are defined as the different alternatives which are studied when an option is applied. For instance, when applying an option which targets the improvement of irrigation efficiency, the different measures studied could then be: changes toward alternative irrigation technologies, changes in irrigation practices, etc.

Why carry out participatory testing and evaluation?
Options or measures need to be tested to state why, and to what degree, they are appropriate for a specific water stress mitigation context, i.e. the effect, efficiency, and so on. The rationale behind these tests is that it will reduce the risk of implementing a measure which is not appropriate for a specific context. Tests should therefore provide relevant information on the different alternatives, regarding the technical feasibility, the economic viability, and the social acceptability, as well as the environmental sustainability. Comprehensive testing is needed because a mitigation measure that is technically feasible may be socially unacceptable. Such testing requires the mitigation measure to be assessed by its receiving communities (Figure 6.1), in order to determine its various consequences. If these consequences do not meet certain explicit evaluation criteria, the measure should be rejected or modified.

![Figure 6.1](image)

Before applying a mitigation measure, stakeholders should be involved in order to assess, from their different points of view, to what degree and according to which criteria such a measure seems relevant in their own context. This can be achieved through a participatory test.
### Evaluation criteria

When making an evaluation, several criteria from the following four categories should be chosen to ensure comprehensive testing:

1. **Technical**: Feasibility (i.e., of option design, installation and maintenance), changes to existing infrastructure and technologies in use
2. **Environmental**: Ecosystem health and biodiversity, carbon and nutrient balances, waste production
3. **Economic**: Viability, efficiency, changes in micro and macro economic factors
4. **Social**: Health, well-being, equity, governance, participation, acceptability

<table>
<thead>
<tr>
<th>Technical criteria</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Water use efficiency</td>
<td></td>
</tr>
<tr>
<td>• Flexibility of irrigation</td>
<td></td>
</tr>
<tr>
<td>• Complexity of the drip irrigation system</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social criteria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Adoption of a new irrigation technology</td>
<td></td>
</tr>
<tr>
<td>• Equity of access to subsidies</td>
<td></td>
</tr>
<tr>
<td>• Farmers’ well-being</td>
<td></td>
</tr>
<tr>
<td>• Expertise</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic criteria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Initial infrastructure investment</td>
<td></td>
</tr>
<tr>
<td>• Maintenance costs</td>
<td></td>
</tr>
<tr>
<td>• Farmers’ incomes</td>
<td></td>
</tr>
<tr>
<td>• Adaptability regarding market fluctuation</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental criteria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil salinity</td>
<td></td>
</tr>
<tr>
<td>• Groundwater pollution</td>
<td></td>
</tr>
<tr>
<td>• Water resource over-exploitation</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 6.1 Example of evaluation criteria used to test and evaluate joint drip irrigation projects (see also section 6.3)

### Testing and evaluation approaches

Many different approaches can be found in the literature. In fact, there are different ways to test and evaluate water stress mitigation options or measures:

- Some approaches focus on some criteria only (e.g., cost-benefit analysis based on economic values), while others take a more multi-dimensional or systemic view (e.g., multi-criteria analysis or integrated assessment based on multiple indicators).
- Some evaluation methods are designed to provide an assessment at one point in time, for instance, while others help to show changes over time (e.g., trends produced through simulation modelling).
- Users can be involved in a variety of ways in the test (e.g. from expert based approaches to interactive participatory methods).
- Different tools can be used in the same approach, and in different ways: for example an existing hydrological model can be used in a participatory or non-participatory manner.
- Finally, tests can be undertaken in the field (e.g., action research) or in a laboratory (e.g., controlled experiments) where there are fewer risks of unwanted changes occurring in reality.
Chapter overview
In this chapter, you will find some answers to the following:
1. How to test and evaluate a panel of mitigation options in a participatory manner, and how to test and evaluate integrated options.
2. Within an option, how to test and evaluate the alternative measures studied.
3. How to evaluate these participatory testing procedures.
In each section, we will give some of the basic theory and specific examples from AquaStress.

Further Reading:

6.2 Participatory testing and evaluation of mitigation options

Once a panel of mitigation options has been identified they can be assessed in conjunction with the various stakeholders who would be affected by its implementation. This evaluation can focus on each option side by side, or on the integration of different options.

Participatory evaluation for option choice using cognitive mapping
Generally speaking, evaluation is the determination of the value of something, judged according to appropriate criteria, with those criteria explicated and justified. Participatory evaluation is a process of self-assessment, collective knowledge production, and cooperative action in which the stakeholders participate substantively in the identification of what has to be evaluated and according to which criteria.

The Cognitive Mapping methodologies can be really useful here, since they could structure the stakeholders’ knowledge by helping to identify the more important elements in their argumentation. A Cognitive Map (CM) can be considered as a qualitative model as close as possible to the cognitive representation of the problem in stages made by participants. CMs are often characterised by a hierarchical structure, according to a ‘means – ends’ approach, where the ends are the objectives to be achieved, and the means the actions. Thus, CM can be used to help participants in identifying possible actions that lead to the achievement of the most important objectives. The causal chain of a CM can identify the other elements impacted by the option.
The evaluation of the different mitigation options, which can be used to mitigate water stress, can be made taking into account their impacts on the achievement of the objectives and the consequences on the key concepts in the CM, i.e. the fundamental aspects to be considered in the evaluation. The most important objectives and the key concepts should be ‘translated’ into criteria. That is, they should be processed and transformed into variables which can be easily measured. Fundamental questions are: How do we judge if the objective has been achieved? How do we judge the positive or negative impacts of option on the key concepts?

The development of a Participatory Evaluation System Experiences in the Guadiana test site (Portugal)

In the Guadiana test site a multi–step cognitive mapping exercise was implemented in order to involve local stakeholders in the evaluation of water stress mitigation options.

1 In the first step, divergent thinking was supported. Participants were encouraged to provide their understanding of the water stress problems in the study area and to give their ideas about possible solutions. The outcome is a CM that emerges from the comparison of individual and group perspectives, forming the broadest possible picture of the problem situation.

Group Cognitive Map developed at the end of the first step of the applied methodology
2 The causal chains of the CM have been used to support stakeholders in the definition of the options’ effects towards the objectives achievement.

Causal chain of one of the selected objectives pulled out from the cognitive map to facilitate the discussion on options’ effects

3 This information was then used to support the debate among stakeholders to define a set of indicators for the assessment of both the achievement of the objectives and the impact of options on the key concepts.

