Water Stress Mitigation:
The AquaStress Case Studies

Mitigation of Water Stress through new Approaches to Integrating Management, Technical, Economic and Institutional Instruments

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Preface

This document, is part of a series of publications from the EU funded Aquastress project ("Mitigation of Water Stress through new Approaches to Integrating Management, Technical, Economic and Institutional Instruments", 6th Framework Programme).

This document is addressed to water managers at the regional or local level and aims at contributing to the analysis and mitigation of water related problems, and water stress in particular. It presents the AquaStress project experience in water stress analysis and mitigation and particularly the AquaStress Case Studies. It introduces the approach followed by the project, and presents indicative results for each Test Site.

The document demonstrates a coherent methodology for water stress diagnosis and mitigation that can be easily adapted and implemented for water problems in any region. A wide range of water stress mitigation options and their evaluation are described, formulating a first list of applicable options to be considered while mitigating water stress.

The report is structured in three parts:

I) The first part introduces the reader to the AquaStress methodology and the eight project Case Studies;

2)The second part is dedicated to the project Case Studies and provides a brief description of the main results. It is subdivided in eight chapters, one for each test site; and

3)The final part summarizes the results from the AquaStress Case Studies.

Glossary

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 deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.)"

AquaStress 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, at an appropriate scale and the adaptability for reaching those is not given.

DPSIR - Drivers/Pressures/State/Impact/Responses

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.

Stakeholders

Within AquaStress, stakeholders are individuals, public or private groups, social actors or institutions of any size that act at various levels (domestic, local, regional, national, and international), have a significant stake in water management, and can affect or be affected by water management problems or interventions.

Mitigation options

Possible strategy, linked to a group of alternative measures, for the mitigation of water stress. Options are categorised as technical (including operation and management options), economic and institutional.

JWT - Joint Work Team

Teams formed in all Test Sites consisting by AquaStress partners from different Work Blocks covering a wide range of expertise. These Joint Teams supported the Case Study Definition and Implementation process in the Test Sites.

Part I

Introduction

Contents

Introduction

Water stress is becoming an important challenge for the majority of countries worldwide, regardless of their climate conditions.
It is indicative that according to the United Nations Environment Programme (UNEP, 2007), two thirds of the global population will be living under water stress conditions in 2025, if there is no change in the current development trends.
In Europe particularly, the problem of water insecurity is of high importance, since 35% of the European population lives under intense water stress conditions (EEA, 2005), whereas the recent drought events in Southern Europe raised concerns on future water security. In this regard, the EU supports policy and research initiatives to address water stress and cooperates with other agencies working on this topic. For example, in 1997, the European Environmental Agency and the UNEP jointly proposed four innovative approaches for addressing water stress problems (EEA and UNEP, 1997): Integrated water management at the river basin scale; Demand management; Water pricing to account for the full cost of water services; and Use of innovative policy instruments (e.g. voluntary agreements, tradable permits).
The topic was also thoroughly addressed by the EC Water Scarcity Drafting

Table 1. Policy and research orientations to address water stress (EC, 2007)

Policy orientations	Research orientations
• Integration of supply-side and demand-side interventions	• Risk and impact assessment of alternative options at the local level
• Wider application of economic instruments and pricing - compulsory metering	• Research on the adaptation of economic activities to water scarcity and droughts, water efficiency and decision-making tools
• Promotion of efficient water allocation and use	• Support, coordination, networking and dissemination of research efforts at the EU and national levels
• Integration of water-related issues in EU policies	
• Fostering the emergence of a water-saving culture in Europe	

Group (2006) that concluded to a set of recommendations. The proposals of the WSDG were adopted by the Commission and are briefly presented in Table I (EC, 2007).

The proposed approaches should be further analyzed and assessed under the framework of change, either physical (climate change) or socio-economic, also incorporating in their analysis the main water policy issues:

- The definitions of rules for intra- and inter-sectoral water allocation in order to achieve water security (de Loë, 2007). In this perspective, the main goals are to ensure equity in access to water and on the socio-economic impacts of water allocation policies, to ensure food security, and to enhance the protection of ecosystems and biodiversity;
- The improvement of efficiency in end-use;
- The need for adaptive management that demands for a shift from reactive, crisis-based to proactive, risk-based management;
- The establishment of processes for participatory decision-making.

Research contributes to these efforts by making recommendations and providing tools for the adaptation of society and economic sectors to conditions of water scarcity. Particularly for water stress analysis and mitigation, the main challenges for researchers are:

- The development of indicators and indices for the site-specific definition of water stress conditions;
- The evaluation of the efficiency of water stress mitigation options;
- The enhancement of information flow in terms of: (i) promoting public understanding of water stress situations, (ii) establishing a link between research and decision-making, and (iii) ensuring a political commitment on mitigation;
- The provision of efficient tools to decision makers for describing and mitigating water stress; and
- The promotion of interdisciplinary approaches and participative, inclusive decision-making in water policies and research.

The AquaStress project

The AquaStress project addresses the research challenges indicated above and contributes to this effort by establishing a Case Study, Stakeholder driven and integrated approach for water stress diagnosis and mitigation, as indicated in Table 2 Project specific objectives were the development of guidelines for implementing integrated water stress mitigation options at local, regional and European scale, the development of new management tools and the promotion of a "culture change" in approaches to water stress through enhanced stakeholder involvement and education. The overall framework of the project is illustrated in Figure I.
The mapping of water stress conditions at the local level was based on a Water Stress

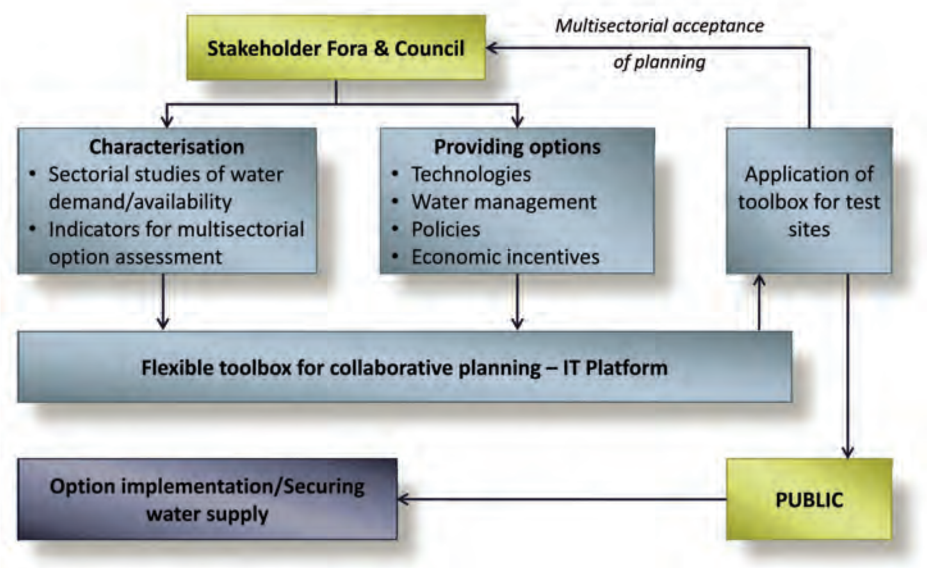

Figure 1. Schematic overview of AquaStress

Table 2. AquaStress contribution to ongoing research on water stress

Challenges in water stress research	Contribution from AquaStress
• Diagnosis and characterization of water stress	• Development of methodology (Case Study and Stakeholder driven) for water stress diagnosis and mitigation • Development of a Water Stress Matrix
• Assessment of the effectiveness of water stress management options	• Analysis of options of different disciplines (technological, engineering, economic options, decision support) • Investigation of linkages with existing policies (e.g. WFD, CAP, local/national development policies) • Implementation of the project methodology to eight Test Sites that cover a wide range of environmental and socio-economic conditions and face different degrees of water stress

• Development of methods and tools to evaluate mitigation options and their potential interactions	• Development of an Integrated Solution Support System (I3S, a web-based application comprising a comprehensive Knowledge Base with all information on water stress analysis and mitigation options), as well as of site-specific tools and models.
• Participatory decision making and planning	• Formation of (i) stakeholder bodies to foster mutual learning and (ii) Joint Work Teams to allow continuous collaboration and response to local needs

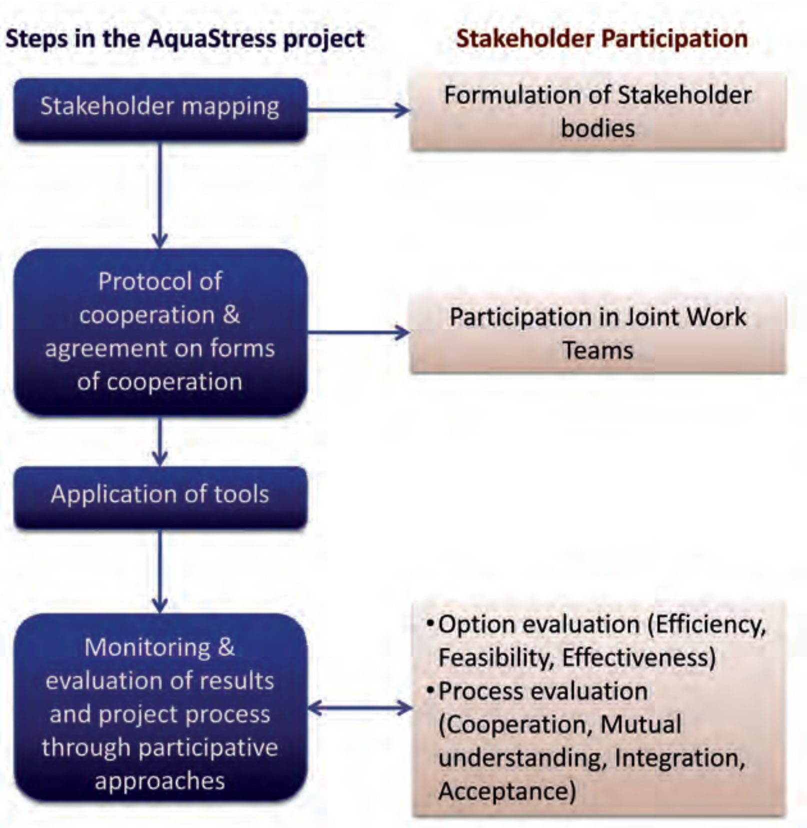

Figure 2. The evolving process of stakeholder involvement in AquaStress

Matrix, developed within the project. The Water Stress Matrix combines quantitative information (indicators on water use, available water resources etc) and qualitative information (maps, administrative decisions etc.) in a way that can be visualized and easily understood by stakeholders.
In addition to the multi-disciplinary integrative framework for describing water stress, another innovative element of the project was the continuous interaction among researchers and stakeholders, through a consultation process, for the definition of water stress problems, the definition of mitigation goals and options and, finally, the evaluation of their effectiveness. The identified stakeholders participated in the AquaStress stakeholder bodies, with the primary objective to integrate local knowledge and experience in the project phases. Furthermore, selected stakeholders became members of the Joint Work Teams, a joint body of researchers and stakeholders assigned with the virtual implementation of options. The evolving process of stakeholder involvement in the project is illustrated in Figure 2.

The AquaStress Test Sites

1. Guadiana basin, Portugal

The Guadiana River is one out of five rivers shared between Portugal and Spain. The river's southern basin is one of the driest areas in the country due to frequent periods of drought. However, the high demand for water for irrigation and the poor quality of the available resources also contribute to the water stress problem.

2. Flumendosa basin, Italy

The Flumendosa-Mulargia basin is located in the south-eastern part of the Sardinia region and supplies water, mainly in Southern Sardinia, for different conflicting uses (domestic, agriculture, industry and energy production). Flumendosa represents a typical Mediterranean region, with water scarcity and quality problems.

3. Vecht, The Netherlands

The Vecht catchment is part of the Rhine basin. The river originates from Germany and flows into the Lake Ijssel, in the Netherlands. The main water stress issues in the Test Site are related to water quality deterioration and groundwater depletion, attributed mainly to agriculture.

4. Przemsza basin, Poland

The Przemsza river catchment belongs to the upper Vistula river catchment and is part of an ecoregion of "central plains", according to the WFD article no 14. The region is significantly transformed by mining and industrial activities, resulting in intense water pollution problems.

5. Iskar basin, Bulgaria

The Iskar River is the longest Bulgarian tributary of the Danube river. The available water resources vary greatly under conditions of either general scarcity or two polar extremes of flood and drought. The region also faces water stress problems caused by pollution from industrial activities.

6. Limassol region, Cyprus
The Limassol region is an indicative example of competing and conflicting water uses in Cyprus. The water stress problems of the island are well documented: limited availability of surface water resources, overabstraction of groundwater, and conflicts between the urban and the agricultural sector, especially during summertime.

7. Merguellil basin, Tunisia
The Merguellil River is one of the three large seasonal flow rivers that extend over the central semi-arid Tunisia.
The region is subject to great climatic variability, whereas the construction of works in the upstream basin decreases the availability of surface runoff to the downstream main use by the agricultural sector. This situation accentuates the overexploitation of Kairouan aquifer.

8. Tadla irrigation scheme, Morocco
The Tadla irrigated perimeter is located on the banks of the Oum Er Rbia River. The intense use of groundwater resources for irrigation has resulted into a significant decrease of the water table, whereas at the same time the salinity of water has increased. Therefore, a transition towards more sustainable irrigation practices is a necessity for the region.

The AquaStress Case Study approach

The analysis and mitigation of water stress in the AquaStress project was based on the definition of water stress related case studies in the eight AquaStress Test Sites. Case studies were defined during the project life and implemented in each test site, through a systematic research framework, aiming to test water stress mitigation options, while ensuring the real involvement of local stakeholders and focusing on particular characteristics of the Test Sites.
Case studies emerged as "in-depth plans covering selected issues and regions within a Test-Site, by implementing specific options or combination of options in all or part of a Test Site, and offering integrated solutions coupling technical, economic, institutional, educational and social aspects", whereas participation was promoted through the establishment and interaction of three multi-stakeholder bodies.
The public participation process was based on the Logical Framework approach, whereas the analysis of water problems followed the Drivers-Pressures-State-Impacts-Responses (DPSIR) framework.

The DPSIR Framework

The DPSIR framework describes the links between the origins and the impacts of environmental problems (Smeets & Weterinds, 1999). It is a more integrated version of the PSR framework proposed by OECD (1994) that was adopted by the European Environmental Agency for describing the interaction between society and the environment. In the field of water management it was engaged by in the CIS Guidance Document No 3, as a means of the identification of responses based on the analysis of the state of the water bodies and the environment and the impacts of the driving forces and pressures upon it (Borja et al., 2005). The tool results to a set of indicators that describe the cause-effect relationships of environmental problems.

Driving Forces: The driving forces are expressed through indicators on natural conditions affecting water conditions, human influences in the water resources of 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 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 have impacts 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 groups (and individuals) in the society, as well as governmental efforts to prevent, compensate, ameliorate or adapt to changes in the state of the water resources and conditions.
Adapted by Walmsley (2002)

The Logical Framework approach involves the implementation of three main steps (AusAID, 2003):

1) The **situation analysis** that consists of the identification and analysis of the major parameters that relate to water problems and the stakeholder analysis. 3Stakeholder mapping refers to (i) the identification of groups that affect or are being affected by the project, (ii) the analysis of their interests and agendas, and (iii) the investigation of patterns of interaction and dependence.
2) The **strategy analysis,** which aims at the identification and selection of the most appropriate responses to the existing water problems.
3) The **implementation and evaluation** phase. This final step involves the evaluation of the selected options based on their effectiveness in resolving the

problem. The evaluation is performed through the use of indicators identified as relevant by the stakeholders.

In accordance to the LFA and DPSIR approaches, the definition and implementation of the AquaStress Case Studies followed a three stage process, portrayed in Figure 3:

Stage 1: Definition of the Case Study objectives. The main issues addressed in this stage are the stakeholder analysis and the identification of the main objectives of water stress mitigation based on a problem tree analysis of the focal problem in the test site;

Stage 2: Selection of water stress mitigation options. The process integrated expert knowledge and stakeholder perceptions in an effort to identify applicable economic, institutional and technical options;

Stage 3: Implementation and assessment of options. Stage 3 includes the preparation of a plan for implementing the Case Study and concludes with the analysis of the efficiency of the applied mitigation options, therefore supporting decision making on cost-effective solutions for water stress mitigation and sustainable water management.

The Case Study stages are more thoroughly described in the next paragraphs.

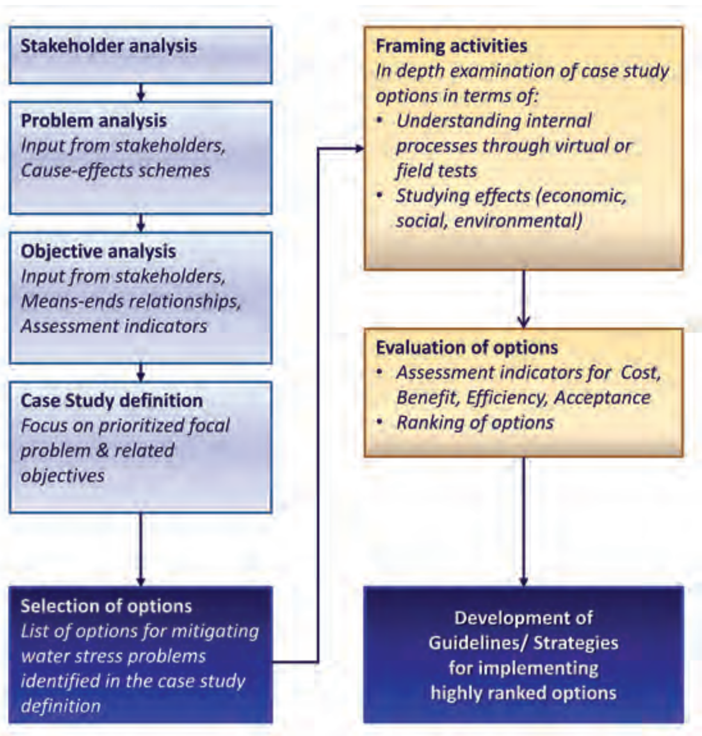

Figure 3. The Case Study definition and implementation process in AquaStress

Stage I: Definition of the Case Study objectives

Stage I identified the defining water stress issues for each Test Site. It was subdivided into four distinct steps: stakeholder mapping, problem and objectives definition, and case study definition.

Stakeholder mapping was performed to select members for the Stakeholder Bodies, who contributed with their knowledge, experience and opinion to the water stress analysis. Three stakeholder bodies were formulated:

1) The Stakeholder Council (SC) consisting of experts in the water sector. The SC acts as an advisory body, commenting on the methods and the actions undertaken;
2) The Public Stakeholder Forum (PSF), which is a mixed panel of researchers and stakeholders, dealing with water stress mitigation;
3) The Local Public Stakeholder Fora (LPSF), which are local councils, composed of primary and secondary stakeholders providing and receiving information from the PSF. Their role is to bring the regional knowledge and experience in the planning process.

The definition of problems and objectives was performed through a joint application of the DPSIR and Log Frame approaches. The tools enabled the representation of problems and goals in a cause-effect scheme, which was commonly developed by researchers and stakeholders, namely the problem and objective trees. It was a participatory exercise that aimed at developing a common understanding of the water stress problems and building consensus on the critical objectives for the region.

The water problems were analyzed in relation to environmental considerations (ecosystem degradation), social considerations (access to water), development considerations (low water productivity, economic efficiency) and water deficit (conflict among users).

The final step is the definition of the AquaStress Case Study that addresses the focal water stress problem in the Test Site, based on the outcomes of the previous steps. The aim was that the Case Studies serve as a learning platform towards understanding the impacts of different water management practices on water stress. Therefore, the Case Study summarizes the critical strategy for mitigating water stress.

The Case Study defined in each Test Site is presented in the table below. Five Case Studies are dealing with the contribution of the agricultural sector to water stress (Flumendosa, Guadiana, Tadla, Merguellil and Limassol Test Sites); two Case Studies are focused on the industrial sector (Iskar and Przemsza Test Sites); and one Case Study is dedicated to participatory water management (Vecht Test Site).

Table 3. The AquaStress Case Studies

Test Site	Case Study
Flumendosa	Integrated and sustainable water management
Guadiana	Use and allocation of water resources among the agriculture, urban, and environmental sectors to maximize environmental, economic and social welfare
Guadiana	Use and allocation of water resources among the agriculture, urban, and environmental sectors to maximize environmental, economic and social welfare
Limassol	Decreasing groundwater overexploitation through the rationalization of the irrigation practices employed, and promoting the use of reclaimed water
Merguellil	Improving water use efficiency in intensively irrigated areas
Tadla	Integrated and sustainable water management
Iskar	Initiation of multi-level participatory process for holistic urban and industrial water management under scarcity and stress conditions
Przemsza	Adaptation of water management in the Przemsza catchment to meet the need of industrial transformation
Vecht	Improvement of water management by the Velt en Vecht Water Board through participatory approach and water system analysis

Table 4. used in Stage I

Goals	Tools applied	Interaction of bodies
• Identification of Stakeholders and involved parties	• Stakeholder mapping	
• Problem definition • Objectives definition	• Joint application of DPSIR & Logical Framework Approach	• Information exchange among PSF-LPSF-project experts
• Case Study definition	• Public participation	• Consultation by project experts and SC, Active Involvement of PSF-LPSF
		• Consultation among PSF-LPSF-project partners

Stage 2: **Selection of water stress mitigation options**

Stage 2 corresponds to the selection of options to be implemented through the Case Studies in order to resolve the focal problem and achieve the desired situation. The options fall under the broad categories of policy mechanisms, economic tools, administrative initiatives, participatory processes, water saving activities, and education and awareness efforts, further aggregated to institutional, economic and technical options.

The selection followed a consultation process, as illustrated in Figure 4 and summarized in Table 5. Project partners were grouped into Joint Work Teams (JWT), one for each Test Site that proposed a first list of mitigation options. As a next step, the feasibility of the alternative available options was discussed with the participating stakeholders. Therefore, the final selection was made with the essential input and acceptance of local stakeholders.

The proposed mitigation options were classified according to their type (technical, non-technical options) and the organizational level (national policy, water resources management, provision of water services) that is responsible for implementing the option. This characterization aimed at defining the stakeholder groups that should be involved in stage 3 "Implementation and assessment of options".

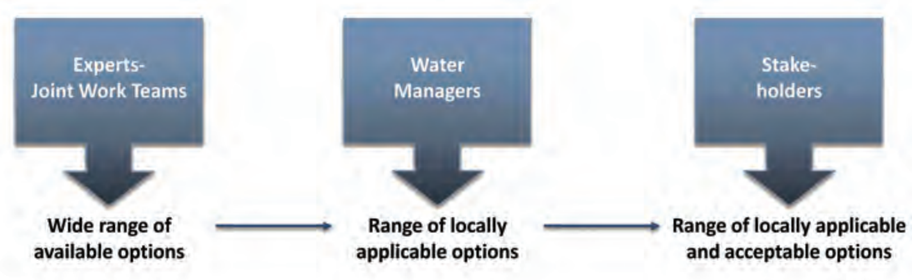

Figure 4. The process of defining the list of available & acceptable options

Table 5. Tools used in Stage 2

Goals	Tools applied	Interaction of bodies
• Development of a list of applicable options	• Expert judgment • Input from literature • Options already applied in the Test Site	• Information exchange between PSF-JWT
• Selection of options acceptable by the stakeholders	• Group discussions • Workshops	• Consultation by SC, Active Involvement of LPSF

Stage 3: Implementation and assessment of options

A Case Study encompasses a qualitative and quantitative analysis of the underlying causes of water stress in order to promote understanding of the measures that can contribute to the mitigation efforts. Thus, water stress mitigation options were analyzed either by virtual implementation (simulation activities and computer tools), by field activities (small scale field activities used for testing the applicability and the efficiency of the proposed mitigation options) or participatory processes (surveys & workshops on water stress issues).

The spatial scale of analysis varied among options and ranged from a specific sub-basin in the Test Site to the whole basin. The scope of this was to test the effects of the mitigation option in the region where the targeted water stress problem is evident.

The results of the testing process were evaluated in terms of:

- Performance for water stress mitigation, under the specific conditions at the Case Study level. Specific criteria used in the evaluation of options were option efficiency (expressed as the cost-profit ratio), effectiveness (expressed as the cost-benefit ratio), and the overall achievement of the stress mitigation goal; and
- Acceptance of the applied options by the local stakeholders (public participation indicators).

The outcome of the Case Study definition and implementation process is the formulation of a set of recommendations for water stress mitigation in the Test Site, based on the evaluation of the mitigation options. Furthermore, the combined experience from the water stress mitigation process in the eight Test Sites was used in the compilation of proposals for the efficient mitigation of water stress.

Table 6. Tools used in Stage 3

Goals	Tools applied	Interaction of bodies
• Analysis of mitigation options	• Modelling/ simulations • Games • Experimental implementation	• Information exchange between JWT-PSF
• Evaluation of options	• Indicators • Workshops	• Consultation by SC, Active Involvement of LPSF
• Recommendations		• Consultation among JWT, SC and PSF

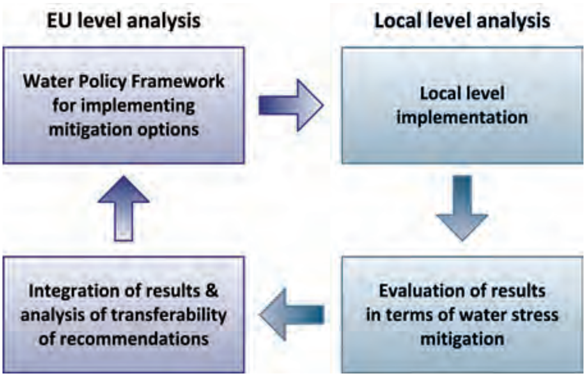

Figure 5.The process of integrating project results towards EU recommendations

Lessons learnt from the AquaStress Case Study process

- The Case Study approach can facilitate the integration of results in developing EU-relevant policy recommendations;
- The formulation and operation of Stakeholder Bodies has enabled information exchange between the public, decision makers and water experts and can enable mutual understanding and the early identification of the true problems;
- Similar sectoral water stress issues were identified in the Test Sites, emphasizing the need for international practices for water stress mitigation;
- Cooperation among different disciplines is not easy to achieve and takes time
  > It can be enhanced through the formulation of interdisciplinary working teams of researchers and stakeh lders
  > The AquaStress interdisciplinary approach has enhanced the insight of collaborating water experts
- Technical solutions are not the only way for coping with water stress. Non-technical options can also contribute significantly to water stress mitigation;
- Stakeholder acceptance should be a key criterion in selecting appropriate options;
- Evaluation is the key step in any planning process;
  > The evaluation of options supports the development of policy recommendations
  > The evaluation of the process aims at the identification of pitfalls and, thus, supports improved integrative planning
- Option impact assessment is highly dependent on available data and information. Therefore, activities to enhance the knowledge base and collect appropriate data should become the first priority;
- Experience from the Case Studies in countries that the New Member States has proven that transition is an opportunity for improvement, not a constraint.

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Part 2

The AquaStress Case Studies

Contents

Enhanced environmental protection through improved agricultural and water management practices

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Sardinia is the second largest island in the Mediterranean. The climate is generally mild and influenced by the air masses coming from the Atlantic, from Africa and from the Arctic. The weather is generally good; over the year there is an average of 300 days of sunshine. The rainy seasons are winter and autumn, with some sudden showers occurring in spring. The Island of Sardinia has 1.680.000 inhabitants distributed in a territory of 24.089 km^2 with a population of 68 inh/km^2 reduced to 30/km^2 in the rural areas. Nearly half of the population lives in the main city of Cagliari and its surroundings.
Figure 6 shows the Flumendosa River basin and the irrigated area selected for the AquaStress project Case Study. The total population inside the Flumendosa basin is 36.000 inhabitants, mainly concentrated in the urban areas and along the coast in particular.
The Flumendosa river basin (1824 Km^2) is located in the central-eastern part of the island. It includes three

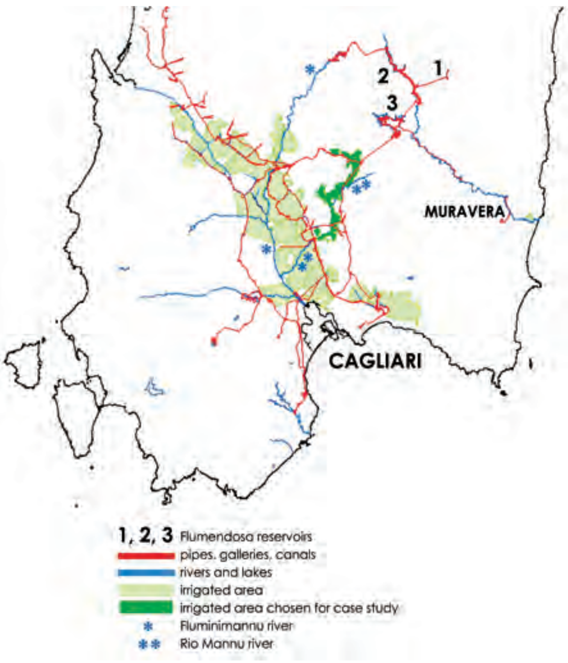

Figure 6: Flumendosa River basin and selected Case Study area

interconnected reservoirs (Flumineddu – Flumendosa - Mulargia), which together with others located outside the basin, constitute the Flumendosa - Campidano hydraulic system (Figure 7), the most important and complex system in Sardinia. The reservoir system supplies water for domestic, agricultural, industrial and hydroelectric purposes, not only inside the basin but mainly in Campidano plain (Southern Sardinia), where the biggest City of Cagliari is located.

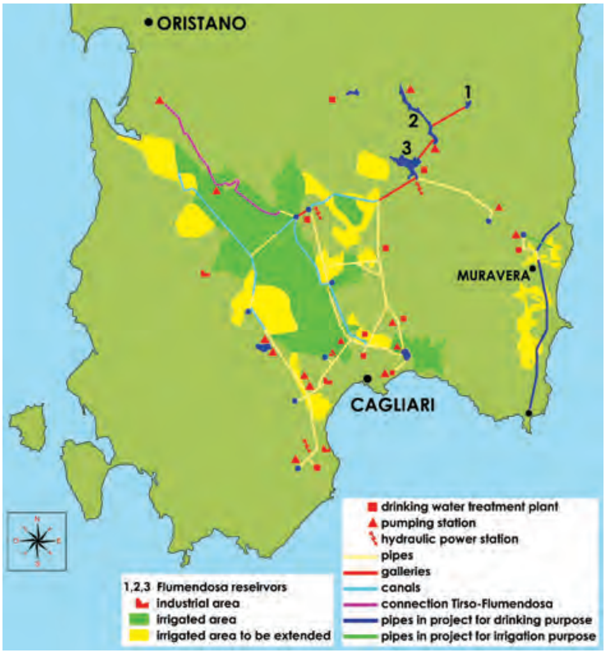

Figure 7: The Flumendosa - Campidano hydraulic system

Water stress conditions

The basic water stress problem in the Flumendosa basin is caused by the operation of the Flumendosa-Campidano reservoir system. During the dry seasons, the limited water availability causes conflict between the main water users, agriculture and domestic use. Furthermore, water quality has deteriorated resulting to a further reduction of usable water resources.
Water stress in Flumendosa basin is also caused by the groundwater overexploitation in the coastal area, which leads to aquifer depletion and sea water intrusion. The Municipalities located near the coastal area are supplied with

groundwater for meeting domestic and agricultural demand. However, water deficit is experienced during the summer months due to tourism, and therefore the construction of a new dam (low Flumendosa dam) has been foreseen in order to supply surface water to the downstream part of the basin.

Water stress issues in the Flumendosa basin can be summarized as follows:

1) Lack of awareness campaigns addressed to citizens.
2) Delay in the reorganisation of water services and water tariffs foreseen by national and regional legislations.
3) Inefficient irrigation practices and crop patterns, especially during drought periods.
4) Water quantity issues:
   > Dry summers causing seasonal water shortage;
   > Conflicts over water uses;
   > Minimal vital flow not respected by dam release;
   > High water losses in the networks;
5) Water quality deterioration, attributed to diffuse pollution. A high load of nutrients is transported during flood events, causing eutrophication phenomena in the reservoirs.
6) Problems in the coastal aquifers due to groundwater overexploitation and insufficient recharge.

Available water resources and uses

The total storage capacity of the Flumendosa-Campidano hydraulic system is about 750 Mm^3, with almost 90% of the water being stored in the Mulargia and Flumendosa reservoirs.

The Flumendosa-Campidano hydraulic system supplies water for urban, agricultural, industrial and hydroelectric purposes. It should also maintain a specific river flow downstream for the ecosystem protection.

The water demand of these users is the following:

- Urban supply : 100 Mm^3;
- Industrial use : 20 Mm^3;
- Agricultural use : 236 Mm^3;
- Environmental protection: 48 Mm^3 for the entire Island (of these, 17 Mm^3 were estimated as MVF in the low Flumendosa river).

Quality issues

Surface water quality

The main problems of surface water are linked to eutrophication phenomena due to their high sensitivity to point and diffuse sources of pollution.

Groundwater pollution

The limited natural recharge of the Muravera plain after the construction of the dams, combined with the overexploitation of the coastal aquifers, has resulted in sea water intrusion. The deterioration of groundwater quality minimizes the available water resources for use.

Quantity issues

Water demand for domestic use

The Flumendosa hydraulic system supplies water resources for domestic use to 137 Municipalities with a total population of about 760.000 inhabitants; this number increases during the summer to almost 250.000 people. Of these 137 Municipalities, 19 are included in the Flumendosa basin (about 23.000 inhabitants) while the others are located in the Campidano plain. Three Municipalities (13.000 inhabitants in total and a tourist increase of about 3.000 during summer), which are located in the coastal area of Flumendosa basin, are served by groundwater abstractions both for agricultural and urban use. Water demand is about 100 Mm^3 and the network losses are estimated at about 50%.

Agricultural water demand

The most intense agricultural activities are concentrated in the south-central and south-eastern parts of the basin, with cultivation of grains, vines, and citrus orchards making up the most common agricultural land uses. Many areas have been reforested, and in the northern parts of the basin natural vegetation cover is still present, a mixture of bare soil, grassland, shrubs, and forests. Livestock breeding (mostly sheep and cattle) is carried out in the entire basin and is responsible for the eutrophication of water resources due to diffuse pollution. The reservoir system does not supply water for irrigation purposes inside the basin where there are no agricultural distribution networks.
Outside the basin, in the Campidano plain, the reservoir system supplies water for the irrigation of about 60.000 hectares (mainly cultivated with citrus orchards, artichokes, sugar beets and vegetables). The total demand for irrigation purposes in the Campidano plain is 236 Mm^3.

Industrial demand

Inside the Flumendosa basin are located four slaughterhouses, two cheese manufacturing industries and several pork manufacturing industries. Treatment plants for urban and industrial wastewater operate in all Municipalities of the basin, but the outflow often fails to meet the required standards.
Outside the basin, the reservoirs supply water for the needs of an industrial agglomeration (Consortium of CASIC) that includes more than 300 different Industries (metal and plastic working paper making, textile production and tanneries, paints, organic and inorganic processes, foods, wood manufacturing, photographic industries) with a total of about 35.000 employers. It also supplies water to one of the most important oil refineries in Italy (SARAS).

Water for Hydropower

There are 19 hydroelectric stations operating in Sardinia, with a total maximum produced power of 431 MW; 4 are located in the Flumendosa-Campidano system: Uvini station (13 MW), San Lorenzo (1.25 MW), Settimo San Pietro (1.3 MW) and Santu Miali station (25 MW). Hydropower contributes 2.2% of the annual energy demand, and the rest is covered by thermoelectric production and wind turbines.

Water for Leisure and Recreation

The environmental uses (which include also leisure, fishing) requires a "minimum vital flow", to ensure the environmental integrity of the rivers, ecosystem balance and aquifer recharge. For the whole Island a total release requirement of 48 Mm^3/year has been estimated, equal to 50% of the average flow of the three driest months (July, August and September). During the AquaStress project the Minimum Vital Flow for the low Flumendosa river has been estimated at about 17 Mm^3/year, but this demand was unmet until now and will probably remain unmet in the future due to drought.