Further Reading:
Supporting drought and flood risk management using a participatory modelling approach

Participatory modelling approaches can be designed as a series of workshops to bring large and heterogeneous groups of actors together. The actors can share their visions and perceptions on the flood and drought risks, and collectively develop and investigate strategies to mitigate these risks. Risk mitigation can typically be aided by technical measures (e.g. dykes, dams, flood retention basins), or by non-technical measures (e.g. education campaigns, emergency planning programmes and institutional coordination). Participatory modelling approaches to flood and drought management have the advantage of being able to develop and evaluate both types of mitigation options. At the same time they provide a forum for increasing social learning and starting the construction of regional adaptive capacity. The encouragement of such management approaches is particularly important in countries where institutional reforms are required (i.e. meeting the objectives of the EU Water Framework Directive), where there are heightened needs for concerted collective management, coordination and action. The main output of a participatory modelling process in this context is a jointly constructed and agreed action plan, which addresses the principal regional concerns of the participants linked to water stress.

Application of a multi-level participatory modelling process: living with floods and droughts. Experiences in the Iskar test site (Upper Iskar Basin of Bulgaria)

The participatory modelling approach developed in the Upper Iskar Basin was designed to facilitate ‘vertical’ talks from high-level policy makers to concerned citizens. The situation was judged as urgent, because the region was recently heavily affected by both severe floods and droughts. The process, organized by Bulgarian and external researchers, consisted of a series of six workshops and two series of participant interviews. The process led six groups of stakeholders through the phases of developing models of the current flood and drought management situation. The stakeholder groups included national-level policy makers, regional-level water managers, citizens and experts. The process addressed their visions and values for the future, the development of a range of measures to mitigate flood and drought risks, creation and assessment of mitigation strategies made from a number of measures, vigorous testing and development of a risk response plan of 24 operational projects for a sub-area of the basin under high risk of flood.
Developing common flood and drought mitigation strategies from technical and non-technical measures

Along with the development, testing and decision-making on preferred technical and non-technical flood risk mitigation measures, the principal outcome of the process (seen through the process’ continuous evaluation) was raising awareness, capacity building and operational networking among participants.

Further Reading:


Supporting the selection of environmental regulations using the choice experiment method

The choice experiment method is a survey-based, non-market valuation method that has become increasingly popular over the past decade for the valuation of public goods and environmental policies. The method involves the creation of a hypothetical market and calls survey respondents to perform sequential choices among different bundles of the goods’ characteristics. The econometric specification is derived using the assumption of random utility.

The choice experiment design crucially relies on the definition of the good to be valued in terms of its attributes and levels. In our specific example the attributes are: flood risk (which can be of high or low level), biodiversity (high or low level), river access (difficult or easy level) and monthly local tax (5%
increase or 5% decrease). The attributes need to be those that the public considers important regarding the proposed policy change, as well as those levels which are achievable with or without the proposed policy change.

**Supporting the choice of a river management plan**

**Experiences in the Przemsza test site (Poland)**

The good valued in this choice experiment study is the river management strategy. Three river management strategy attributes were chosen: surface and underground flooding risk, biodiversity found in the habitats and access to the river for recreational purposes. All three of these attributes were specified to have two levels.

We employed a simple choice experiment to estimate the value of three management options (plans) for the Bobrek wetland in Poland. The local public’s valuation of several wetland management attributes, including flood risk reduction, biodiversity conservation and improvement of recreational access, were investigated. A latent class model was estimated to account for heterogeneity in the preferences of the local public.

### Assuming that the following three wetland management plans were the only choices you had, which one would you prefer?

<table>
<thead>
<tr>
<th>Management plan Characteristics</th>
<th>Management plan A</th>
<th>Management plan B</th>
<th>Neither Management plan: Status Quo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood risk</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>River access</td>
<td>Difficult</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Monthly local tax</td>
<td>5% decrease</td>
<td>5% increase</td>
<td>Same as now</td>
</tr>
<tr>
<td>I prefer (Please tick as appropriate)</td>
<td>Management plan A</td>
<td>Management plan B</td>
<td>Neither management plan</td>
</tr>
</tbody>
</table>

### Results of the local public’s valuation of three management plans considering different attributes

The results reveal that there is considerable preference heterogeneity among the local public; however all respondents prefer those wetland management plans that minimise the flooding risk. The results of this study are expected to assist policy makers in undertaking effective flood risk reduction measures and formulating efficient, equitable and sustainable wetland management policies in accordance with the WFD (2000/60/EC).

### Further Reading:

Assessing the water saving potential and ease of implementation of different mitigation options using Bayesian networks

A Bayesian network (Bn) is a dynamic representation of a system involving numerous cause-effect relations. Each variable in a network is quantified using a probability distribution over two or more states, and the relationships between variables are quantified using conditional probability tables. When a variable in a Bn is instantiated, the probability distributions of all other variables (i.e. the probability of them being in state A, B, C etc) are updated through a process called forward or back-propagation. This dynamic characteristic of Bns makes them suitable for performing what-if analysis. Bayesian networks can be constructed with stakeholder groups to demonstrate the cause-effect relationships within a specific problem domain. Once the model structure is agreed it can be populated with conditional probabilities elicited from stakeholders using conditional probability statements to quantify the weights of those relationships. For example a conditional probability statement would be, ‘given event B, what is the probability (x) of event A?’ The notation for presenting the results of the preceding statement is: \( p(A | B) = x \).

There is no standard method for combining conditional probabilities elicited from stakeholders. However the literature on Delphi techniques provides examples that use different numbers of iterations and the results suggest that increasing the number of iterations improves the level of accuracy of the resulting forecasts.

The most basic Delphi technique reported uses a single round of consultations and is the approach that has been used in the following example for determining the potential impacts of water demand management options on total demand in the city of Sofia, Bulgaria.

Water saving in Sofia
Experiences in the Iskar test site (Bulgaria)

Ten stakeholders involved in water demand management (WDM) were asked to propose an exhaustive list of measures for the city of Sofia. For each measure the stakeholders were asked to specify the ease of implementation and water-saving potential of the different WDM options, given a range of response options. For ease of implementation these were - (i) very difficult (ii) difficult (iii) medium (iv) easy (v) very easy, and for water-saving potential – (i) very high (over 15%) (ii) high (10-15%) (iii) medium (5-10%) (iv) low (3-5%) (v) very low (less than 3%).