Table 7 below presents the hydrological balance of Sardinia (the average available resources, the water demand for the different uses, including the environmental requirement, and the registered deficit).

Hydraulic system	Resources (Mm^3/anno)			Demand (Mm^3/anno)				Environmental release (Mm^3/year)	deficit (Mm^3/year)	% deficit
	Surface Water	Groundwater	Total	Domestic	Irrigation	Industry	Total			
Sulcis	13	26	39	10	24	20	54	1	-17	6
Tirso	213	55	268	41	220	11	272	9	-13	4
Nord occidentale	196	49	245	69	162	49	280	12	-48	17
Gallura	34	5	39	25	26	2	53	1	-15	5
Posada+Cedrino	31	8	39	11	45	0	56	6	-23	8
Orientale	28	5	33	10	26	1	37	1	-5	2
Flumendosa+Leni+Cixerri	274	70	344	131	318	43	491	17	-165	58

Table 7. Hydrological balance of Sardinia

Institutional capacity

The national water legislation framework is in the process of reform in an effort to conform to the EU water Framework Directive. Environmental legislation in Italy can be largely regarded as a consequence of the implementation of European Directives, but, although Italian legislative and institutional framework is broadly coherent with Europe, there is a large gap between policy provisions and implementation efforts, mainly attributed to the delays in developing an environmental policy.

The major constraints in the Flumendosa basin can be summarised as follows:

1) Administrative fragmentation at the civil, agriculture and industrial sectors.
2) Unbalanced economic management: this concerns in particular the urban and agriculture sectors where tariff levels do not allow the complete coverage of costs.
3) Institutional and legislative framework incompatibility; the required "River Basin Authority" has not yet been formed as there are conflicts concerning the formation of the Utility, which will be in charge of the integrated water system management.
4) Lack of data and limited accessibility to existing information/data.

Infrastructure

The high losses in the water networks and the dependency on the water from the reservoirs are critical issues in the basin:

1) Vulnerability in the water supply: it is dependent on the big multi-sectorial hydraulic systems not yet interconnected for 78% of the supply, which greatly increases vulnerability in cases of drought.
2) Very high percentage of water leaks: for every three cubic meters distributed, only one is invoiced. Network leaks are in the range of 50%.
3) Inefficient irrigation system: 302 km of the distribution system are open canals, resulting in high evaporation losses. Furthermore, irrigation practices are inefficient and water is still priced according to the size of the irrigated area and not volumetrically.

Social and economic equity

The social issues are strongly interconnected with the governance dimension, and the lack of cohesion at the territory level is one of the main social issues affecting water stress. Over the years, wrong strategies in water management, poor involvement of users in the formulation of management strategies and the almost complete lack of dialogue between high and low level stakeholders, have given rise to strong social conflicts and high diffidence towards the governance with a consequent lack of cohesion.

The poor system capacity integration is causing conflicts for the reorganisation of the water regulatory framework (tariff systems, infrastructures innovation) with the consequent severe delay. The inadequate tariff system, together with the lack of "water culture" at the societal level, has so far encouraged the inefficient use of water at the household level. The poor maintenance and development of infrastructures has lately increased consumer diffidence in the provided water service and strained the relationship between water companies and users.

Environmental protection

Land use is largely influenced by grazing: natural pastures have been extended to satisfy large sheep grazing requirements and a large proportion of cultivated land is dedicated to pasture. Many areas have been reforested and in the northern parts of the basin, natural vegetation cover is still present with a mixture of bare soil, grassland, shrubs, and forests.

The Flumendosa and Mulargia reservoirs are fed by the Flumendosa river and Mulargia stream respectively, which are characterised by rapid changes in water flow due to the particular characteristics of the local climate.

Water stress analysis and mitigation

Water stress analysis

The focal problems and the objectives for the region were identified through a participatory process. The stakeholder groups involved in the project are depicted in figure 8.

The primary objectives for water stress mitigation in the Flumendosa basin are:

- Increase water use efficiency & productivity in agriculture;
- Improve agricultural practices in order to decrease the discharge of pollutants;
- Optimize dam operation as to Minimum Vital Flow to the river;
- Apply economic instruments for managing water use;
- Improve public knowledge on sustainable water management.

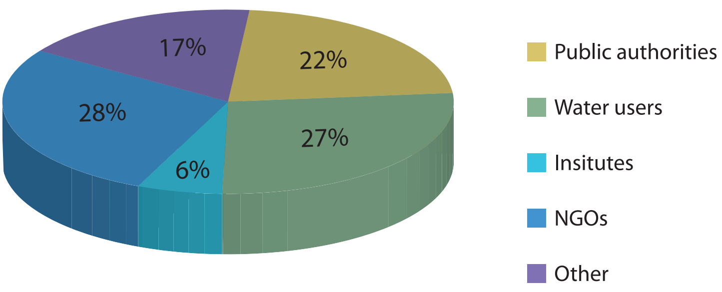

Figure 8: Stakeholder groups

Water stress mitigation

Different options proposed by the partners for the Flumendosa test area were examined and discussed with stakeholders, in order to determine those applicable in the area.
Stakeholders were involved in the development and refinement of mitigation options throughout the case study implementation, in the form of personal discussions with individual team members and participation in JWT meetings.
Starting from about 13 options, only 6 were selected, all falling into the category of technical options: Reduction of fertilizer use, Introduction of rapeseed and sunflower cultivation, Removal of undergrowth, Adapting crop locations to soil profiles for better use of rainfall, Irrigation scheduling on the base of historical data of rainfall and evapo transpiration (water saving), and Enhanced reservoir operation for maintaining VMF (Vital Minimum Flow).
The first two options are addressed to water managers and farmers and aim at the improvement of agricultural practices, whereas the next three are related to the irrigation practices at the farm level. The sixth option was examined in an effort to integrate environmental protection in water resources management.

Outcomes

The AquaStress project has provided a valuable opportunity to analyze particular problems related to water stress in the test area.
The analysis of the selected options gave some indication on how to overcome these problems, in terms of water quantity, water quality, environmental protection and overall for effective water management. An indicative example is the release of Minimum Vital Flow because the natural flow directly downstream of the dams was reduced by nearly 90%.
Since water stress in Flumendosa basin is characterised by different components (water scarcity, water management, water quality, water tariff) the most important recommendation for water stress mitigation is to face the problems in an integrated manner, starting from the institutional framework which must guide the challenge.

Added value to EU water stress diagnosis & mitigation

Water management at the agricultural sector based on a test-site / stakeholder driven approach is in accordance with the main goals of the European Water Framework Directive that introduces the societal and stakeholder dimension in the water management co-decision process.
The problems faced in the Flumendosa test site are common to other Mediterranean Countries, both in Southern Europe and in North Africa, and project results are applicable to the other similar regions.
The research activities of the Flumendosa case study were strongly connected to the involvement of public and technicians at different level. During the development of the project, several activities were dedicated to training and dissemination

actions: summer schools for pupils, different training courses for technicians, and dissemination activities such as participation at local trade fairs and brochure printing and dissemination.

These actions, aiming to publicize the research activities, achieved the wide dissemination of the AquaStress project at the local level, and the appreciation of the public and of the involved stakeholders. Moreover, the stakeholders had the opportunity to demonstrate their commitment in fields such as environmental protection and safeguarding water resources, which improved acceptance of users.

Lessons learnt

- **Successes:**

> Integrated approach to options evaluation. Results were evaluated considering the effects on water balance and quality, crop yields and economic benefits.

> Participatory approach: Valuable contributions through the involvement of stakeholders in the assessment of water stress issues; decision making process; data collection and elaboration formulation of realistic options, evaluation of results.

> The organization of dissemination, training and capacity building activities allowed not only the transfer of knowledge and know-how, but also the increase of awareness of water related problems to a large number of users.

- **Pitfalls:**

> Difficulties were experienced in the involvement of farmers: it is important to choose the appropriate period to interview them; to look for meeting opportunities external to the project; to use easier language in questionnaires/interviews.

> Realistically, the participation of local users in the testing and evaluation of the mitigation options would have required more time, since the majority of time was dedicated to their training rather than their involvement.

Further reading

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Bauer M., Botti P., Zaccolo S., Olsson O., (2009), Enhanced Reservoir Operation as an instrument for supporting water stress mitigation: A case study on the Low Flumendosa basin, Sardinia, Italy, Book Chapter in Koundouri P. (ed.): "Water Stress Mitigation Instruments for Implementation of EU Water Policies: Economic, Engineering and Participatory Tools", Routledge (for thcoming Spring 2009).

Use and allocation of water resources among the agricultural, urban, and environmental sectors to maximize environmental, economic and social welfare in the Moura-Serpa-Mértola region

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The Guadiana River Basin is the fourth largest of the Iberian Peninsula, with an area of 66800 km^2, 83% of which is located in the Spanish territory and the remaining 17% in the Portuguese territory (INAG 2001). The hydrological regime is typical of the Mediterranean region, with high intra and inter-annual discharge variations, potential floods in the winter and frequent droughts during the summer. The Portuguese area of the Guadiana River Basin belongs to two administrative regions: Alentejo and Algarve, as illustrated in Figure 9, each one with different characteristics. The Alentejo region is considered one of the poorest regions in the EU and is characterized by an aging population and by a negative dynamic at the demographic, economic and social levels. In the downstream area of the basin, despite the significant development over the last decades especially due to tourism, the Algarve region presents a lower demographic dynamic comparatively to the area of the Algarve region located outside the Guadiana river basin. In terms of economic sectors, tourism and

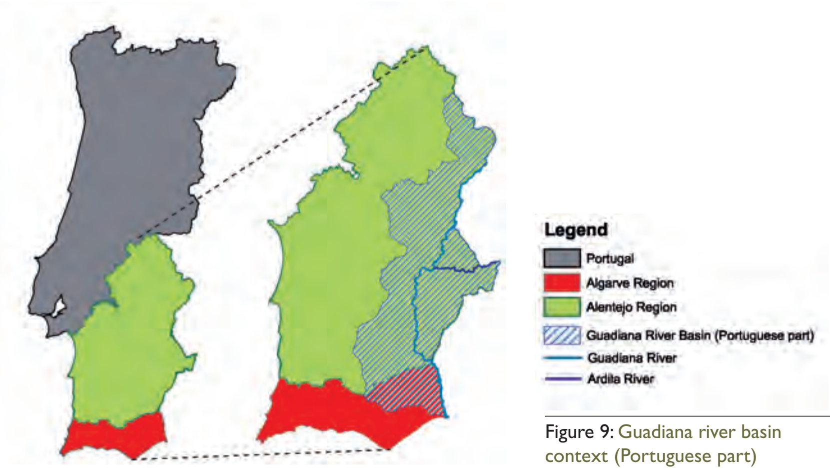

Figure 9: Guadiana river basin context (Portuguese part)

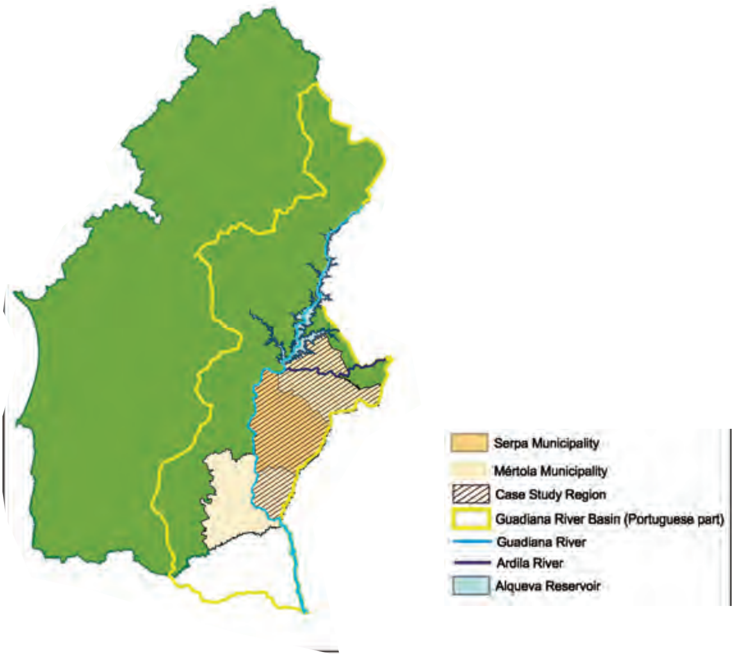

Figure 10: Illustration of the Portuguese Guadiana Case Study Region (CSR)

agriculture together with stock raising activities prevail in the basin.

The climatic conditions of the region, which is vulnerable to drought, combined with the effects of intensive agriculture practices carried out in almost the entire Portuguese Guadiana River Basin, lead to serious water problems in terms of both quality and quantity.

The full implementation of the Alqueva multipurpose project is expected to lead to major water management changes in the Guadiana basin, particularly in the sectors of agriculture and tourism, thus contributing to the social and economic development of the Alentejo region. The construction of the network system supplied by the Alqueva reservoir will allow the development of new (110.000 ha) irrigated projects, such as the Ardila irrigation subsystem (30.000ha), introducing a change from traditional rain-fed extensive agriculture practices towards irrigated and more intensive water use regime. Moreover, water from that system will also be used for supplying the domestic and industrial sectors. Although this project will have a positive social impact on the region, it may also result to an uneven development of the basin, by enhancing the expansion of important agricultural exploitations and tourism activities at the expense of small farms and more traditional rural activities.

The Portuguese Guadiana Case Study Region (CSR) is located on the left margin of the Guadiana River Basin, in the Alentejo region, shared by the municipalities of

Moura, Serpa and Mértola. Serpa is the only municipality that is entirely located on the CSR. Moura and Mértola municipality limits overlap with the CSR limits, as illustrated in Figure 10. The CSR is a mainland bordering region with the lowest population density (17 inhab/km^2), the lowest GDP and the biggest index of social desertification of the country. The main economic sector in the region is agriculture that is characterized by inefficient water use due to inadequate irrigation and rain fed agriculture practices. Thus, a major paradigm shift in agriculture is necessary, and that shall encompasses changes in crop patterns, agriculture practices, water sources allocation, water demand and a new water pricing policy.

In this context, the Ardila irrigation sub-system will supply water to about 30.000 ha located in the North and East of the Serpa Municipality. The area overlaps with the two main aquifers of the region (Moura-Ficalho and Gabros de Beja), which already suffer from water quality issues (see Figure 11).

The main purpose of the Portuguese Guadiana Case Study is to contribute to the sustainable development of a southern European region that is representative of EU investments for irrigated agriculture, by improving water resources use through proper water allocation and management among the agricultural, urban, and industrial sectors in order to maximize the environmental, economic and social welfare in the Moura-Serpa-Mértola region.

Water stress conditions

The CSR's main water stress problems are related to water shortages that occur at the local level, since the available water resources in the region are insufficient even in normal years. Water shortage becomes even more severe during dry periods, especially during the irrigation period, thus emphasizing the need for inter-annual water reserves. Additionally, the development of the Alqueva multipurpose project within the CSR, by means of the development of the Ardila irrigation subsystem, may intensify agricultural impacts on water resources that will have to be carefully assessed. Even though the use of drip irrigation is increasing in the region, the expansion of the agricultural area has led to overexploitation of the existing natural resources, mainly through groundwater abstraction from natural aquifers, contributing to water stress conditions in the region. According to INAG, the Serpa and Mértola regions are most critical and include some areas facing severe drought risk, whereas Moura municipality is apparently more sensitive to run-off drought than to (rain-fed) agricultural drought.

Available water resources

The hydrography of the CSR includes three main perennial rivers and their complex tributary network. All these rivers – the Guadiana and two tributaries of it, the Ardila and the Chança rivers –, are shared with Spain.

Regarding groundwater resources, two main high productive aquifers are located in the CSR (Figure 11): (i) the Moura-Ficalho aquifer in the Moura municipality that is mostly

used for public water supply (60% of the current water abstractions), and (ii) the Gabros de Beja in Serpa municipality, which is used for public water supply and irrigation. In the remaining area of the basin, and more specifically in the Mértola municipality, mostly low productivity aquifers can be found that are used for agricultural purposes and also for supplying water to small and/or isolated settlements in the region.
The main surface water sources for public water supply in the CSR are the Ardila River, for the Moura municipality, and the Enxoé reservoir, for both the Serpa and Mértola municipalities. The CRS will be soon additionally supplied with water by the storage reservoirs of the Ardila project (currently in construction phase). Finally, some small private reservoirs that exist in the region are also used as surface water resources mainly for agriculture.

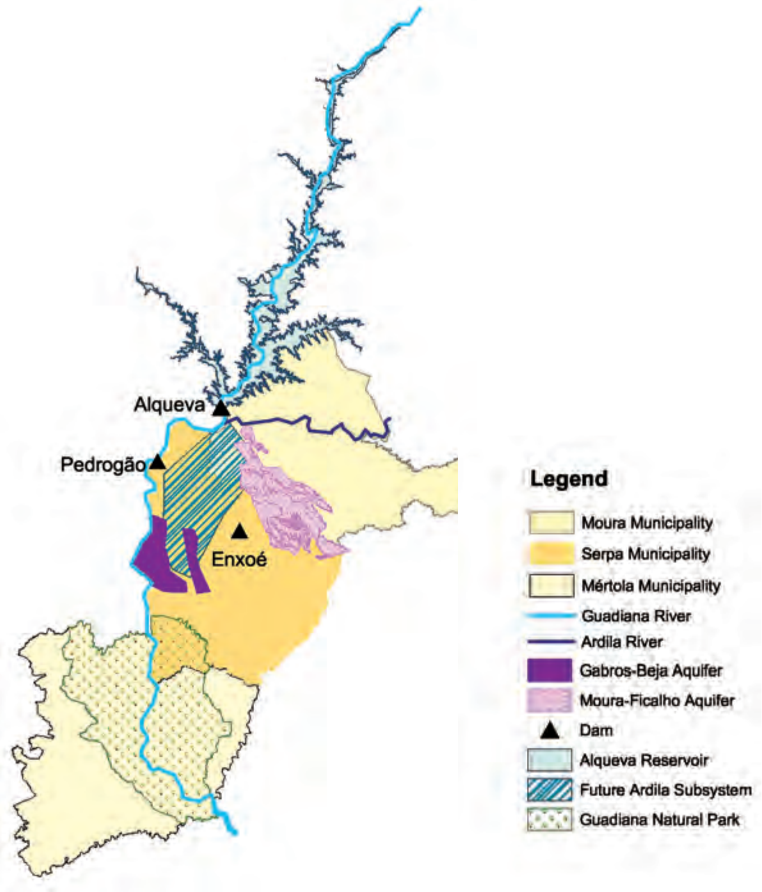

Figure II: Main water supply sources and special areas in the CSR

Water use in the domestic, industrial (tourism & production) and agricultural sector

The volume of water used in the CSR for urban supply, industry and tourism purposes currently adds up to 16 hm^3 year. Agriculture is, by far, the main water use sector, with an approximate consumption of 13.5 hm^3/year, representing more than 80 % of the total water demand. The urban sector represents only 1.83 hm^3/year and industry around 0.24 hm^3/year (Table 8). This last sector has a very small influence in terms of total water demand and allocation.

Table 8. Water demand of main economic activity sectors in the CSR municipality regions

Water Supply (hm^3/year)	Domestic	Industry	Agriculture
Moura	0.38	0.12	3.10
Serpa	1.24	0.03	8.55
Mértola	0.21	0.09	1.77

Quality and quantity issues

Some areas of the Serpa and Mértola municipalities very often face water shortage problems, either for irrigation, domestic or livestock water supply. Up to the beginning of this decade, this water quantity problem was mostly related to the frequent lack of water supply sources availability, thus emphasizing the need of inter-annual reserves. Currently, water pollution also became an important issue. In the case of surface water, pollutants originate mainly from point-pollution sources such as untreated wastewater discharges from the domestic sector as well as the sparse industrial sector, and diffuse sources, coming mostly from agricultural areas surface runoff. Groundwater quality problems are more closely related to diffuse pollution and particularly to the use of fertilizers and other agro-chemicals. In fact, irrigation causes the leaching and runoff of nitrates, sulphates and other pollutants into the water resources, and irrigated agriculture has been developing very fast in the CSR.

The pollutant loads combined with the high summer temperatures frequently stimulate algal blooms, leading to the eutrophication of the surface water reservoirs, a situation already affecting the Enxoé dam reservoir.

Institutional capacity

In Portugal, the transposition of the Water Framework Directive (EU 2000) into National Law, by means of the Law 58/2005, provided the opportunity to frame a new water law, as the former dated back to 1919 and was completely outdated. According to Law 58/2005, eight River Basin Districts (RH, Regiões Hidrográficas) were set and aggregated in five River Basin District Administrations (ARH, Administrações de Regiões Hidrográficas: Norte, Centro, Tejo, Alentejo and Algarve), which are the main water resources planning and management units. The ARH's have a stronger regional role through decentralized services, in order to ensure water resources management at the

River Basin level. The existing INAG (National Water Institute) has broader jurisdiction, as the national water authority, and coordinates the ARH's at the national level. This new water management framework is promising, creating great expectations with regard to ARH's performance and adequacy.
The water resources entitlement regime was also reframed in 2007 and addressed issues like water rights, licensing, rules of delimitation of public water domain as well as the role of authorities involved in water management.
Meanwhile, Portugal and Spain also enhanced their transboundary collaboration with the celebration of the Albufeira Convention, in 1998, which, among other water related issues, establishes the Commission for Convention Development and Appliance (CADC), intended to facilitate transboundary river basins management and also to monitor the bilateral application of the WFD in the Iberian Peninsula.

Infrastructure
The majority of existing hydraulic infrastructures for agricultural water supply are private projects of single or small groups of farmers and have been identified as: schemes based exclusively on direct groundwater abstractions; schemes based on groundwater abstractions but supported by small storage capacity means (mostly man-made earth pools, referred locally as puddles); schemes based on small dam storage reservoirs; and, some cases of direct water abstraction from the Guadiana River.
Irrigated agriculture will be supported by the implementation of a public irrigation project, the Ardila sub-system, whose water distribution network is currently on its final stage of construction.
Urban water supply is mostly provided from the existing aquifers. Moura is supplied with water from the boreholes of Fonte da Telha and Gargalão (in the Moura-Ficalho aquifers) and the Ardila river abstraction pumping station. In the Serpa and Mértola (left margin of the Guadiana) Municipalities, a primary water supply system, which abstracts water from the Enxoé storage reservoir, mostly supports public secondary water supply systems. The population not served by the main water supply system (e.g. in Mértola) is being supplied by small and independent systems based on local low productivity groundwater sources. As a result, in peak demand periods – July to September –, there is a high risk of failure in meeting the domestic water demand.

Social and economic equity
Although agriculture remains the predominant economic activity in the region, the new paradigm regarding collective irrigated agriculture could set a ground-base for the development of new enterprises/industries, currently almost absent in the region. Until now, the lack of multi-sectorial development has led to the migration and consequent aging of the population, representing a trend present in most of the Alentejo region, where both the Guadiana River Basin and the CSR are located. Investors coming from other regions or countries, mostly Spain, have shown a strong interest for the region, since irrigated agriculture is now starting to prevail in the CSR. This context is well illustrated with the example of the increasing trend of irrigated olive production in the

CSR. The olive sector is considered strategic in the national Portuguese Rural Development Program (GPP, 2007). The PRDP sets the strategic context for national rural development policies that defines the Communitarian Strategic Orientations. The main objectives are the modernization and improvement of the organization of the sector in order to reach a higher level of sustainability for both internal and external markets.

Environmental protection
The Guadiana River Basin Plan indicates that about 1/4 of identified flora species is of interest for conservation. The majority of these species is located in the Guadiana Valley Natural Park (which occupies part of Mértola and Serpa municipalities) and in some stretches of Guadiana's tributaries. This park was created as a compensation for the construction of the Alqueva multipurpose plant, which is also compelled to observe a minimum environmental flow regime for the protection of the downstream estuarine zone. It exhibits great interest from the environmental and ecological point of view, possessing a great diversity of habitats, fauna and flora species.

Water stress analysis and mitigation

Water stress analysis
The selection of the specific Case Study Region (CSR) and of the study goals resulted from a participatory process that began early in the first year of the Project. Several national, regional and local institutions were involved in the process that aimed at identifying and analyzing the different water related problems existing in the region and further more at understanding stakeholder perceptions on water stress situations.

This process led to the signature of a Protocol of cooperation in October 2005, in order to make official the involvement of the invited stakeholders, who accepted to collaborate with the Project and monitor the different activities. These stakeholders were: (i) regional and local stakeholders: the Commissions for Coordination and Regional Development of the two regions involved (Alentejo and Algarve)(based on which the current ARHs were created), two inter-municipal primary water supply companies ("Águas do Centro Alentejano" and "Águas do Algarve"), EDIA (Company for the development and infrastructures of the Alqueva system), COTR (Operative and Irrigation Technologies Centre), and FAABA (Federation of the Farmers Association of the Low Alentejo); (ii) national stakeholders: CAIA (Commission for the monitoring of environmental impacts of the Alqueva system, also informally representing the INAG, National Water Institute), IDRHa (Agriculture and Rural Development Institute) and two NGOs, LPN (Liga de Protecção da Natureza) and Euronatura. Following the protocol declaration, several meetings (individual or with small thematic groups) were held, in order to analyze the specific Guadiana basin water resources problems and to propose potential water stress mitigation options, aiming to frame some potential Case Studies for implementation.

Based on the outcomes of these meetings, the Project Partners framed a list of potential Case Studies that were subsequently discussed with the Stakeholders, firstly individually and finally in a Joint meeting. By then (May 2006), this participatory process resulted in the definition of a specific Case Study Region (the left margin of the Portuguese Guadiana Basin, comprising Serpa and parts of the Moura and Mértola municipalities, see Figure 10), and the commonly accepted goal was defined as: "how to better use and share water resources among the different sectors in order to maximize environmental, economic and social benefits". After some refinement of the case study selected and a more accurate definition of each AquaStress partner's contribution (joining the Guadiana CS Joint Work Team, JWT), the final Case Study goals of the CSR were approved in a joint meeting with the Stakeholders (December 2006), and the case study implementation phase was initiated.

Water stress mitigation

The main objective for the Guadiana Case Study, defined after the stakeholder consultation process, was to: "Contribute to the sustainable development of a southern European region with a relevant EU investment in irrigated agriculture, by improving water use and allocation of water resources in the agricultural and urban sectors". In accordance to that statement, two main mitigation activities were framed:

- Rationalization and optimization of water resources use (Availability Enhancement), aiming at optimal and (possible) integrated management of surface and groundwater resources, taking into account existing and foreseen socio-economic development scenarios for the CSR.
- Definition of best irrigation management practices (Demand Side Rationalization), aiming at the definition and assessment of the most water efficient (and profitable) crops and irrigation practices that can be applied to a region with limited irrigation tradition, thus contributing to an adequate (i) socio-economic development of its population during the transition from (or regional co-existence of) rain-fed agriculture to irrigated agriculture, as well as to (ii) environmental protection.

For these two activities, corresponding mitigation options were developed, evaluated and discussed with the stakeholders through sessions, modeling workshops and meetings, in order to develop water resources management strategies with a broad support for mitigating water stress in the CSR. The options are described in Table 9, also indicating the responsible partner.

The options evaluation process took place in the form of several workshops, meetings and working sessions, in which participated the JWT, the Public Stakeholder Forum, invited experts and the end-user farmers. In these sessions, the case study water stress mitigation options were presented, formatted and evaluated by the key-actors involved in each particular option or group of options. Sessions were held in various phases of the project, namely during: case study formulation and implementation (3 workshops); institutions involvement (3 workshops); field work implementation (2 workshops); and option selection and validation (4 workshops).

Table 9. Mitigation options description

Mitigation Options	Description	Responsible partners
Surface water control (quality & quantity)	A modeling framework was defined to assess sustainability of land uses in water limited environments, and to allow the calculation of the maximum amount of a pollutant that a water body can receive (TMDL) and still meet water quality standards in reference to different uses of water resources, and an allocation of that amount among the pollutant sources.	Hidromod (PT)
Reservoir management	Several alternatives regarding the operation and management of the Enxoé dam and reservoir were analyzed with the objective of determining the best way to use the water in the reservoir in the context of the new hydraulic network (Ardila Sub-system)	UHan (Ger)
Groundwater control (quality & quantity)	A methodology based on the use of simulation models (GLEAMS) was applied to the CSR to evaluate the variations of nutrient (nitrates) concentrations taking into account the legal limits with reference to the most common agricultural practices that threaten water quality.	IRSA (Ita)
Water pricing (focused on agriculture)	Within the review of water pricing policies, an economic study was performed to determine the willingness to pay for water and the most relevant criterion in the definition of a feasible water pricing. Moreover, water price elasticity was also estimated.	UCL (UK)

Mitigation Options	Description	Responsible partners
Wastewater reuse	The possibility of implementing a water reuse framework in the CSR was analyzed and taken as a possible way to reduce small scale water shortages due to its highly reliable, easy and low-cost operation and maintenance.	UB (SP)
WSM-DSS: Integration of options	The implementation of the WSM-DSS enabled the integration of different water management options developed for the Guadiana Case Study and the simulation of different scenarios, options and strategies defined through a stakeholder driven process, contributing to the mitigation of water stress.	FEUP (PT)
Irrigation water management	The "Best Olive Irrigation Practices" option supported the analysis of farmer practices with the objectives of optimizing their production systems and reducing water losses. This activity was based on the collaboration of a group of irrigated olive farmers in order to identify which set of irrigation practices resulted in better production yields and to disseminate these findings to the less productive framers.	FEUP (PT)-Cemagref (FR)
Tailoring cropping patterns	This option aims at evaluating current agricultural water use through Serpa-Mértola case study and future water scenarios, namely with the Ardila irrigation perimeter. Three scenarios were designed, representing crop distribution options, depending on olive and cereal markets evolution, under the hypothesis of an area of 40 000 ha available for irrigation.	Cemagref (FR)

Outcomes

Regarding surface water resources, the mitigation options "surface water control" and "reservoir management" were developed under close collaboration of the responsible partners and succeeded in identifying the sources of pollution and modelling the pollutants inflow to the Enxoé reservoir. The results allowed technicians to set maximum load thresholds for several substances (nitrates, phosphorus, etc) according to the water level in the reservoir, so that the reservoir can be operated according to these levels, maintaining the water quality at more acceptable values. Similarly, one of the alternatives for the operation and management of the Enxoé dam (emptying the reservoir, suggested by the end-users) may contribute to the solution of the water quality problem due to the large amount of organic matter in the reservoir. This alternative could be analyzed, accepted and taken by the stakeholders as a feasible option to implement.

One of the most important groundwater issues, nitrate leaching, was analyzed by modeling and comparing the behaviour of different cropping patterns, taking into account the most representing soils in the CSR. The analysis allowed the evaluation of the environmental impacts of the growing trend of olive cultivation in the region. Using this methodology, the task of land use mapping by the stakeholders will be facilitated.

The possibility of wastewater (re)use was also discussed with the stakeholders, in order to reduce groundwater abstraction. This option was considered a possible solution for small scale implementation, thus reducing water demand at plot-level.

With the newly built infrastructures in the CSR, water supply will expectedly rise to meet an increasing water demand due to the expansion of irrigated agriculture. However, as in most public irrigation projects, the use of those infrastructures and of the water will come at a certain price that is not yet officially set. To aid decision makers and stakeholders with this situation, an economic study was developed to determine the willingness to pay for water and the most relevant criterion in the definition of a feasible agriculture water pricing scheme. Moreover, water price elasticity was also determined. This result is of utmost importance for rural development in the CSR as it will allow both decision makers and farmers to better predict the effects of water price variations on its rational use.

As mentioned before, irrigated agriculture will be the driving force to increase water demand. Since olive crop is the most representative crop growth in the CSR, the "Best Olive Irrigation Practices" were defined. The BOIP determined some important aspects of olive cropping that can be put into practice not only by the end-users – mainly farmers –, but also by local research and rural extension centers in order to support less productive farmers in adapting their production options to water scarcity situations, thus increasing water and production factors productivity. In this scope, a participatory approach was followed, for the determination of the key aspects of olive production with the

farmers that allowed the identification of the practices for benchmarking.
Although olive farming is very important for the CSR development, there are several other crops that can be cultivated in the region. The identification of the CSR "Best Cropping Patterns" was developed in an effort to characterize the different cropping patterns and allow end users to define their cropping strategies based not only on their water demands but also on the information regarding actual field crop use, practices and farmer perspectives toward the upcoming changing process.
The integrated analysis of the aforementioned options was conducted using the WSM-DSS (WaterStrategyMan Decision Support System Tool). The tool supports the analysis of the most important aspects of the mitigation options in a prospective way, hence permitting the simulation of a multitude of water demand/supply scenarios that involve: land-use; surface and ground water sources; existing water distribution and reservoir infrastructures. The WSM-DSS enables decision-makers to formulate and evaluate short and mid-term policies, including economic instruments, to address water scarcity related issues, and also enables researchers to study the technical, economic and environmental implications of water management options.
The chosen method of option integration adds an important value to the case study, as it may operate with different solutions that have been evaluated and discussed with the stakeholders in the context of an emerging new reality on water resources availability.

Added value to EU water stress diagnosis & mitigation

The changing paradigm of agricultural practices existing in the case study region represents an interesting example of one of the high strategic values at the European scale. The development of the case study brought out some potential positive and negative aspects of the new investments taking place in the region, and their direct and indirect effects on the social-economic setting. An important effort was made regarding the integration of the different uses and water resources, intending to set a basis for the achievement of improved water resources management within and among water consuming sectors. The importance of updated and integrated knowledge was also pointed out as a relevant aspect in the achievement of the goals set in the Water Framework Directive.

Lessons Learnt

- There is a general negativity regarding research projects by the local stakeholders, mostly due to the large number of projects that in the near past have taken place in the region without any real feedback or positive impacts to local stakeholders.
- Research projects often have long-term perspective goals whereas most stakeholders and institutions need technical and financial support that can produce some immediate and short term effects. This contrast in perspectives usually works against easy communication and synergy creation among researchers and stakeholders.

Further reading

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Integrated groundwater management

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Akrotiri is the third largest aquifer in Cyprus. It is a coastal deltaic alluvial aquifer located a few kilometers west of the city of Limassol. The aquifer is replenished by the Garyllis river, which flows in the east and the Kouris river in the west. The Kouris River, in the west of the Akrotiri plane, is the largest river of Cyprus and drains a catchment area of 300 km^2, extending far up into the Troodos Mountains. The catchment of the Garyllis River is much smaller (65 km^2) (Hydrological Year Book – 1984 in Water Development Department Report, 2002). The hydrological and climatic conditions of the topographic catchment of the Kouris River, extending up into the Troodos massif, reaching altitudes of 1600 m asl within a distance of 30 km, are very different from the situation on the Akrotiri peninsula. The average precipitation within its catchment (surface area 290 km^2) was 730 mm for the period 1951-1980.

However, after the construction of Polemidia dam in 1965 on the Garyllis river and the construction of the Kouris dam in 1987 on the Kouris river, the natural groundwater recharge regime has changed dramatically. The discharge rate is regulated by rare reservoir spills and controlled releases from the dams. Moreover, as a result of the past dry years (the low rainfall events in the last decade), water influxes to the artificial lakes have decreased.. Due to the semi-arid climate in the region, the ETP is, on average, more than double the precipitation (average 500 mm/year), which is typical of Mediterranean areas. As a consequence, the natural recharge of the aquifer has been interrupted, since surface water was used in order to address the water deficit in the island. Artificial recharge has been achieved through controlled water releases from the Kouris and Yermasoyia dams, by using constructed recharge ponds. Occasionally limited quantities of water pumped from the Garyllis aquifer are also used for this purpose.

The dramatic reduction in recharge resulted to a serious deficit in the water balance of the aquifer. In the last years, the general water table level into the plain stabilized below sea level and the inland progression of the fresh water/sea water interface has greatly increased.