To calculate conditional probabilities for single measures the number of practitioners who said that the measure would achieve a specific water saving range was divided by the total number of practitioners who cited that specific WDM measure. So, if five practitioners cited an education...
and awareness campaign, and one predicted savings of 3-5% and four predicted savings of 5-10%, the conditional probabilities for different water-saving potentials would be: 3-5% = 1/5 = 0.20, 5-10% = 4/5 = 0.80.

Using the above technique, conditional probabilities were collected for the water-saving potential and ease of implementation for the seven most frequently mentioned WDM options, over two different implementation horizons. Figure 7 shows the options grouped into maximum, moderate and minimum programmes, based on their water-saving potential.

<table>
<thead>
<tr>
<th>PROGRAMME</th>
<th>WDM OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM</td>
<td>• Education/Awareness campaign</td>
</tr>
<tr>
<td></td>
<td>• Introduction of Increasing Block Tariff (IBT price structure)</td>
</tr>
<tr>
<td></td>
<td>• Pressure reduction programme</td>
</tr>
<tr>
<td></td>
<td>• Outdoor restrictions</td>
</tr>
<tr>
<td>MODERATE</td>
<td>• Water efficient appliance standard</td>
</tr>
<tr>
<td></td>
<td>• Household water appliance retro</td>
</tr>
<tr>
<td></td>
<td>• Education/Awareness campaign</td>
</tr>
<tr>
<td></td>
<td>• Pressure reduction programme</td>
</tr>
<tr>
<td>MINIMUM</td>
<td>• Education/Awareness campaign</td>
</tr>
<tr>
<td></td>
<td>• Outdoor restrictions</td>
</tr>
</tbody>
</table>

Options grouped into maximum, moderate and minimum programs

Further reading:


Supporting the selection of water stress management rules using simulation games

The selection and development of water stress management rules requires negotiation between the different stakeholders, in particular water users and water managers.

The traditional rational approach to these issues emphasizes the importance of formal modelling, rational planning and cost-benefit analysis. This type of approach is linked with mainstream operational research, linear programming and game theory, which tries to find optimal solutions. Today we are increasingly facing problems in which several actors with different interests are involved. In such circumstances the aim is not to find an optimal solution but to reach satisfactory solutions that are acceptable to the different actors. Thus, decision makers and stakeholders need new methods and tools to define water management rules in collaboration with others. Several studies have attempted to describe and analyse participatory methods. These methods are considered to be the most appropriate and effective approach to assess agricultural sustainability. They provide more active
roles for stakeholders in the management planning process and in decision making. Besides participatory modelling, many other practical tools are currently being used for decision making, such as computer-based decision support systems (DSS) and simulation games. The outcome of simulation games is not defined in advance but is discovered during the course of social interaction. Different behavioural patterns may therefore emerge from the interactions between actors. To demonstrate the interest of simulation games to support integrated water management, we report on a simulation game applied on a small basin in central Tunisia.

**Application of a simulation game based on DSS Experiences in the Merguellil test site (Tunisia)**

The ‘AquaFej Simulation Game’ aims to define management rules for water stress situations with the common agreement of water users and authorities. For implementation of the game we selected a small sub-basin of the Kairouan plain, the Rouissat area. The upstream basin collects the water resources and is closed by a storage reservoir managed by a regional institution for agricultural and rural development. The downstream basin is located in the plain of Rouissat where the Fej Wadi supplies a small aquifer covering an area of ca 50 km², before ending in a sebkha which corresponds to salt pounds.

The AquaFej simulation game is based on a hydrological model of watershed functioning, and on models of agricultural water uses based on a DSS about farming systems. The main objectives with simulation are to (i) negotiate water allocation rules between farmers and dam managers, (ii) show the consequences of individual choices with respect to cropping plans for regional development, while taking economic and environmental indicators into account.

A detailed field survey identified seven different groups of farmers which...
were defined according to their method of access to water, their geographical location in relation to the two dams and the size of the farm. During the simulation game the farmers quickly accepted both farm typology and models.

During the game, simulated cropping patterns were not affected by the rules for water allocation from the dam. That is to say, the water allocation rules did not affect the way farmers chose their cropping patterns. This first result shows a gap between theoretical farmers’ behaviours predicted by authorities and actual behaviors played by farmers.

Further Reading:

Support water management decision-making using a multi-criteria analysis approach
AquaDT is a multi-criteria decision-aid tool. It is a combination of software and a deliberation process tool that facilitates the process of decision-making when adaptive, participatory and multi-level management arrangements are critical to success. AquaDT can be found on i3s.aquastress.net. AquaDT structures the deliberation process, by assisting in the framing, scoping, generation, and finally the evaluation and comparison of alternatives. It enables people to think about their values and preferences from several points of views through communication about the problem definition, the setup of alternatives, and criteria.
AquaDT is arranged in four blocks providing input sheets and output graphs for inserting and evaluating the judgments of the stakeholders. This is organized as an interaction between a moderator and the participants of a session (Figure 6.2)

Structuring the decision problem
AquaDT structures the decision problem by defining alternative options and determining evaluation criteria. Input sheets are provided for their exact definition. This task is facilitated by a moderator to ensure that all
Figure 6.2 The iterative AquaDT process

decision makers use the same set of options. As a multi-criteria decision is a highly dynamic process, AquaDT allows the basic parameters to be easily added, excluded and edited.

Quantifying the judgments
As the actual core of the multi-criteria evaluation, each individual stakeholder assigns scores to the option and weights to the criteria. Menu items are provided that are adapted to the particular characteristics of the criteria, e.g. concerning the scale or the scope of potential values.

Reflecting the individual evaluation
A number of output graphs visualise the original judgments and aggregate them in terms of weighted scores, sustainability scores and a ranking of options. Additionally, a comparison with the group results is given. This reflects back the individual evaluation to the decision-maker and thus facilitates well-considered judgments and coherent reasoning.

Figure 6.3 Using the AquaDT steps
Finding a group consensus
The individual judgments are synthesised and fed back to the group using output graphs similar to the individual evaluation. To illustrate the group’s consensus or dissent different statistical measures are given. Additionally, the values of the individual participants are presented. Thus, AquaDT not only provides a final recommendation for the best option, but also offers structured information about the patterns of the stakeholders’ perspectives. This facilitates deliberation, creativeness and common agreement on solutions for the common problem.

Using AquaDT to support the modernisation of water supply systems
Experiences in the Przemsza test site (Poland)
AquaDT tool was translated into Polish to make it more accessible and understandable to local stakeholders. Representatives of local authorities, ecology organisations and citizens involved in modernising the process of the water supply system in the area of Olkusz were asked to have training in the use of AquaDT. The training started with the introduction of the main scope of the AquaDT instruments and the usability. The participants were then divided into three groups of interest and guided by the trainer, from structuring the decision problem to finding a group consensus.
The basic pay-off matrix consisted of six alternatives:
1. Continue pumping the Olkusz - Pomorzany mines according to the existing procedure and draw water via a deep-well pump from the Mieczysław shaft in the liquidated Bolesław mine
2. Partially flood the mining voids whilst continuing to drain water in the area around the main drainage pump chambers near the Bronisław and Olkusz shafts
3. Completely flood the mining voids and at the same time build an alternative deep-well intake in the Bronisław or Stefan shaft in the Olkusz mine or in the Chrobry shaft in the Pomorzany mine
4. Drill a deep-lying well in the eastern part of Olkusz district
5. Dispatch drinking water from the surface reservoir in Dzieckowice,
6. Revision of existed deep-lying wells and completion of extra deep-lying wells - when needed.

These options had to be evaluated according to the following criteria:
1. Investment and operational cost
2. Social cost
3. Environmental cost
4. End-user price of water
5. Water supply warranty
6. Organizational difficulties in alternative setting
7. Possible unemployment on a local labour market

In the end of the process, participants made a final ranking of the options. Option 1 had the higher score, option 4 the lowest.

Further Reading:

6.3 Participatory testing and evaluation of alternative measures

Following the selection of a specific mitigation option, a number of alternative measures may be identified and tested. At this stage of a water stress mitigation process, operational choices are assessed to determine which ones will be implemented.

Evaluating ‘best’ irrigation practices using a benchmarking approach
The Benchmarking approach is defined as a comparative analysis of specific practices inside a given sample. The goal is to identify the best
improving competitiveness, performance, efficiency

combination of agricultural and irrigation practices with regard to improving competitiveness, performance and efficiency of the system in which they are applied.

This approach can be used in the agricultural field, in order to better manage irrigation and save water. To do so, all components of the farm production system have to be assessed and analysed. The best plots, regarding production, quality parameters and gross margin, are identified, based on the comparison of simple criteria among the farmers of the group. This approach also needs to take into consideration the identification of the main constraints of the farms. The most successful examples are then used to identify strategies and best practices that can later be disseminated to other farmers.

Participatory benchmarking of olive crop irrigation practices
Experiences in the Guadiana test site (Portugal)

An important step when developing a benchmarking approach is to find agreement, between the participants, on the criteria used to rank the practices. In other words, prior to the information collection and comparison, the participants should first agree on what key-aspects of the production system production are most important when trying to determine ‘best practices’. This was achieved in the Guadiana case study, by organising participative workshops for farmers and rural extension technicians, which comprised a collective discussion with and among the farmers to assess the impacts of the activity at different scales. This allowed them to quantify the production factor’s relevance as well as the most important steps throughout the production process, namely irrigation and agro-chemical application.

This process allowed the co-construction of a conceptual production system for irrigated olive groves based on the following components: inputs, processes, outputs, qualitative impacts and external factors. Several items were discussed and scores were taken for each component.
HOW TO TEST AND EVALUATE

establishing the main criteria for the benchmarking of the farmers’ practices. The final scores had the consent of all the participants.

<table>
<thead>
<tr>
<th>Component</th>
<th>Criteria (decreasing order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>• Chemicals</td>
</tr>
<tr>
<td></td>
<td>• Labor</td>
</tr>
<tr>
<td></td>
<td>• Energy</td>
</tr>
<tr>
<td></td>
<td>• Fertilizers</td>
</tr>
<tr>
<td>Processes</td>
<td>• Irrigation</td>
</tr>
<tr>
<td></td>
<td>• Pruning</td>
</tr>
<tr>
<td></td>
<td>• Chemical treatment</td>
</tr>
<tr>
<td></td>
<td>• Fertilization</td>
</tr>
<tr>
<td>Outputs</td>
<td>• Olive</td>
</tr>
<tr>
<td></td>
<td>• Sub-products</td>
</tr>
<tr>
<td></td>
<td>• canolives</td>
</tr>
<tr>
<td></td>
<td>• Biomass</td>
</tr>
<tr>
<td>Qualitative impacts</td>
<td>• Local labor</td>
</tr>
<tr>
<td></td>
<td>• local economy</td>
</tr>
<tr>
<td></td>
<td>• pollution</td>
</tr>
<tr>
<td></td>
<td>• prevention of rural exodus</td>
</tr>
<tr>
<td>External factors</td>
<td>• Climate</td>
</tr>
<tr>
<td></td>
<td>• PAC</td>
</tr>
<tr>
<td></td>
<td>• world economy</td>
</tr>
<tr>
<td></td>
<td>• external markets</td>
</tr>
</tbody>
</table>

List of the different complements of the conceptual system for irrigated olive tree production

Further Reading:

Supporting the choice of a groundwater level using an existing hydrological model in a participatory manner

When hydrological models are used in support of water management decisions, stakeholders often contest these models because they perceive aspects to be inadequately addressed. The pressure may be such that the model is abandoned completely, even when some of the information it produces is useful. To avoid the costly development of a new model (which may be contested again!) a facilitator can lead a discussion about the hydrological model in which:

- the stakeholders explain which real-world phenomena are really important for them;
- the modellers explain the structure and parameters of the model, the scenarios that are evaluated, and the confidence they have in the model output;
- the facilitator makes sure that all participants understand what decision(s) are to be taken, what information is needed, what information can be
produced by the model, and what uncertainties remain. The participants jointly assess whether the uncertainties are acceptable and a decision can be made. If not, the facilitator focuses the discussion on how to reduce these uncertainties and/or develop new options that can be evaluated using available knowledge.

**Model use in the GGOR procedure**

**Experiences in the Vecht test site (the Netherlands)**

GGOR stands for ‘desired groundwater and surface water regime’. The Dutch water board Velt and Vecht had to define a GGOR for the Bargerveen. This Natura 2000 area harbours a rare species of living high peat that requires a high ground water level. The mainly agricultural land use in the surrounding area requires a much lower level. The Water Board invited the national nature conservation agency and the local farmers and residents to co-develop a GGOR that would strike a balance between the competing water interests.