The Akrotiri region is a part of the irrigation area of the Southern Conveyor Project. During the last years, tertiary treated water, derived from the Lemesos (Limassol) Sewage System, was transferred to the inland plain to be used for direct irrigation. This water has also been used in projects of artificial recharge of the Akrotiri aquifer.

Water stress conditions

The available renewable freshwater resources are highly limited, and water related problems include both water quantity and water quality issues. Despite the huge investments in water infrastructure, the conflict among users for the allocation of water resources, particularly the competition among agriculture, domestic use including tourism, and the environment, is challenging the existing water management practices in the island. Specifically in the Test Site region (see Figure 12), the conflict is more intense, since:

- The region is one of the main tourist destinations in Cyprus,
- The agricultural production in the area accounts for more than 50% of the fruit trees, 50% of the vegetable and 60% of the table grapes production of the country, and
- The water system of the region is very complicated.

Available water resources

According to data from the Water Development Department, the available fresh water resources for the year 2005 are 93*106 m^3/yr from surface water bodies and

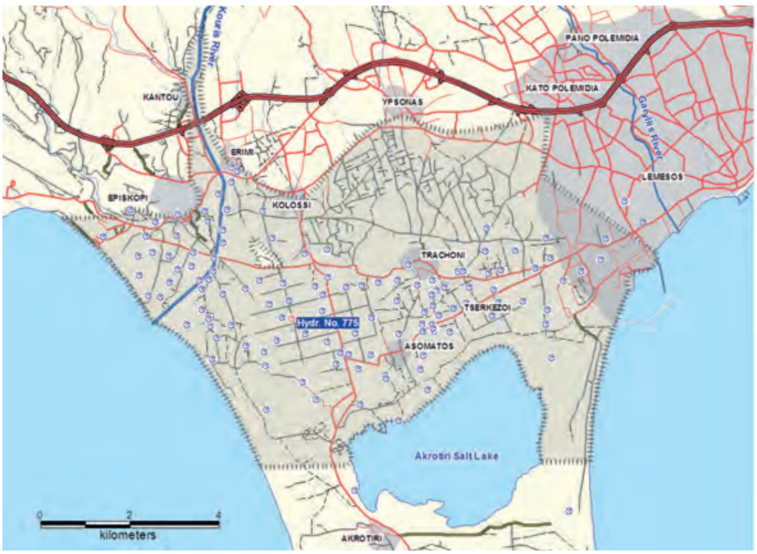

Figure 12: The Test Site region

12.7*106 m^3/yr from groundwater sources. Non conventional water resources are also being used, particularly 6.8*106 m^3/yr of re-used water. Annual water withdrawals account for 120*106 m^3, of which 100*106 m^3/yr originate from groundwater resources. Furthermore, 23% of the available water resources are diverted to neighboring regions.

Water use in the domestic, industrial (tourism & production) and agricultural sector

The domestic consumption of the region accounts for almost 12.8 hm^3, while the domestic water consumption for the tourism (seasonal population) accounts for 3.6 hm^3, which is almost 26% of the island's total seasonal consumption. The domestic sector is supplied from surface waters that are treated in the Limassol-Amathus Water Treatment Plant (almost 7.8 hm^3), and from groundwater - boreholes and springs (almost 8.2 hm^3). Irrigation water demand in the region accounts for almost 31 hm^3 of which 24 hm^3 are supplied from the major government irrigation schemes. In addition, the annual water demand for animal husbandry in the region accounts for 820,000 m^3 and the industrial demand for 1.5 hm^3 or 43% of the total industrial demand of the island. Environmental demand in the region accounts for 5 hm^3 (3 hm^3 groundwater, 1.5 hm^3 municipal domestic and 0.5 hm^3 treated effluent).

Quality and quantity issues

The high rate of water withdrawals results to water quality problems of two types in the Lemesos region: salinization and pollution by a range of anthropogenic causes.

Salinization of coastal aquifers is the most common water quality problem. The Akrotiri aquifer in the Limassol region is one of several coastal aquifers affected by overpumping with a high concentration of chloride in the groundwater as a result (NTUA, 2006).

The main sources of pollution in Cyprus are: untreated wastewater discharges from the urban and industrial sectors, solid waste landfills, agricultural runoff and livestock waste (MANRE, 2005).

The significant drivers and pressures that have an impact on water quantity are:

- Droughts and climate change impacts;
- Uneven distribution of rainfall;
- Conflicts between urban and agricultural use;
- Increased water demand for irrigation and tourism during summer;
- Inter-basin water transfers;
- Illegal drilling and over-pumping;
- Ineffective exploitation of many water development schemes;
- Excessive use of fresh water for irrigation due to reluctance towards the use of tertiary treated water.

Institutional capacity

The overall management of water resources (surface water, groundwater and wastewater) is undertaken by the government, which has the jurisdiction to construct waterworks and undertake their management. However, as legislation on water has evolved on an ad hoc basis, an umbrella law or regulation doesn't exist. The institutional framework is rather complex and includes numerous statutory water laws that sometimes overlap, with divided authority and recognition of private rights.
The co-operation among different agencies and services for the management of water resources is sufficient when taking into account the different approaches and goals set by each one. However, the fragmentation of responsibilities has caused many problems in all sectors. Regarding infrastructure, the situation is good, since only one department is in charge of water management at the executive level (WDD),. However, effective decision-making, implementation of works and legislation enforcement remain difficult, as legal and managerial responsibilities are allocated to the District Officers. These difficulties lead to considerable delays in project authorization, implementation and overall water management.
The District Officer is the controlling authority at the user level. The WDD and the Department of Agriculture act as advisory bodies of the District Officer on technical matters. However, this arrangement cannot be considered satisfactory, because many authorities are responsible.
It is broadly recognized that this fragmentation, especially at the user level, where the WDD acts only as advisor, has many disadvantages. This situation is expected to change with the creation of the "Directorate for Integrated Water Management", which will be the only national authority with the responsibility to undertake the management of the water resources of Cyprus.

Infrastructure

Water infrastructure in the region includes reservoirs, treatment plants and boreholes:

- Surface water stored in the three dams of the region, namely the Kouris Dam (of a total capacity of 115 hm^3), the Polemidhia Dam (of a total capacity of 3.4 hm^3) and Germasogeia Dam (of a total capacity of 13.5 hm^3), which is used for domestic and irrigation purposes.
- Certain quantity of the stored surface water resources is treated and used for domestic purposes in the Lemesos Water Treatment Plant which has a capacity of 40,000 m^3/day and potential capacity of 80,000 m^3/day. The plant receives raw water from the Kouris Dam and supplies water to the Lemesos city, some villages west of Lemesos and to the British Bases of Akrotiri.
- Ground water extraction (from Germasogia, Kouris, and Akrotiri aquifers) from a number of boreholes is used for domestic and irrigation purposes.
- Treated effluent from the Lemesos Sewage Board Treatment Plant is used for agricultural and landscape irrigation.

The irrigated areas in the region fall in two categories: Areas within the Major

Government Irrigation Schemes of the region (Akrotiri West and Germasogheia-Polemidhia) and areas outside the Government Irrigation Schemes.
Water from the Kouris Dam (the biggest dam in Cyprus) is transferred to the eastern part of Cyprus (Kokkinochoria region) through the pipeline of the Southern Conveyor Project.

Social and economic equity
The two major water use sectors are agriculture (about 70%) and the domestic sector including the tourist industry (almost 25%). The conflict between them is more intense during summers, when rainfall is low and both sector water demands peak. This is further aggravated by the unequal contribution of agriculture (only 2.9%) and tourism (about 20%) to the GDP, and the fact that the domestic sector pays full cost recovery prices for its water, while irrigation water is heavily subsidized. Many water development schemes are not currently working efficiently due to problems related to the lack of labor in the agricultural sector, the cultivation of water demanding crops based on economic criteria only, and the maximization of area used for irrigated agriculture in order to achieve a sufficiently high rate of financial return.
In case of drought, conflicts also exist between farmers from different basins, as the existing water management framework is a highly flexible system that allows significant inter-basin water transfers. Local farmers demand full coverage of their demand before any transfer is made. Even though in the past farmers have accepted to use tertiary treated effluent during drought periods, in the last few years this effort has subsided, because of the availability of fresh water from the dams and the general distrust in the quality of the treated water.

Environmental protection
Threats to the ecosystems of the Case Study area relate to:
- Areas designated for the abstraction of water intended for human consumption. The main problems of sea intrusion and aquifers depletion in the area are attributed to low recharge and excessive abstraction;
- Nutrient sensitive areas, including areas designated as vulnerable zones under Directive 91/676/EEC and areas designated as sensitive areas under Directive 91/271/EEC: The Polemidia dam north to the city of Limassol has been designated as an urban waste sensitive area under the Directive 91/271/EEC

Environmental concerns are increasing because of the intensity of water utilization compared to the scarcity of water resources in the recent years. These are further escalating due to the influx of tourism in choice areas and the general growth of economic activities. Water quality of both surface and groundwater, however, is generally good for domestic and irrigation uses. However, insecticide residues and high nitrate concentrations have recently been observed in dams and aquifers, especially in areas of intensive agriculture.

Water stress analysis and mitigation

Water stress analysis

The Limassol case study demonstrates how over-abstraction for irrigated agriculture can lead to severe depletion of a major aquifer with negative consequences for the groundwater quality (salinisation of groundwater through intrusion of sea-water), conservation of wetland functions (Akrotiri marshals), as well as adverse impacts to agriculture itself.

The main causes of the region's focal problem include:

- Unsustainable aquifer management, as a result of (i) the reduction of the natural replenishment of the aquifers due to the rare water releases by the upstream constructed dams (Kouris, Plomidhia and Germasogia dams), (ii) the low artificial recharge of the aquifer of Akrotiri with treated wastewater, due to the reluctance of the wide public of the Episkopi Local Authority to agree with this option, (iii) illegal over-abstraction from existing legal boreholes and abstraction from illegal boreholes, (iv) the limited availability of natural resources due to the aridity and drought periods experienced in the site, and (v) the limited availability of alternative sources of water supply, since the construction of the third desalination plant of the country in the Limassol area, is not acceptable to the local society due to its high cost ;
- Unsustainable irrigation management since most of the water extracted goes to agriculture.

  Responses to these problems should be seen from three perspectives (water balance, environment, economics and social issues), also taking into account the available water sources, the existing water usage and environmental quality.

  The region's water focal problem is affected by, and at the same time influences different components, forming a continuous loop between cause and effect. Sea intrusion and aquifer depletion are affected by natural conditions (aridity, drought), social issues (public opposition in the use of reclaimed water), economic policies (subsidies) and profit (agricultural production).

Therefore the primary objectives for water stress mitigation are to:

- Build social consensus on sustainable aquifer management, through the introduction of reclaimed water (from the existing WWTP of Limassol as well as the future WWTP of the Western Villages of the study region) into the Water System;
- Build social consensus on sustainable agricultural development, focusing on the reduction of groundwater overexploitation through the rationalization of irrigation practices;
- Apply economic instruments for managing water use; and
- Improve public knowledge on sustainable water management.

Water stress mitigation

Different options were proposed by the partner for the Limassol Test Site that were subsequently examined and discussed with stakeholders, in order to evaluate which ones were really applicable in the area. Following the Stakeholder consultation results, the mitigation options selected were as follows:

Mitigation Options	Objective	Water management level
Economic options		
Economic analysis and the acceptability of the aquifer recharge with reclaimed water	Improve water availability and supply options	Water Management
Technical options		
Sustainable Aquifer Recharge (groundwater flow and seawater intrusion remediation)	Improve water availability and supply options	Water Management
Sanitary Risk Assessment (reclaimed water reuse)	Define water quality standards for reclaimed water reuse	Water Management
Rationalise Irrigation Demand (irrigation practices and water use)	Improve irrigation efficiency	Water Management

Outcomes

The analysis of agricultural practices at the Limassol Test Site aims to promote and build social consensus for integrating water demand and supply management. Focus is placed on policy proposals for sustainable agricultural development and on the use of reclaimed water either directly for irrigation or for aquifer recharge. Policy proposals support decision making towards sustainable agriculture, placing emphasis on enhancing stakeholder involvement.

Sustainable agriculture practices are analyzed and evaluated in terms of water stress mitigation through the assessment of the introduction of new crops (suitable for winter cultivations) irrigated with reclaimed water, and the ranking of crops in terms of net economic output (water efficiency vs. economic yield).

The use of reclaimed water for irrigation is analyzed in an integrated framework, in terms of (a) economotechnical-environmental sustainability of reclaimed water use for irrigation and aquifer recharge, and (b) acceptability of reclaimed water use, by analyzing the inhibiting and/or supporting factors that formulate the wider public perceptions towards reclaimed water reuse in agriculture. Main outputs include the definition of best practices (water quality and quantity) for artificial recharge with reclaimed water at the Akrotiri aquifer (recharge rates versus sustainable yield), and the technical and economic analysis of waste water treatment processes for meeting water quality standards for irrigation with reclaimed water (treatment technology versus water cost)

Added value to EU water stress diagnosis & mitigation

The implementation of the Limassol Case Study and the associated interventions have a clear European dimension in the sense that they:

- Address issues regarding the improvement of the adaptive capacity to climate change;
- Improve the capacity for cross-sectorial integration in water resource management • and planning;
- Promote sustainable development through the adoption of an integrated approach to policy making in which economic, social and environmental objectives are achieved at the same time;
- Will be implemented through participatory and stakeholder driven approaches (to assess water demand and water saving), a prime requirement of the WFD, thus producing a fundamental culture change in mitigating water stress.

Lesson learnt

- Stakeholder participation process: effectiveness demands for thorough stakeholder analysis, good development of relationships and trust on site, opening of informal communication channels (rather than official meetings only), thorough decision analysis. Institutional stakeholders can be brought together by helping them to exchange information
- Difficulties in engaging a wide spectrum of stakeholders in the public participation process. The test site confirmed the political nature of water management. It also reiterated the need for time to develop sufficient trust among participants in order to find outcomes that meet the different interests of involved parties. It also highlighted the need to differentiate between societies' experience of public participation, and that some societies might have a different starting point. Therefore, if they were to reach similar endpoints, sufficient resources would need to be made **available according to each society's needs.**

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Improving the efficiency of water use in intensively irrigated areas

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The Merguellil catchment (Figure 13), situated in central Tunisia, has limited and fragile water resources, like the other four Mediterranean sites of the AquaStress project. It faces an increasing water demand (mainly for agriculture and drinking water), with agriculture representing the most important user (more than 80 % for Tunisia).

The main water stress problem in the Merguellil catchment is related to the overexploitation of groundwater. The Kairouan aquifer is an indicative example of overexploited aquifers in free access. It is one of the most significant aquifers of Tunisia, and has displayed a continuous drop of the water table during the past twenty years.

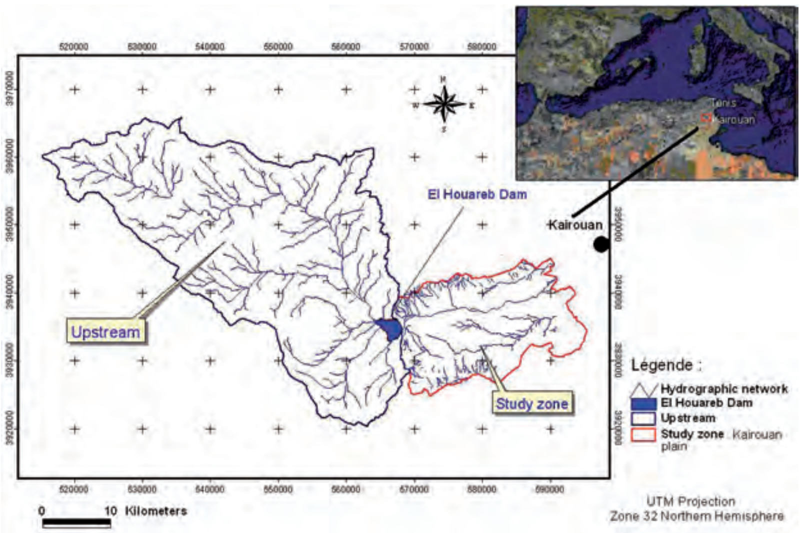

Figure 13: The Merguellil catchment

However, this situation does not prevent the farmers from pumping.
This unsustainable state requires new water management approaches and a change in stakeholder behaviour. Reaching a common agreement on water management is essential for preserving not only the sustainability of water resources but also social equity and regional development.

Water stress conditions

The water stress situation in the Merguellil catchment can be summarized as a limited resource availability facing an increasing water demand. The water resource is limited by the semi-arid climate (and its spatial and temporal variability) which means an uneven spatial distribution (in surface short floods rapidly infiltrating and evaporating, i.e. a very poor availability; a much larger storage capacity and availability in aquifers). The natural state is modified by the large El Haouareb dam, which increases the surface storage, and by many smaller dams and other works for soil and water conservation that lead to a significant decrease in the surface runoff and input to the large dam and in infiltration to aquifers.
The Merguellil catchment presents two contrasting aspects: a hilly upstream part (1200 km^2), with an altitude between 200 and 1200 m, and a very flat downstream area, part of the Kairouan plain, that extends over more than 300 km^2.

Available water resources

This semi-arid zone is exposed to a high variability of rainfall in time and space: annual means vary between 200 mm and 400 mm. Extreme annual rainfalls observed in Kairouan were 703 mm in 1969/70 and 108 mm in 1950/51.
The Merguellil catchment is endorrheic and the river flow is seasonal. However, the plain is subject to flood events (about 80% of the annual flow is produced in 12 days). Prior the construction of the El Haouareb dam, at the border between the upstream part and the Kairouan plain (Figure 13), the largest floods of Merguellil reached the sebkha el Kelbia (an often dry large salt lake) and smaller floods vanished in the Kairouan plain by both evaporation and infiltration to the phreatic aquifer. For the period 1989-2005, the mean annual flow of Merguellil river, calculated at the entry of the El Haouareb dam, was 17 Mm^3 (extremes of 2.5 and 37.6 Mm^3). Groundwater resources may complement the surface water resources but they are not evenly distributed: three small aquifers cover the lower part of the upstream catchment; the thick and large aquifer in the Kairouan plain alluvium is the most important of central Tunisia.