The key uncertainty was the effectiveness of a hydrological buffer zone.

**Proposed hydrological buffer zone**
The best available hydrological model of the area was contested. After in-depth discussion, the participants agreed that it could be used to roughly estimate the relative effect of different buffer zone widths on the total surface area with high peat growth potential.

This allowed a trade-off between the Natura 2000 goal attainment and loss of agricultural land.

Further Reading:


Supporting the implementation of joint irrigation projects using multiple participatory methods
In many situations, the ‘best’ technical measures proposed by experts to mitigate water stress are not adopted by the end-users. This is the case when the constraints of the end-users have not been clearly taken into consideration in the development of the solution, or when they have not been prepared to handle the new technique. To overcome this issue, the context of application should be carefully assessed in relation to the end-users. Capacity transfer as well as knowledge sharing is also crucial. Finally, local knowledge should be integrated in the development of the solutions.

The Participatory Technology Development (PTD) approach follows this purpose. It aims to make a link between the technical and theoretical
knowledge of experts and the empirical and practical knowledge of the local communities, in order to develop more efficient technical solutions. A typical PTD approach follows four stages:

1) Participatory diagnosis to determine end-users’ problems and identify common objectives
2) Co-development of solutions between experts and end-users
3) Co-testing of solutions with end-users through field experimentation or virtual testing
4) Co-evaluation with indicators of success and decision-making

Thanks to this approach, the innovation is directly linked to a demand that has been explicitly expressed by the end-users. The involvement of the end-users follows thus from their own interest. This efficient involvement increases the chances of the technique being implemented in the field and finally being adopted by other end-users.

A PTD approach asks for appropriate participatory tools which can both support capacity building as well as concrete decision-making. Role-playing games and policy simulation exercises perfectly illustrate these two purposes.

A role-playing game can be described as a goal-directed activity conducted within a framework of defined rules involving characters who role-play. In other words, the participants play a situation in which they have to interact, make decisions, etc. The experimental exploration of decision-making enables them to go beyond their usual interpretative frameworks, which opens their minds and stimulates creativity. The play dimension of role-playing games is also important because it naturally creates a distance between the game and the real world, which allows sensitive issues to be discussed. For all these reasons, role-playing games are particularly appropriate to raise participants’ awareness about complex issues, such as a change process. However, such a tool necessitates a lot of preparation in order to be accepted and useful for stakeholders who are not there to ‘play’.

In a policy simulation exercise, participants develop and analyse scenarios. Following specific rules, it allows them to test different choices of solutions within a model that reflects reality. Policy simulation exercises are consequently more embedded in reality than role-playing games and can be used for supporting actual decision-making. They can be used with stakeholders in order to test a specific mitigation measure, before implementing it in real life.
Supporting the implementation of joint drip irrigation projects: Experiences in the Tadla test site (Morocco)

In the Tadla test site, the PTD approach was implemented to support groups of Moroccan smallholder farmers in the collective modernisation of their irrigation system. Different participatory tools were used during the process: farmer-to-farmer visits, a role-playing game and a policy simulation exercise.

At first, farmer-to-farmer field visits were organized in farms where drip irrigation was already used. This allowed farmers to gain knowledge on the technique, and create a knowledge network between novice and well-skilled farmers.

Then a role-playing game was used to raise awareness among farmers about the scope and contents of a joint project of modernisation. During this game, farmers had to play the different steps required to develop a virtual project. They then assessed which consequences a joint project would have in their context, and learned how to implement it.

During the last phase, once farmers were engaged in changing their system, a policy simulation exercise based on the actual field situation enabled farmer groups to test different scenarios consisting of technical and organisational choices. This tool allowed them to design their own project, by choosing the types of infrastructure which best suited their own constraints.
As a result, four farmer groups produced a feasibility study for their joint drip irrigation system. Among these, one group has now achieved the infrastructures of their project, and another group has bought a plot to build the storage basin.

Further Reading:
Dionnet, M., Barreteau, O., Daré, W. et al. (2006) : Survey on past experiences and practice on the use of Role-playing games in the field of water management & Proposal for a common framework, AquaStress Deliverable 5.3-1 Download: http://www.aquastress.net

Supporting the stakeholders understanding of industrial water processes using Systems Dynamic Modelling
System Dynamic Modelling (SDM) is a methodology for studying and managing complex feedback systems, typically used when formal analytical models do not exist, where system simulation can be developed by linking a number of feedback mechanisms. Constructing, examining, and modifying SDMs follow an iterative approach. Starting from conceptual qualitative models, simple quantitative models are built with few feedback loops and little detail, so as to allow the construction of an initial working numerical simulation model. The working model can then be modified and improved as necessary to show the desired level of detail and complexity.

One of the steps in the design of an SDM is the construction of a Conceptual Model. A Conceptual Model is a structural diagram of key variables and interactions, representing the dynamic nature of the system, which includes interconnections of system components and identification of reinforcing and balancing feedback loops and delays that affect the system dynamics. Such diagrams open the discussion of complex systems to include people who find verbal descriptions too complicated or too long and involved. Often a single map replaces pages of text required to describe all of the variables and their interactions.
Conceptual models are very popular for practically any kind of system. Scientists and domain experts prefer them, because of their transparency and clarity. They are also extremely useful tools for participatory projects and studies because they facilitate discussion and comparison of different interpretations of the system’s structure (i.e. which variables are involved and how they are linked) in a way that can also be easily understood by non-experts.

**Use of System Dynamics Modelling Experiences in the Iskar test site (Bulgaria)**

The Kremikovtzi water system is very complex, involving industrial water use and recycling, as well as shortages in fresh water resources. SDM has been developed and applied, aiming at defining feasible operational scenarios under varying climatic conditions and water shortages. The operational policies for the whole system were investigated, in order to: (a) increase the water recycle rate under normal years, and (b) investigate operational policies in times of drought. The simulation scenarios have been organized into three groups, labelled as ‘normal year’, ‘dry year’ and ‘very dry year’. Twenty three operational scenarios were run in total. Using the developed SDM, the simulation scenarios show that:

- For ‘normal year’ scenarios, it is possible to increase the system total recycling rate from the present 44% to 54%, by increasing the recycling rate at the wastewater treatment plant from 60% to 75%, saving on average 400,000 m³/month of fresh clean water.
- The ‘dry year’ scenarios show that it is possible to keep all units operating normally during ‘dry year’ conditions (rainfall and surface run-off 50% of normal), if the recycling rate at the wastewater treatment plant is set to 90%. The total system recycling rates will range from 62% to 58%, depending on other utilisation of reused water.
- The most interesting results come from the ‘very dry’ year scenarios (rainfall and surface run-off at 25% of normal). The model clearly shows that despite stopping various industrial units and recycling practically everything, the need for fresh water is still above 2,300,000 m³/month and the system total recycling rate cannot rise to more than 63%. The reason for this is that by stopping the units, there is not enough wastewater produced in the plant, while the units that operate continuously still need fresh clean water to operate.

**Further Reading:**
6.4 Evaluating learning in participatory testing procedures

Participatory processes can have valuable outcomes linked to individual and collective learning and the improved coordination of stakeholders. The extent to which such factors occur during participatory process stages can be gauged using a variety of ‘process evaluation’ techniques. These include:

- methods for taking ‘snapshots’ of participants’ perceptions of their own learning and other topics of interest such as closed or open-response questionnaires and individual or group interviewing and debriefing techniques;
- methods for studying dynamics and the development of these outcomes through the process including participant observation and participant self-evaluation techniques aided by video-recordings and personal journals.

Measuring changes in indicators of for example ‘learning’ required at least two snapshots – typically ex-ante evaluation and ex-post evaluation. Care should be taken as well in the interpretation of such results to determine if external factors to the process could also have had an impact on the results. Some evaluation methods can also drive continuous improvement of process organisation and aid participant self-reflection.

Participatory risk management
Experiences in the Iskar test site (Bulgaria)

Process evaluation included ex-post closed-response questionnaires completed by participants at the end of each workshop (WS) to evaluate the learning progress and viewpoint exchange through the participatory process of a series of six workshops.

Further Reading:

### 7.1 Involvement of decision makers

The relevance of a water stress mitigation plan, once put down on paper, depends on decisions related to its implementation. The key player for translating project proposals into actions is the decision maker. We consider decision makers in this context as the persons who are in the position to give formal permission or to furnish the necessary funding. The importance of their involvement should not be underestimated. Many examples can be found of interactive processes that resulted in proposals that were enthusiastically endorsed by all stakeholders, but which were not implemented because the decision makers were not committed to the results. This section highlights some of the possible differences in the mental maps of the parties who have to work together in this stage.

Traditional approaches to decision analysis focus mainly on the generation and evaluation of alternatives. The alternatives are considered as the means to reduce the differences between a given present and future desirable state. The assumption is that decision makers are interested in using the best available information for evaluation and for the comparison of the alternatives. In reality, the use of information in decision making is rational only to a certain point. For any decision maker, his or her mental model will affect what is noticed and what is taken to be significant. Only when the information provided by a water manager fits the mental model of the decision maker, can it be used to support decision-making processes. Here we provide our views about how these interfaces can be improved.

In the Vecht case, deliberate efforts were made from the very start of the project to involve representatives of the future decision makers into the planning process. Initially, these representatives were not very eager to attend the project meetings, and preferred to follow the process from a distance. ‘We want to keep our hands free for the future’, as one of them put it. Intensive lobbying at several levels was successful after approximately six months. This is considered one of the key factors to the successful stage of raising commitment and funds, which followed afterwards.
The first notion is that decision making is about politics being informed by water managers. Water managers and experts discuss plans and risks related to implementation of the plans and to inactivity. Water managers implicitly assume that the better the quality of the information they provide, the better the decision that results from it. The question is what is perceived as quality and what as a risk. The decision maker’s perception may change from the water manager’s perspective. For example: in the case of water shortages, the water manager’s perspective may be based on the risks that are threatening the system’s sustainable management. As a result he will look at demand-management types of options to solve problems. On the other hand, the risks perceived by the decision makers may be related to the water user’s demands, leading to a preference for water supply types of options. Necessary action that reduces risk to the water system may be risky in political terms.

The second notion is that of the policy cycle and the windows of opportunity it offers. If water experts want to move forward with various ideas it is insufficient to write them up and explain their merits. Rather, there is a need for long term political action. In particular, it is necessary to wait for the opening of ‘policy windows’ and then to frame the proposals in a way which would make them attractive to decision makers in that specific circumstance.

The third notion is that the distinction should be clear between the ‘decision maker’, the person who makes the final call, and those that influence and assist him in the decision-making process, because:

- The jurisdictions for allocating resources, financing, defining responsibilities may be spread out;
- The decision-making process may incorporate a series of approvals by different administrative bodies (e.g. first by the municipality, then by the district etc); and
- The decision can be based on a number of suggestions from competing authorities.
7.2 Participation of decision makers in the AquaStress test sites

In the AquaStress Project, we identified decision makers through stakeholder analysis and we invited them to participate in the project as members of the stakeholder bodies. Table 7.1 lists some of the decision makers involved in the project. Their involvement was primarily aimed at defining the institutional framework for water stress mitigation, but they were also actively involved in the selection and evaluation of options. As a result, the conclusions and recommendations put forward for the test sites had real value for the local communities, and could be included in the planning agenda of the decision-making authorities.