Water use in the domestic, industrial (tourism & production) and agricultural sector

Before the 20th century, the local mostly nomadic population exploited the region as an extensive grazing area. Significant changes occurred in the last century, with a spectacular demographic growth and a rapid development of agriculture, in response

to local and national encouragement. Irrigation is now widely spread all over the Kairouan plain and is highly dependent on groundwater, leading to the overexploitation of the plain aquifer. In the upstream part, the crop pattern varies and irrigation is employed less.
In Tunisia, consumption and water requirements of the public irrigated areas are relatively documented by the local water management authorities. However, water consumption through the private irrigated zones is unmetered, even though great water quantities are extracted from the aquifers.

Figure 14: The El Haouareb dam

Infrastructure
In 1989, the El Haouareb dam was built for preventing catastrophic floods. In fact, the majority of the water from the reservoir infiltrates (and recharges groundwater) or evaporates and as a result the reservoir has often dried up. Dam releases are very exceptional.
The numerous works for water and soil conservation in the upstream catchment result in a significant decrease in the river flow, and completely modify the regional water balance. Moreover, they do not represent a new reliable local water resource.

Water stress analysis and mitigation

Water stress analysis
The analysis of water stress problems in the Merguellil catchment was based on a consultation process. An Info day, Meetings and AquaStress JWT workshops were organized in 2006 in which many stakeholders (individual farmers, farmers associations, regional and central services of the Agriculture Ministry in charge of water resources management) were involved.
Discussions demonstrated that there is an urgent need to preserve the water resource at the regional scale while increasing the welfare of the people. This requires increasing the added value of water and ensuring equity between upstream and downstream (the water productivity being higher downstream) users.
Relevant technical solutions may help but they cannot solve the whole problem. They have to be complemented by social, economic and institutional proposals, to be debated first among local stakeholders, regional and national authorities.

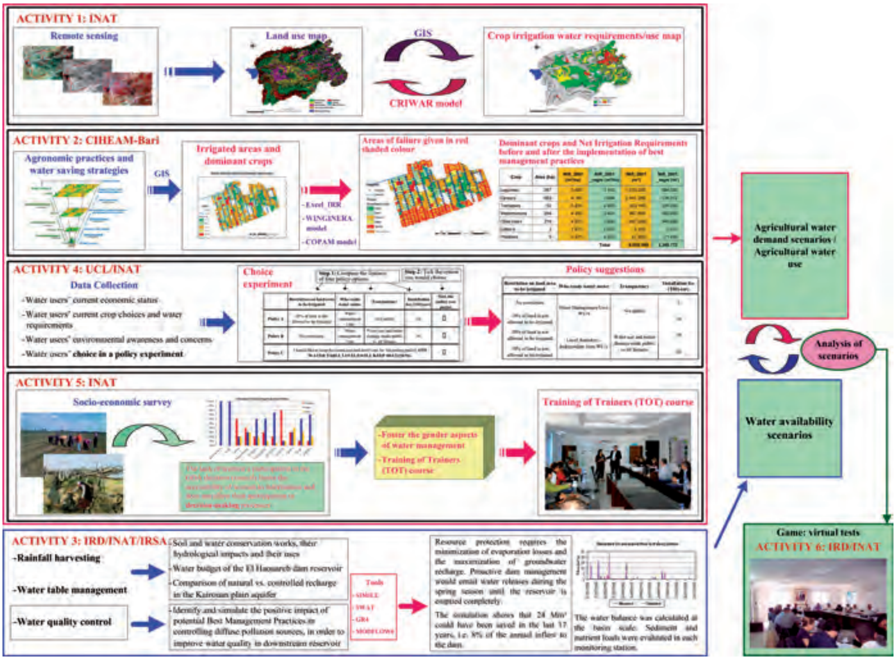

Figure 15: The Merguellil Case Study activities

Water stress mitigation

The case study addresses the double focal problem of improving the efficiency of water use in an intensively irrigated area with a two-fold answer. The first point considers the water resource (i.e. technical solutions), while the second one concerns socio-economic aspects of water management (i.e. non-technical solutions). Six activities were identified (figure 15), three technical and three non-technical. The activities were implemented in different sub-regions in the catchment that were considered typical of the issue addressed.

Specific objectives were (i) to assess the water resources availability and agricultural use in the Merguellil region, (ii) to evaluate the effect of water pricing policies, (iii) to highlight the importance of the role of women in water management, and (iv) to test a participatory approach for defining management rules for the water shortage with the common agreement of water users and authorities in the El Fej-Rouissat zone. Thus, the mitigation options analyzed were:

1) The improvement of agricultural water management by assessing agricultural water needs and groundwater use;
2) The improvement of irrigation efficiency;
3) The improvement of the availability of high quality water at the catchment scale by assessing different schemes of land use patterns and management;

4) The framing of efficient water pricing schemes and institutional settings;
5) The fostering of the integration of women in agricultural water management;
6) The introduction of a participatory approach for defining water management rules.
Testing of the first option was based on the joint application of remote sensing and spatial techniques for assessing crop water requirements. The methodology was tested on the Kairouan plain in the center of Tunisia and concerns approximately 300 km² in the downstream of the El Houareb dam. The main outputs were a detailed agricultural crop map (Figure 16) and maps with the estimation of agricultural water needs for different time steps (monthly and annual). Figure 17 showcases the results for the annual time scale.

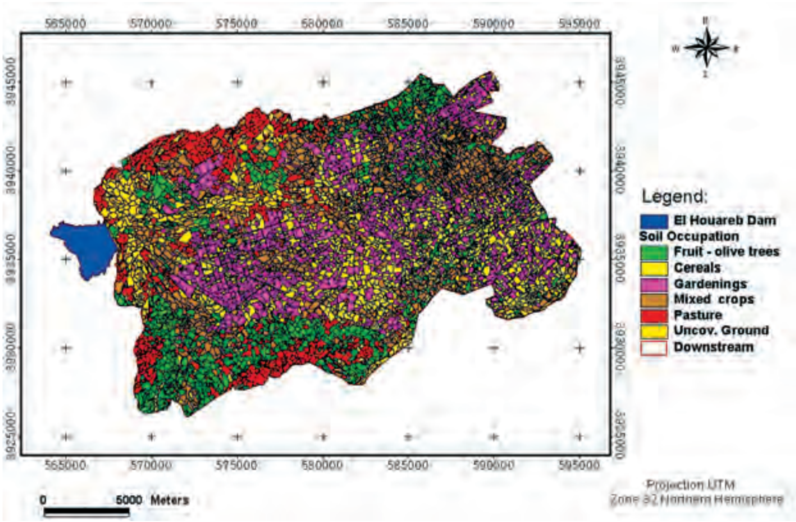

Figure 16: Land use map of the downstream Merguellil catchment

The second option (irrigation water management) aimed at the promotion of sustainable land and water management in the agricultural area of Chebika, located downstream of El Haouareb dam, in Merguellil Valley (Tunisia). The area is characterized by highly variable precipitation pattern and frequent drought periods that lead to an increase in irrigation requirements, failure of the on-demand irrigation network, overpumping of groundwater, hydrological imbalance and negative environmental and socio-economic consequences. In fact, the area is exposed to increasing pressure from the irrigation sector and serious water shortage problems resulting in decrease in the groundwater table and accelerated land degradation.
The current situation analysis results indicated several areas of failure due to excessive water demand as illustrated in Figure 18. For these areas, a list of options was proposed and discussed with local stakeholders, which refer to the distribution network (e.g. substitution of hydrants with those with flow and pressure regulators, replacement of

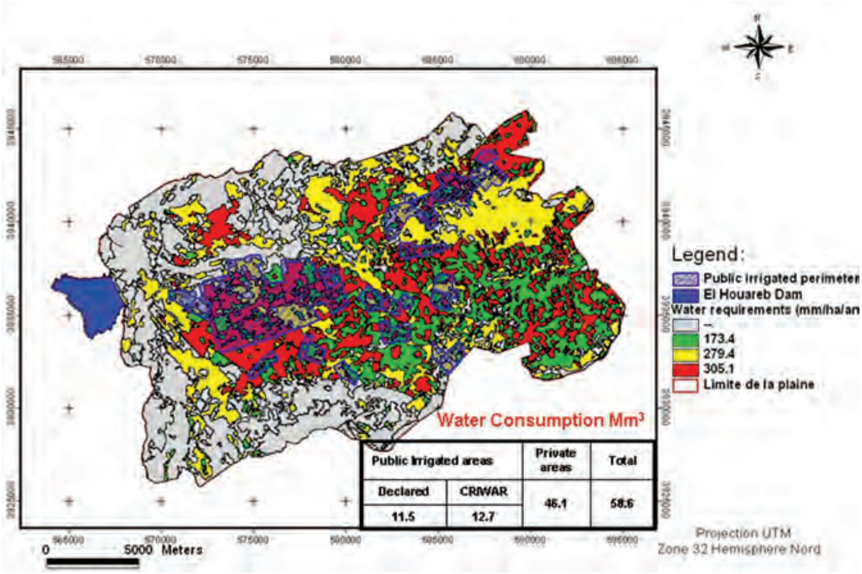

Figure 17: Irrigation water consumption in the Kairouan plain obtained by combining remote sensing data and CRIWAR model (ASTER image on April 2004)

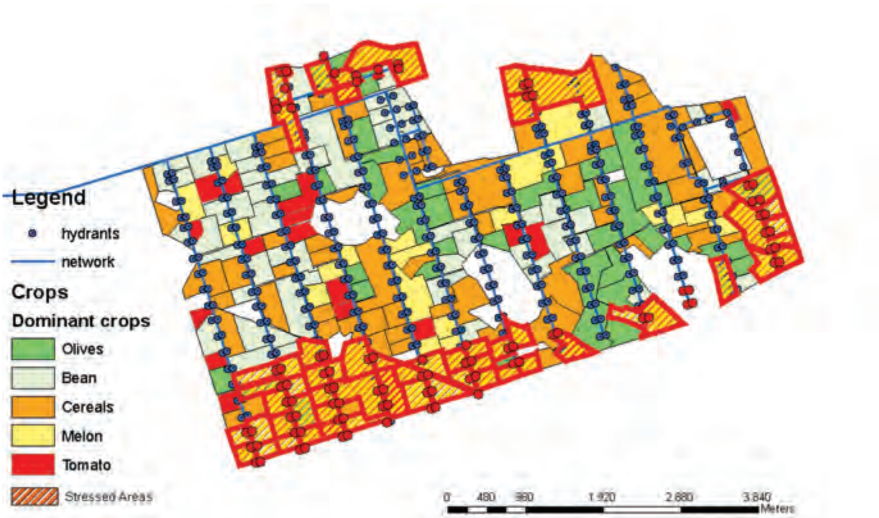

Figure 18: Irrigation district in the Merguellil watershed - the areas of failure are given in red

old pipes), the farm scale (e.g. improved design of on-farm irrigation systems, real time irrigation scheduling, modern agronomic practices) and the irrigation district (e.g. cropping pattern optimization, Introduction of water tariffs based on consumption).

The third option examined corresponds to enhancing the availability of high quality water at the catchment scale by assessing different schemes of land use patterns and management; specific actions include rainfall harvesting, the management of the groundwater table and alternative land use schemes.

Regarding rainfall harvesting in contour ridges, it became evident that due to the climatic variability and the small size of these conservation works, this new storage is very uncertain in time. Farmers cannot rely on it for irrigation and have not really adopted the option. Saving water could be achieved by releasing water after each precipitation event from the formulated lakes without agricultural use around them.

Groundwater is a major concern because it is the only permanent water resource, able to withstand a series of drought years. Groundwater recharge is regulated by the El Haouareb dam. Therefore, the protection of groundwater resources requires a proactive dam management that will minimize evaporation losses and maximize groundwater recharge. The proposed scheme includes water releases each spring until the reservoir is completely empty. In case of irrigation deficit, supplementary water could be pumped from the Kairouan plain aquifer. Simulations demonstrate that 24 Mm^3 could have been saved for the last 17 years, i.e. 8% of the annual inflow to the dam, if a proper dam management was undertaken.

Alternative land use management corresponds to:

- The location of water reservoirs. The results clearly show an increase of the surface runoff by removing some important reservoirs. An increase of about 2.2Mm^3/year in the water volume was observed at the watershed outlet. Consequently the sediments at the outlet will also increase, reaching a sediment load of about 141T/day. Those sediments may settle in the karstic fissures in the bottom of the reservoir causing a reduction in infiltration, and therefore, in the recharge of the downstream aquifer.
- A reduction of 20% of the used fertilizers for durum wheat, olive, almond and apple cultivations. The results showed a slight reduction of 1.65 % in the durum wheat yield, while no change was observed for the other crops. As far as the runoff loads it concerns, a reduction has been noted in the simulated loads for the reduced fertilizer use, compared to the actual situation. This reduction ranged from 0.3 to 9 % for sediment, from 3 to 13% for nitrates, from 2.5 to 12% for total N and from 10 to 24 % for total P.

As a further step, the impact of the climatic change on water availability in the Merguellil catchment was evaluated, using the global climate change scenarios. The results have shown that climate change would have an impact on the quantity and quality of the surface runoff. In a yearly scale, all the components of the water and

Figures 18b: Merguellil Case Study training course

nutrient balance are foreseen to decrease. Accordingly, a longer arid period in summer will lead to a decrease of the sediment and nutrient load in that period.

An important issue examined in the Merguellil Case Study was the formulation of efficient water pricing schemes and institutional settings. Using the Choice experiment method it became evident that farmers are willing to shift to a collective action regime and pay a price to stabilize groundwater table provided that 1) the water pricing system is transparent; 2) public information about each farmer's groundwater use and any negative behaviour (e.g. sabotage of meters) is available; and 3) independent monitors are hired.

Another non technical option for the improvement of agricultural practices is the integration of women in agricultural water management. A social survey was undertaken, and many stakeholder meetings were held, in order to analyze the actual gender situation in the Case Study area of Kairouan (Merguellil Valley), Tunisia, and to establish a dialogue among all interested stakeholders for a sustainable and equitable development of the agricultural sector.

The survey showed that 40% of women participate in the planning of agricultural activities linked to water and are informed of the exploitation evaluation, and 60% of the surveyed women specify that these activities are exclusively the responsibility of the manager, who is generally the husband or the owner of the exploitation.

A training course on "Gender Aspects of Water Resources Management" was organized, addressed to the local stakeholders and managers (both women and men), who were trained to transfer the knowledge into the local society. Stakeholders actively participated in the course and were keen to set up strategies for the promotion and strengthening of the integration of gender aspects in water management (Figure 18b).

Finally, a main activity within the Merguellil Case Study was the promotion of a participatory approach for defining water management rules on the basis that building relevant management rules requires a negotiation between the different stakeholders, in particular different types of water users and water managers.

A simulation game was organized, using the work developed within the European

Figures 18c: Merguellil Case Study training course

WADEMED project in order to define management rules of the water shortage with the common agreement of water users and authorities scale.
Local institutional partners, as well as farmers, have been involved in the participatory approach test "AquaFej" that refers to water management in the El Fej-Rouissat zone(Figure 18c).

Outcomes

The Merguellil case study contributed to the test site with:

- A better understanding of private and public land use and an evaluation of the water requirements for agriculture, in an effort to improve better agriculture water management.
- Guidelines for the regional stakeholders on sustainable management of land and water resources.
- A detailed analysis on farmers' preferences regarding the stabilization of the groundwater table and their willingness to pay in order to achieve collective action.
- Promotion of the women's role in water resources management by providing information and training on gender aspects, especially in the irrigated sector and in water management.
- The Aquafej simulation game, used to define management rules for the water shortage with the common agreement of water users and authorities scale.

Added value to EU water stress diagnosis & mitigation
The Merguellil case study resulted in the elaboration of methodologies and best practice examples, applicable to any region with similar water stress problems:
- Remote sensing methodology to elaborate a detailed map of private irrigated areas and thus to evaluate agricultural water consumption and needs.
- Best irrigation practices.
- Best agricultural practices to preserve water resources quality.

Furthermore, following the principles of the WFD, participatory processes were promoted with emphasis given to women's role in agricultural water management in south Mediterranean countries and the need for access to information (i.e. public info on water use and meter sabotage).

Lessons learnt
- Farmers are interesting in using new less water-demanding cultivars, regulated deficit irrigation strategies, early sowing and mulching techniques and night-time irrigation practices, as long as they are informed and educated about these options and furthermore reinsured that they would improve the efficiency of agriculture;
- The capacity of local authorities, that are involved in water management, should be improved and besides financial support they should be equipped with adequate tools for performing their activities;
- All relevant stakeholders should be involved in water management in order to achieve a sustainable and equitable development of agricultural sector including Gender Aspects.

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Towards sustainable agricultural water management

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The Tadla irrigated perimeter is a part of the Oum Er Rbia river basin and is located on the banks of the Oum Er Rbia River, some 200 km northeast of Marrakech and 170 km southeast of Casablanca. The total irrigated surface is about 100,000 hectares composed of two sub-perimeters: Beni Amir (30,500 hectares) on the right bank and Beni Moussa (69,500 hectares) on the left bank.