<table>
<thead>
<tr>
<th>AquaStress test site</th>
<th>Examples of decision makers involved in the project</th>
<th>Benefits from their participation in the project</th>
</tr>
</thead>
</table>
| Flumendosa, Italy                         | • Ministry of Environment  
                            • Regional authority (Committees for public works and environment)  
                            • Sardinian Water Body for sewage and water distribution                                                              | • Study on minimum vital flow  
                            • Link between water stress and the WFD  
                            • Communication and information exchange with other stakeholders  
                            • Setting up of integrated water management plan  
                            • Integrated water services provision  
                            • Scenario analysis                                                                                  |
| Guadiana, Portugal                        | • CAIA/INAG (Commission for the Environmental Impact Accompaniment, National Water Institute)  
                            • IDRHa (Agriculture and Rural Development Institute)  
                            • COTR (Operative and Irrigation Technologies Centre)  
                            • EDIA (Company for the development and infrastructures of the Alqueva system)  
                            • ARH (River Basin District Administrations)  
                            • City councils  
                            • AdA (Multimunicipal primary water supply company)                                                        | • Preliminary analysis of BMPs for olive cultivation  
                            • Criterion for the definition of a feasible water pricing.  
                            • New perspectives on water resources management and water stress mitigation  
                            • Provision of a preliminary analysis of wastewater reuse  
                            • Implementation of a Decision Support System Tool (the WSM-DSS) to the case study region       |
| Limassol, Cyprus                          | • Water Development Department  
                            • Water Board of Limassol  
                            • Community Council                                                        | • Update on research on water stress                                                                                      |
| Przemsza, Poland                          | • Municipal Department of Environmental Protection and Agriculture                                                   | • Strengthening of public understanding of water stress  
                            • Capacity building for the integrated water management                                                               |
| Vecht, The Netherlands                    | • Velt and Vecht Water Board  
                            • Province of Drenthe  
                            • Ministry of Agriculture                                                    | • Development of ‘Balanced Surface and Groundwater Regime’                                                                |
| Iskar, Bulgaria                           | • Ministry of Environment and Water  
                            • Danube Basin Directorate  
                            • Municipality of Samokov                                                    | • Experience on participatory processes                                                                               |
| Tadla, Morocco                            | • Regional office of Agricultural Development  
                            • Ministry of Agriculture                                                      | • Virtual and field implementation of joint irrigation projects                                                          |
| Merguellil, Tunisia                       | • Regional office for Agricultural Development                                                                         | • Testing and evaluation of acceptability of the best irrigation practices  
                            • Promotion of participatory processes (especially on the women’s role)                                               |

Table 7.1 Involvement of decision makers in the AquaStress project: indicative examples
### All phases of a project

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involvement of stakeholders from the very start is of key importance. It is not always easy</td>
<td>Project management</td>
</tr>
<tr>
<td>to realise. Take the time and devote the means to it that it requires.</td>
<td></td>
</tr>
<tr>
<td>Use I3S on i3s.aquastress.net</td>
<td>Use of tools &amp; methods</td>
</tr>
</tbody>
</table>

### Planning the project

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different people may follow different approaches to planning: rational, deliberative and</td>
<td>Process management</td>
</tr>
<tr>
<td>political theories. Be aware of these approaches, their pro’s and cons.</td>
<td></td>
</tr>
<tr>
<td>The nine-step approach followed in AquaStress is worth considering in similar phases in</td>
<td>Project management</td>
</tr>
<tr>
<td>other projects</td>
<td></td>
</tr>
<tr>
<td>The ProST planning tool is designed for use in distributed participatory processes, with</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>connections to knowledge bases.</td>
<td></td>
</tr>
</tbody>
</table>

### Identification of water stress related problems

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>The DPSIR approach is useful, but it has its drawbacks. Combination with the Log Frame</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Analysis improves on that.</td>
<td></td>
</tr>
<tr>
<td>The DPSIR/LFA approach must be combined with stakeholder-driven processes</td>
<td>Project management</td>
</tr>
<tr>
<td>The Water Stress Framework was developed to provide a framework for water stress indicators.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>The AquaStress project developed new algorithms for the use of Remote Sensing techniques,</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>resulting in a powerful tool for water stress identification.</td>
<td></td>
</tr>
<tr>
<td>Stakeholders should be involved in water stress mitigation planning. However, a number of</td>
<td>Project management</td>
</tr>
<tr>
<td>preconditions must be satisfied. If they are not, the participatory work should be kept to</td>
<td></td>
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<tr>
<td>a minimum.</td>
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</table>

### Definition of the goals of a project

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective-oriented planning, part of the LFA, is useful in defining and presenting the</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>goals and necessary means of a project.</td>
<td></td>
</tr>
<tr>
<td>Stakeholders may identify project goals in a wider range than anticipated by the initiator.</td>
<td>Project management</td>
</tr>
<tr>
<td>Take the time for goal definition with the stakeholders.</td>
<td>Process management</td>
</tr>
<tr>
<td>In many interactive processes balances must be found to accommodate the needs of all</td>
<td>Process management</td>
</tr>
<tr>
<td>parties involved, with respect to their roles, responsibilities and boundaries.</td>
<td></td>
</tr>
</tbody>
</table>
### Identification and selection of options

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experts, water managers and stakeholders must all provide their specific and essential inputs in the selection of options.</td>
<td>Project management</td>
</tr>
<tr>
<td>Case-based reasoning organizes knowledge in such a way that one can find similar cases to one's own. AquaStress developed a tool for its application in water stress mitigation.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td><strong>For an overview of options and measures that we investigated, see tables 5.1, 5.2 and 5.3 in section 5.1.</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Testing and evaluation of options and measures

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing reduces the risk of implementation of a measure which is not appropriate.</td>
<td>Project management</td>
</tr>
<tr>
<td>Cognitive Mapping can be useful in participatory evaluation by helping to identify the more important elements in an argumentation.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Participatory Modelling enables actors to share visions and collectively develop strategies, while increasing social learning and adaptive capacity.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>The Choice Experiment Method is a valuation method for public goods and environmental policies.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>A Bayesian network is dynamic representation of a system, incorporating conditional probabilities. They are suitable for what-if analyses.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Simulation games are useful when the aim is not to find an optimal solution, but a solution which is acceptable to all (or most) actors.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>AquaDT is a multi-criteria decision-aid tool. It can assist in the framing, scoping, generation, evaluation and comparison of alternatives.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Benchmarking can be used to identify strategies and best practices to be disseminated to other actors.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Unnecessary development of mathematical models to meet stakeholders' demands can be avoided by leading the discussion along a series of key issues.</td>
<td>Project management</td>
</tr>
<tr>
<td>Non-acceptance of technical solutions by end-users can be avoided. For this purpose we developed the Participatory Technology Development approach.</td>
<td>Process management</td>
</tr>
<tr>
<td>System Dynamic Modelling is a very suitable methodology for studying and managing water stress problems.</td>
<td>Use of tools &amp; methods</td>
</tr>
<tr>
<td>Evaluate the interactive learning process.</td>
<td>Project management</td>
</tr>
</tbody>
</table>