Figure 19: The Tadla irrigated perimeter

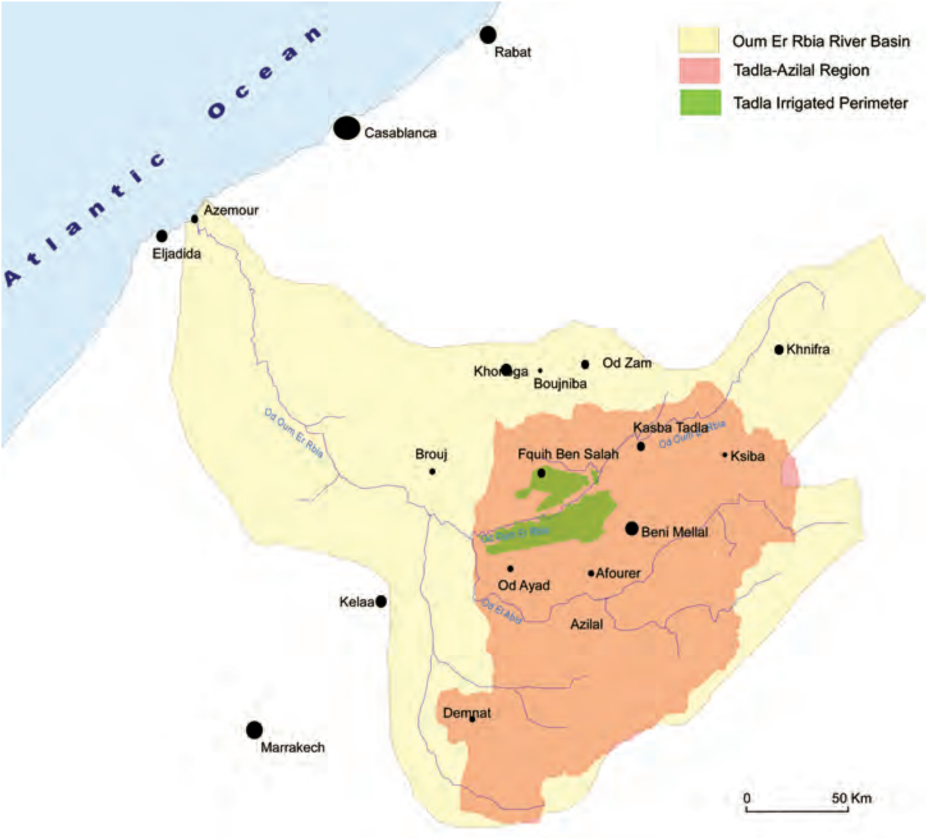

Figure 20: The Um Er Rbia river basin

Water stress conditions

The main water stress issues in the Tadla test site could be summarised as follows:

- Surface water scarcity as a consequence of drought and aridity, deforestation in the mountain region and increase in water demand. By the end of the 1970s about 1 billion m^3 of surface water was available for the Tadla irrigated perimeter. Currently, less than 500 m^3 are supplied to Tadla;
- Groundwater overexploitation due to surface water scarcity, limitations of the groundwater abstraction law and increasing water demand;
- High irrigation water losses due to the use of traditional irrigation methods;

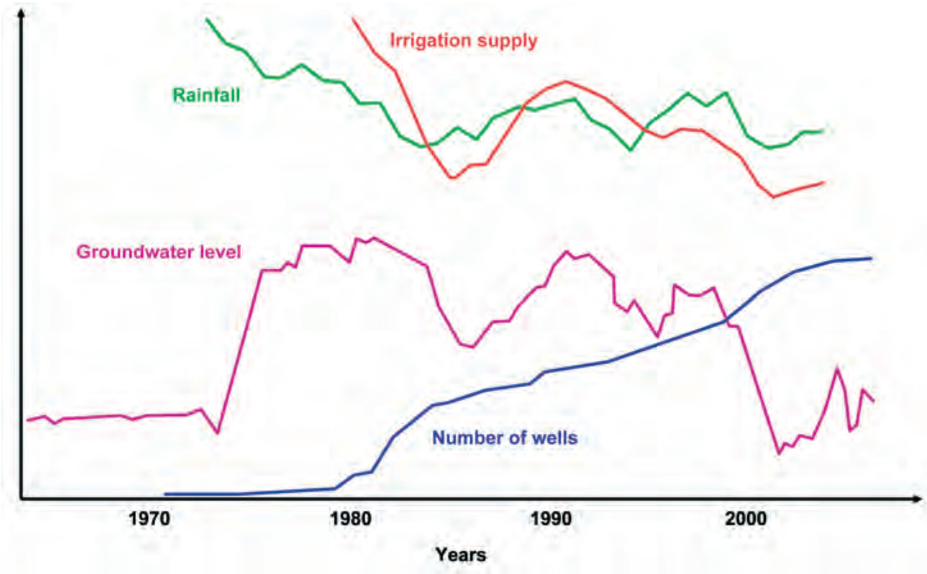

Figure 21: Water system figures

- Conflicts among drinking water, irrigation, industrial water and hydropower generation uses;
- Degradation of water quality resulting from groundwater and drainage water recycling, non rational use of fertilizers, intensive cultivations and agribusiness development.

The main environmental problem at the scale of the River Basin is that there is no outflow to the sea (Atlantic Ocean).

Available water resources

The average rainfall in Tadla is about 300 mm. The Beni Amir sub-perimeter is supplied with water directly from a diversion dam at the town on the Oum Er Rbia river (annual average discharge of 38.6 m^3/s). In 2001, the Ahmed El Hansali dam (740 million m^3 of capacity) has been built to regularize the Oum Er Rbia discharge. The Beni Moussa sub-perimeter is supplied with irrigation water from the Bin El Ouidane Dam (1500 million m^3 of capacity). In the region there are two main phreatic aquifers, which are used for irrigation, and two confined aquifers (Eocene and Turonian), which are mainly used for drinking water. More than 12,000 private wells and tubewells are used for groundwater exploitation by the farmers at the scale of Tadla plain.

Water use in the domestic, industrial (tourism & production) and agricultural sector

The Oum Er Bia watershed basin, where Tadla is included, is the second most important watershed of Morocco. It covers an area of 3,500 km^2 with a total surface water production of 3,680 Mm^3/year that varies from 1,300 Mm^3 to 8,300 Mm^3. Surface water is used for irrigation, domestic, industrial use and hydropower generation, with agriculture being the main consumer (using more than 90% of the water resources at the Oum Er Rbia watershed scale). Surface water is used to irrigate four large and some small and middle scale perimeters which are:

- The Tadla irrigated perimeter (100,000 ha);
- The Doukkala irrigated perimeter (104,600 ha);
- The Tassouat Aval irrigated perimeter (49,000 ha);
- The Tassouat Amont irrigated perimeter (51,700 ha);
- The small and medium scale perimeters (64,000 ha involving downstream and upstream basin, Dir de Beni Mellal [Tadla], downstream of Oued El abid, downstream basin).

Concerning domestic and industrial water use, many big and medium sized towns (e.g. Casablanca, Marrakech, El Jadida, Safi, Khénifra) are directly supplied with surface water from the Oum Er Rbia river basin. Groundwater is solely used for drinking in the Tadla plain. However, some industries are directly supplied from the irrigation network.

Quality and quantity issues

The quality of surface water is generally good upstream of Oum Er Rbia river and its tributaries until the level of Khenifra city, downstream of which water quality degrades rapidly. Urban wastewater is directly rejected in the river from Khénifra to Kasba Tadla, resulting in water quality degradation; critical values of pollution indicators were observed (i.e.: DCO= 205 mg/l; Fecal Coliform: 3.5 10^6/100 ml). The salinity of the Oum Er Rbia water is a also high at the upstream of the Beni Ami irrigated perimeter and ranges from 1000 mg/l to 1500 mg/l).

The degradation of the mineralogical quality of groundwater at the downstream of Beni Moussa perimeter and about half of the surface of the Beni Amir perimeter and the increase of Nitrogen compounds concentration in groundwater in the Tadla irrigated perimeter pose serious threats on the groundwater resources of Tadla, and particularly the unconfined aquifer. The average increase rate of nitrates is about 4 to 5 mg /l/ year, whereas a maximum concentration of 60 to 80 mg/l was observed.

Institutional capacity

In Morocco, the water law 10-95, enforced in 1995, defines the water resources management framework. At the river basin scale, the water resources management is under the responsibility of the River Basin Agency (ABHOER). The ABHOER coordinates the allocation of surface water resources among the main users: agriculture (Tadla, Haouz and Doukkala), domestic use (Casablanca and other coastal cities) and hydropower generation. The ORMVAT (Office Régional de Mise en Valeur Agricole de Tadla) is responsible for irrigation water management and distribution in the Tadla irrigation scheme. The 28,000 farmers of Tadla are organized on Water Users Associations (WUA) and on WUA federations. The WUAs are responsible for the negotiation of the allocation schemes and also for the distribution of irrigation water in their territories. Other professional organizations (livestock breeding, sugar beet, citrus, olive cultivation, etc) play an important role on water resources management though the determination of crop patterns and consequently the water demand for agriculture.

Infrastructure

The surface water resources of the Tadla irrigated perimeter are supplied from two large dams: Bin Elouidane on Elabid river, with 1500 million m^3 capacity, and the Ahmed Alhansali dam on Oum Er Rbia River, with 1500 million m^3 capacity. The irrigation water is distributed through a network of main canals (200 km), secondary canals (630 km) and tertiary canals (1800 km).

More than 12000 wells, equipped with individual pumping stations, are used by farmers for groundwater exploitation. The perimeter is also equipped with a large surface drainage network composed of more than 1400 km of ditch collectors.

Social and economic equity

The main economic activity in the Tadla plain is agriculture, including the related manufacture activities (e.g. olive oil-work, sugar refineries, flour-mill). There are approximately 28,000 farmers within the 100,000 ha for an average farm size of 3.4 ha per farm.

Farms of less than 5 hectares are held by 82% of the farmers and account for 41% of the total area, while parcels greater than 20 hectares are held by only 2% of the owners, covering 27% of the area. The principal crops are sugar beet, wheat, alfalfa, olives, citrus, various vegetables, and some spices, and the majority of crop production is used for internal consumption within Morocco. The Tadla irrigated perimeter is one of the most important in Morocco in terms of contribution to the Gross National Product (e.g. 23% of sugar beet, 13 % of citrus, 12% of olives, 16% of milk, 11% of meat).

Water stress analysis and mitigation

Water stress analysis

The Tadla case study focused mainly on the improvement of irrigation water management in the area. The following main topics were addressed:

- How irrigation efficiency can be improved using modern technologies, and how farmers can be organized to increase their access to these technologies;
- Which alternative cropping patterns can be proposed to reduce water demand;
- How integrated management of groundwater and surface water can be achieved;
- How farmer groups behavior could be taken into account for water resources management.

Water stress mitigation

Water stress mitigation efforts focused on irrigation. A list of water stress mitigation options was selected for further study in collaboration with the local public stakeholder forum ("water saving scenarios"). A combination of models, tools and consultation discussions were used to evaluate the option implementation effects. The table below demonstrates the options that were investigated, and the achieved results.

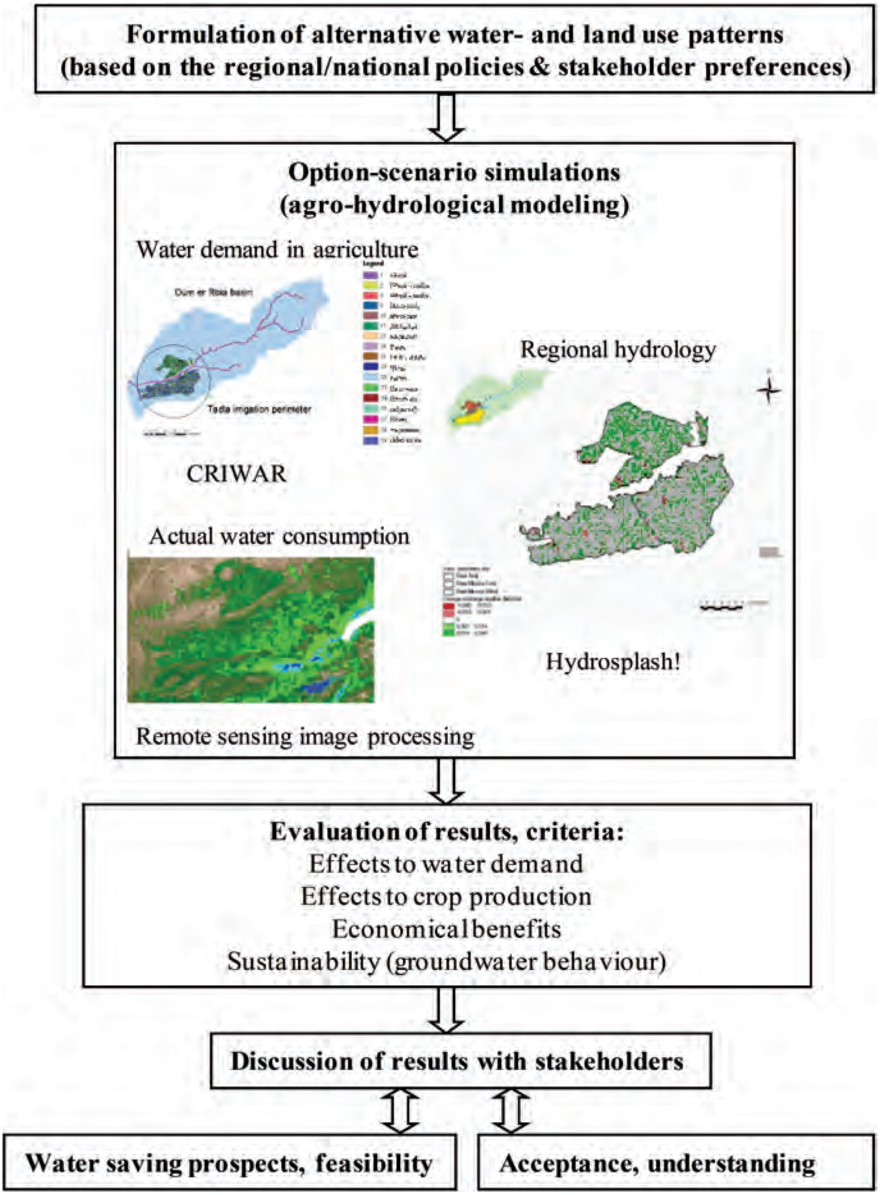

Figure 22: Formulation of alternative water and land use patterns

Mitigation options	Evaluation of results
Participatory process to support joint irrigation projects	This mitigation option aimed at the introduction of modern irrigation techniques (drip irrigation) through a joint irrigation project where a group of smallholder farmers were involved. A typical joint drip irrigation project is a combination of joint hydraulic infrastructures (storage basin, head station unit, etc), individual field equipment (water meter, distribution tubing, etc) and a management structure. The option design was a collaborative process, where different local stakeholders participated including farmers, the ORMVAT, the River Basin Agency, local experts in drip irrigation systems and Morocco, French and German researchers (AQS research members). The mitigation option has been tested I) virtually and 2) in the field, since farmers were interested in developing a joint irrigation project. Training sessions have been also organized with several farmer groups in order to disseminate the option.

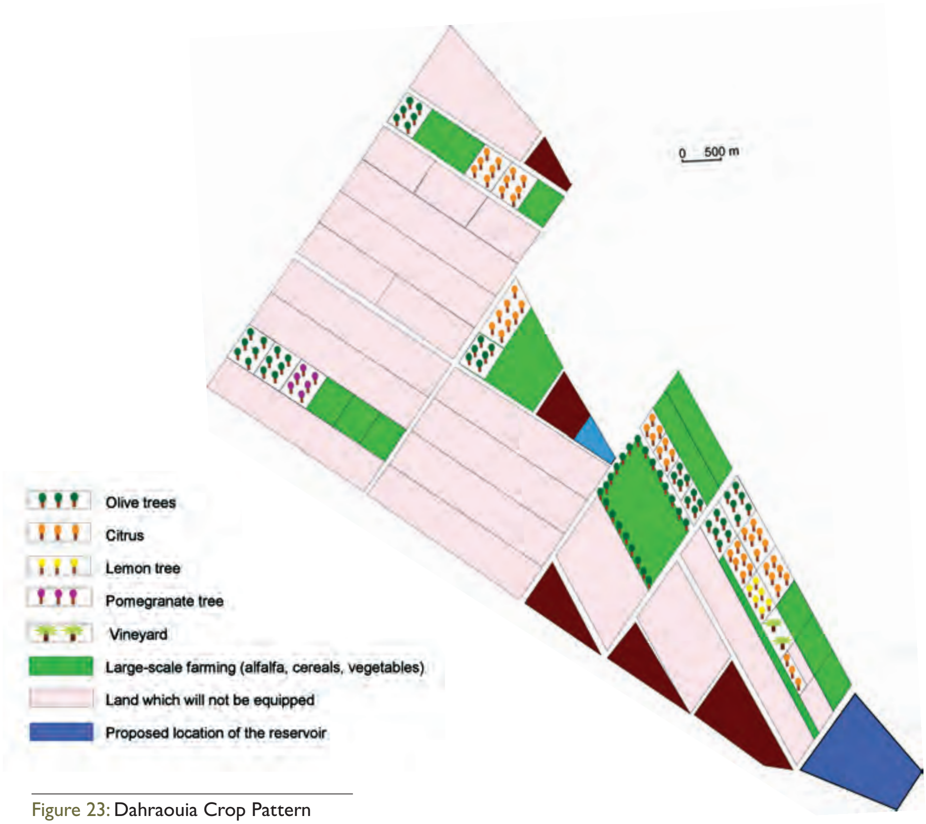

Figure 23: Dahraouia Crop Pattern

Mitigation Options	Evaluation of results
	The testing & evaluation results of this option are encouraging but additional time is needed to assess the impact of the option in terms of water stress mitigation. However, even though the joint irrigation project is not yet operational, the approach used to support the group in the design of their project (both technical and organisational aspects) has proved to be robust. As a result, the World Bank requested to use it in training sessions with other farmers of the Tadla scheme. In addition, the water user association, which will be created to manage the new infrastructures, provides a great opportunity for the active involvement of farmers in water management issues at the basin level.
Minimizing losses in irrigation	The study demonstrates that the introduction of efficient irrigation techniques such as drip irrigation is a promising option. These techniques involve different cropping patterns than those followed traditionally. As a result 15-20% of irrigation water can be saved. However, care should be taken with a large scale introduction of drip irrigation: Groundwater tables might drop if surface water savings are simply used elsewhere; the question of what will be done with the "saved" amount of water should also be addressed.
Tailoring cropping patterns	Modeling results showed that substantial water savings are achieved with alternative crops or modifying planting dates. Promising alternative cropping patterns and adjusted crop calendars could be established, so that the evaporative demand of crops can be reduced, and better use can be made of rainfall. Examples of investigated alternatives that reduce water demand in the area are: • Replacement of part of the alfalfa with maize; • Increase the area cultivated with wheat; • Change the planting dates (e.g. of sugarbeet) to earlier sowing in order to avoid growing periods with peak temperatures.