### Decision making

<table>
<thead>
<tr>
<th>Conclusion or recommendation</th>
<th>Application field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be aware of differences between the mental maps of experts and decision makers.</td>
<td>Process management</td>
</tr>
<tr>
<td>Be aware of the windows of opportunity that the policy cycle offers</td>
<td>Process management</td>
</tr>
<tr>
<td>Try to involve decision makers from the very start, at a level that is appropriate to the stage in which the project is.</td>
<td>Project management</td>
</tr>
</tbody>
</table>
### GLOSSARY

| **BAT** | Best Available Technique |
| **Benchmarking** | A comparative analysis of specific practices inside a given sample. |
| **BMP** | Best Management Practice |
| **BREF** | BAT Reference document |
| **Case study** | The case studies within AquaStress are in-depth plans covering selected issues or options within the test sites, offering integrated solutions combining technical, economic, institutional, educational and social aspects by implementing specific options or combinations of options. |
| **CEM** | Choice Experiment Method |
| **CM** | Cognitive Map |
| **DPSIR** | Drivers/Pressures/State/Impact/Responses<br>Concept adopted in the CIS Guidance Document No 3 for the identification of responses based on the analysis of the state of the environment and the impacts of the driving forces and pressures upon it. |
| **Drought** | Droughts are recurrent climate-related risks that affect a particular area during a period of time. Vlachos (1988) for example describes a drought as a ‘non-event’, i.e. it is unique among natural hazards because it is not a clear event, like a flood, earthquake, or hurricane. Unlike the latter for instance, we cannot follow its course on a map. |
| **DSS** | Decision Support System |
| **Evaluation** | Evaluations try to establish whether activities, systems or arrangements are effective or efficient. They reflect on what has happened and is happening in order to learn and adapt for the future. Therefore, evaluations not only support iterative improvement of the tools and processes themselves, but can also provide guidance on the management of complementary processes (e.g. governance or stakeholder engagement). |
| **I3S** | Integrated Solution Support System |
### Institutions
Formal laws and organisations determining the interaction of sectors and administrative levels to implement plans and measures, but also as informal rules, norms and behaviour that generally structure human interaction.

### IPPC
**Integrated Pollution and Prevention Control**

### ISWSI
**Integrated Sectoral Water Stress Index**
(see WSF)

### JWT
**Joint Work Team**
Teams in all test sites consisting of AquaStress partners covering a wide range of expertise. These JWTs supported the case study definition and implementation processes in the test sites.

### LPSF
**Local Public Stakeholder Forum**
Bodies formed by local stakeholders and end-users in each test site, closely cooperating with the Regional Partner throughout the project (secondary and primary stakeholders – small-scale end-users), and supporting project activities such as data provision, evaluation of options, participation in the case study selection process – implementation – evaluation, and in the training and dissemination activities. The LPSF provide the local knowledge to the Regional Partners and to the IP through their representation in the Joint Assemblies as members of the PSF.

### Measure
Measures are well-specified activities which are planned and implemented to reach a desired situation.

### Objective
The intended physical, financial, institutional, social, environmental or other goals which a programme / project is expected to achieve and which lies in its own sphere of influence (Novartis Foundation for Sustainable Development (2005)).

### Option
Options are groups of measures which target comparable water stress mitigation goals.
Options are categorised in:
- technical options (including operation and management options) which are subdivided into water demand management options and water supply management options
- economic options
- institutional options.

### PTD
**Participatory Technology Development**
| **Stakeholders** | Within AquaStress, stakeholders are individuals, public or private groups, social actors or institutions of any size who act at various levels (domestic, local, regional, national and international), and who have a significant stake in water management, and can affect, or be affected by, water management problems or interventions. |
| **Testing** | The controlled application of the chosen mitigation option. This test is a way to confront an option to the system in which it will be applied. It is conclusive in gathering information about the positive or negative effects a mitigation option generates in a specific context. |
| **Test site** | In the AquaStress project, eight test site areas in Europe and Northern Africa were used in the project to co-define, develop, test and evaluate the options for water stress mitigation. |
| **Water demand** | Water demand is defined as the volume of water requested by users to satisfy their needs (EEA, 1999). It does not automatically equal the amount of used water or the amount of supplied water. In the AquaStress project ‘user’ is not restricted to human beings. The amount of required water is calculated for each sector. The water demand is a theoretical amount of water based on the literature, statistical data and/or local expertise on water needs of different sectors. |
| **Water scarcity** | Water scarcity was defined by stakeholders of the project as a situation in which the water demand exceeds the water supply of a particular water system. Water scarcity can be temporal (e.g. extreme dry summer) but is also related to polluted water (e.g. nitrate pollution). |
| **Water stress** | Definition given by The European Environmental Agency (EEA): ‘Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes the deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.).’ In AquaStress we adopted this definition: Water stress occurs when the functions of water in the system do not reach the standards (of policies) and/or perceptions (of the population) on an appropriate quantity and quality or at an appropriate scale. |
| **WFD** | Water Framework Directive |
**WSF**

**Water Stress Framework**

The Water Stress Framework (WSF) is generated through a combination of two elements: the Integrated Sectoral Water Stress Index (ISWSI), which captures the level of water stress in the different water consuming sectors, and the Potential Margin (PM), which is an assessment of the available water resource supply in the indicated water system. There are three main possibilities for the use of this tool: 1) to evaluate and monitor water stress at the local level 2) for regional assessments and 3) for intersectoral comparison of water stress.
The Integrated Solution Support System (I3S)

What is I3S?
I3S is a collection of software utilities. Some of these utilities, such as numerical models are stand-alone, whereas other utilities, such as the various knowledge bases and the process support tool, are interconnected.

How does it support your water stress mitigation process?
I3S supports the water stress mitigation process by providing a set of tools or links to external tools which can help in carrying out specific tasks in a process. One of these tools, the process support tool, allows you to develop the participatory process in a participatory setting in order that you can find the appropriate solution to the problem. It helps to keep the process easily understood. Several knowledge bases complement the system to allow you to find information, including real-life cases.

What is in the I3S?
1) Knowledge bases on:
   a. test sites and case studies, including water stress mitigation processes
   b. water stress mitigation options
   c. water stress indicators
   d. useful software functionalities and tools providing such functionalities
2) A gaming tool
3) A participatory multi-criteria tool
4) A cognitive mapping tool
5) A water stress index calculator tool
6) A case-based reasoning tool
7) Additions?

Where can I find I3S?
http://i3s.aquastress.net/

What can you do for I3S?
One of the key features of I3S is that it allows you to look for similar cases and real-life experience on options. The value of I3S will increase when more information is incorporated in the system, in order that others can learn from your work. Hence, if you share your experiences, the system will become more valuable!
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