Mitigation Options	Evaluation of results
Irrigation water management	Poor management at the main canal level can lead to inefficient water distribution and increased water shortages at the field level. A study on the hydraulic behavior of the Tadla main canals showed that water delivery to the secondary canals is impacted by the hydraulic behavior of the main canals. Bottlenecks were identified affecting the hydraulic management of the main canals.
Conjunctive management of groundwater and surface water	A tool was developed to support water managers in decision making with regard to the control of excessive water table depletion when defined thresholds are exceeded. This task was carried out by evaluating scenarios that correspond to different management options, by means of a groundwater flow model based on the piezometric data coming from the monitoring network activities. The water managers are given the possibility to choose the most suitable management option comparing the simulated scenario with a target piezometric situation.
An Integrated Agent-Based Model (ABM) to Consider Combinations of Options for Water Stress Mitigation	An agent-based model of the Tadla Irrigation Scheme has been implemented to assess social, economic and environmental impacts of water stress mitigation options. These impacts are measured in terms of effects on farm income and on the groundwater balance. Local stakeholders (Farmers and Water Managers (ABHOER, ORMVAT) have been involved to develop scenarios for the simulation and to gather input data for the model. Preliminary simulation results suggest that some of the proposed water stress mitigation options could be beneficial in the social, economic and environmental dimension as well: Cultivating more grain while reducing the area planted with alfalfa allows saving large amounts of groundwater and can be economically feasible for small farmers if higher sale prices can be realized. Drip irrigation projects can also have a positive effect on the groundwater balance. They provide a promising means for small farmers to increase their income (especially when changing to fruit or vegetable cultivation) given that they can make the best use of the collective investment.

Outcomes

The joint collective projects activity fit into the problematic of how to improve the water use efficiency and the collective management of surface and groundwater at a local scale. Collective irrigation projects are crucial for small scale farmers, as they will allow them to benefit from the same irrigation technology and increase their organisational capacities regarding water management. This option is also important for stakeholders in charge of agricultural and water management in their efforts to improve global water use efficiency in the irrigation scheme. Indeed, the Moroccan state has just started an ambitious program of 450,000 ha for water saving in which 250,000 ha will be converted from surface to drip irrigation.

On the other hand, solutions for the area are to be found in the reduction of evaporative demand, in combination with the use of more efficient irrigation techniques. A replacement of the high water demanding crops in favour of less water demanding crops can save water, especially when cropping dates are defined 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 dry summer months.

The choice of alternative cropping patterns highly depends on the expected profitability for farmers, within limits set by the irrigation department. The water saving potential of the historically cultivated crops in Tadla is limited. However, as world market prices show drastic changes, in particular for grains, other transitions could be explored as well, taking into account the local economic constraints and the water savings opportunities.

The Tadla groundwater management tool acts as a DSS that allows managers to integrate groundwater in the definition of water resource allocation schemes. Efficiency is a consideration not only for individuals, but also for the collectives as a whole.

Added value to EU water stress diagnosis & mitigation

The current context of water shortage and scarcity in Morocco could be considered precursory of what could happen in Europe in the near future according to the global climate change. In addition, the south Mediterranean countries can play a complementary role for Europe's agricultural production in the future. From this point of view, the south Mediterranean Tadla site could be seen as complementary to the AquaStress approach, as similar problems are repeated to some extent across Mediterranean agricultural regions.

The participative approach could be used in a similar context in the Mediterranean and responds to the Water Framework Directive requirements for an active participation of water users. The developed methods and tools could be used by other countries with a similar water stress context.

Lesson learnt

- A successful project should start from the field (Case study approach) in order to develop the interaction between research and stakeholders;
- The interdisciplinary configuration of the team has made it possible to design adequate research activities;
- Scenarios have an important role in the interaction with stakeholders and linking the different research activities;
- The formulated "water saving scenarios" proved to be a practical way to bring together the different AquaStress disciplines (agro-hydrological, economical and participatory approaches);
- The scenarios showed that the addition of storage facilities (i.e. groundwater aquifers) would improve the situation in the Tadla plain, so that water wzould be available for release during drier periods. In combination with the use of drip irrigation, this adds flexibility to irrigation planning in order to reduce stress at critical crop growth stages. This also increases the reliability of water supply;
- Insight was gained in how to limit consumptive use during the summer months, when there are high evaporative demands and scanty rainfall, in order to make better use of the available rainfall. This is in line with contemporary vision that one should seek opportunities to increase infiltration and retention of rainfall in the soil (increasing natural moisture reserves) instead of depending on irrigation only;
- The option testing of minimizing losses in Tadla made clear that the downstream effects of local interventions need to be understood (basin approach). The introduction of drip irrigation saves water at a local level, but will impact downstream areas, where water availability will decrease. An expansion of modern (drip) irrigation technology thus has to be implemented in a controlled manner, and the general question that should be addressed is: "What implications do the options have on water dependent (ecosystem) services downstream?"
- Option simulations played a key role in interactions with stakeholders. Demonstrating the quantified effects to stakeholders stimulated lively discussions on future trends and possible solutions regarding crop patterns and water use in the area;
- A new round of discussions with stakeholders in Morocco should be initiated on the application of irrigation technology;
- A better link between the case studies would have allowed a better comparison and improvement of approaches.

Further reading

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Sharing water under conditions of scarcity and stress

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The Iskar test site is situated in the South-West part of Bulgaria and is delineated by the borders of the Upper Iskar river catchment - from the river spring in Rila Mountain to the monitoring station at the town of Novi Iskar (Figure 24). The total area of the site is 3668 km^2. The Iskar River is the longest river in the Bulgarian part of the Danube River Basin and has significant economic importance.

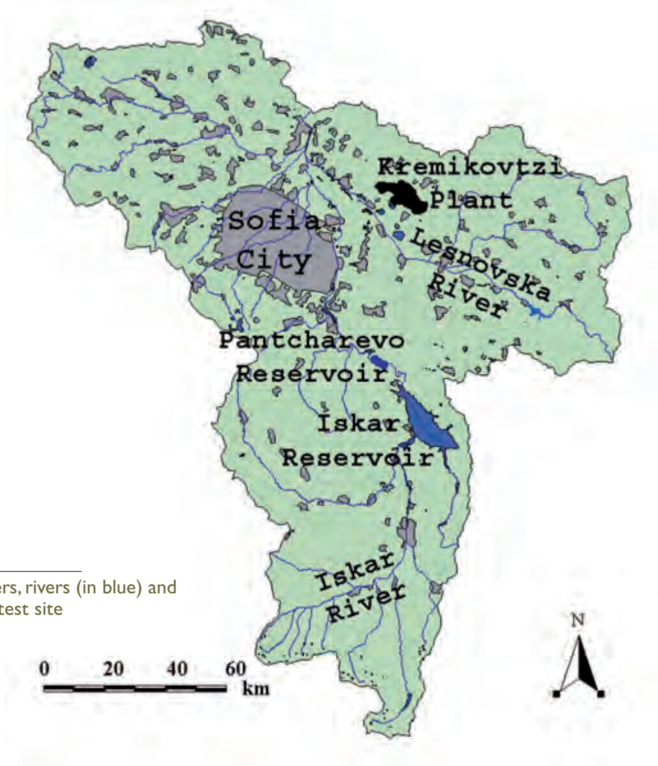


Figure 24: Geographical borders, rivers (in blue) and settlements (in gray) of Iskar test site

Water stress conditions

Water stress in the test site is attributed to natural and manmade causes: seasonal river run off, alternation of periodic droughts and floods, conflicts among water users, increased urbanisation and population growth of the capital, illegal deforestation, uncontrolled disposal of domestic and industrial wastewaters and wastes, old pipelines in water networks, high percentage of drinking water losses in the water supply network, inefficient management of the water resources, etc. The AquaStress project contributed to the analysis of the inter-relationships and cause-effect schemes among the water related problems and enabled the identification of the water stress focal problems in the test site, so that suitable mitigation options could be suggested and evaluated.

Available water resources

The average amount of water abstracted in the Upper Iskar basin is 361.330.000 m^3/year, according to data provided by the National Statistical Institute for the period 2000-2004. Only 6% of the water is abstracted from underground sources, while the remaining 94% is taken from surface sources. The main surface water body in the basin is the Iskar River. A series of water reservoirs were built upstream; two of these are used for water supply, Iskar, the biggest water reservoir in the country (655,3.10^6 m^3), and Beli Iskar (1,5 10^6 m^3). Another reservoir of economic importance in the region is Ognianovo reservoir (3,2 10^6 m^3), which is situated on one of the biggest tributaries of Iskar, the Lesnovska River (Figure 24).

Water use in the domestic, industrial (tourism & production) and agricultural sector

The water resources in the basin are used for domestic water supply, industrial water supply, hydropower production, irrigation and recreation. The Ministry of Environment

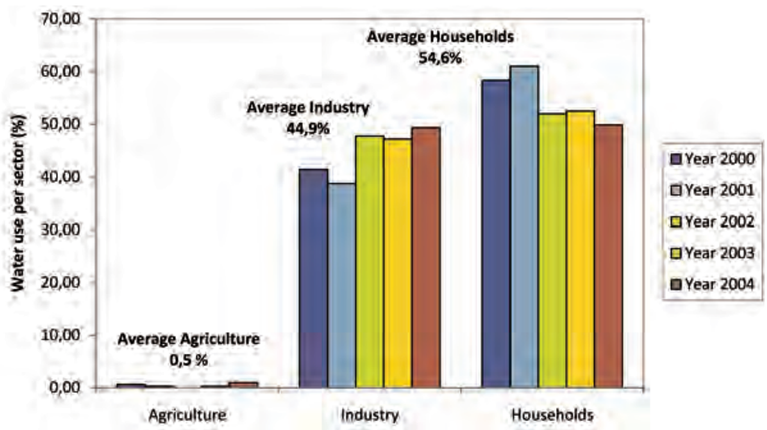


Figure 25: Water used by sectors for the years 2000-2004 (data from the National Statistical Institute)

and Water (MOEW) issues long-term and monthly permits for water abstraction quotas. In case of a dry year, the water abstraction permits set the following priorities: household, health care, irrigation, others (including industry), stipulated in article 50 of the Water Law. Figure 25 presents the water utilization by the main water use sectors for a 5 year period (2000 to 2004) and illustrates that the two big water consumers in the region are the households and industry.

Quality issues

As a result of the anthropogenic impacts there is significant deterioration of the surface water quality between the river spring and the final monitoring station. The biggest industrial plant in the region, the metallurgic enterprise Kremikovtzi, discharges its wastewaters into Lesnovska river, which is a tributary of Iskar (Figure 24). In the last years, an improvement of the surface water quality is observed especially in the oxygen regime, oil and heavy metal concentrations (data from Ministry of Environment and Waters).

Institutional capacity

The Council of Ministers is responsible for the approval of the national water management plan. The Ministry of Environment and Water is the National executive body on issues related to environment and water. The water supply and sewerage policy at the National Level is executed by the Ministry of Regional Development and Public Works. It coordinates the activities among the Water Supply and Sewerage Implementing Agency, the State Enterprise responsible for the water supply and sewerage activities and the municipalities. The water supply and sewerage sector is regulated by the Commission on regulation of water services (economic aspects) and monitored by the Ministry of Heath (drinking water quality aspects: Chemical-epidemic inspections).

Infrastructure

According to data from the National statistical Institute, 99% of the population in the Iskar test site are supplied with water by public authorities. However, a big part of the water supply infrastructure is outdated and does not correspond to the requirements for comfortable living. Some sections of the water network are out of operation due to significant damages. The water losses are very high and uncontrollable. This, combined with the depletion of water resources, has led to low pressure in the water supply and seasonal water shortages in many settlements, especially in the territory of the Elin Pelin municipality. In this municipality only 60% of the population is served by municipal sewerage systems and 53% of the population by municipal wastewater treatment plants. The direct discharge of municipal and industrial wastewater into the receiving water body significantly deteriorates the surface water quality and practically impedes its further utilization.

Social and economic equity

In the Iskar basin there are four municipalities – Samokov (28 settlements), Sofia, the capital of Bulgaria (38 settlements), Gorna Malina (14 settlements) and Elin Pelin (19 settlements). The Upper Iskar basin is part of the South-Western Economic Region according to the UNDP index for human development. The indexes for this region are higher than the average values for the country. The industry in the Upper Iskar is a significant factor determining the water consumption and water levels in the reservoirs as well as water pollution. There is a long term tendency towards ageing of the population in the smaller municipalities, mainly attributed to the concentration of younger people in the capital. At present, Sofia city has the highest workforce concentration in Bulgaria, and as a result there is an increase in water consumption in the Sofia agglomeration, provoked by the increased demand for drinking and industrial water.

Environmental protection

The environmental sustainability of urban water systems is usually measured with indicators of optimal resource utilization (e.g. use of water, nutrients, energy and land) and minimal waste pollution (e.g. gaseous emissions, wastewater effluent and solid waste) (Lundin and Morrison, 2002). Such indicators have not been evaluated for the Iskar test site, but considering the ranking of Lundin and Morrison (2002) it could be placed somewhere between level C (Minimum standard for environmental protection and health objectives is met) and level B (Standards for environmental protection are met and exceeded, but still focused on compliance issues and end-of-pipe solutions. Regular monitoring of drinking water, storm water, and wastewater quality is in place).

Water stress analysis and mitigation

Water stress analysis

A research based approach was developed in the AquaStress project and applied for the Iskar test site for the profound analysis of water stress issues. The process went through four phases, which are briefly described below.

Phase 1. Establishment of Local Public Stakeholder Forum (LPSF)

The first phase corresponds to the stakeholder analysis and formulation of the AquaStress stakeholder bodies. The process of Iskar LPSF establishment started in the beginning of the project and lasted five months. Several participatory tools such as stakeholder mapping, interviews and analyses, workshops and meetings were applied. Finally the Iskar LPSF consists of fourteen members, representing a broad range of water sector stakeholders coming from state or municipal Institutions, water services, water consumers, NGOs and citizens.

Phase 2. Identification of the focal water stress problems

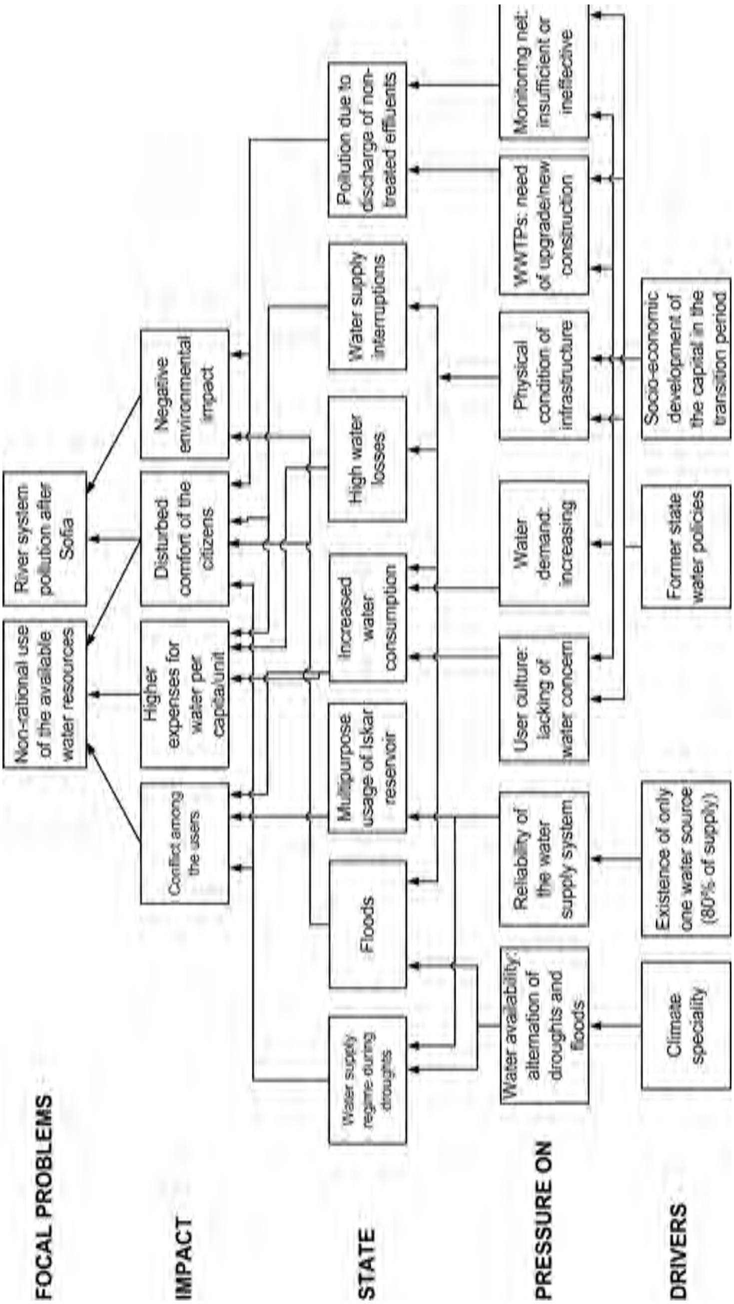


Figure 26: DPSIR approach, applied for Iskar test site to identify the focal problems

During the second phase, the LPSF members applied the DPSIR approach by means of roundtable discussions. Each member of the LPSF contributed with their knowledge of the system and experience on its problems. The team work resulted in a comprehensive analysis of the situation, elucidated the focal problems and provided an opportunity to identify the strategic goals for solving these problems. Two focal problems in the region were identified and illustrated in Figure 26.

The first focal problem was defined as "Non-rational use of the available water resources" and relates to water quantity. It is a result of four driving forces - climate, existence of only one main water source, former state water policies and socio-economic development of the capital in the transition period. These have led to irregular feeding of the water reservoirs, high water demand, high water losses, limited awareness of water consumers, etc.

The second focal problem was determined as "River pollution after Sofia" and relates to water quality. Figure 26 shows that this is a result of anthropogenic activities, such as the lack of municipal and industrial wastewater treatment plants, low level of monitoring, malfunctioning of the existing wastewater treatment plants.

Phase 3. Establishment of Join Work Team (JWT) of Researchers

A Joint Work Team of researchers was established in order to assist the LPSF in the selection and implementation of the most suitable mitigation options. The process of establishing the JWT took five months and aimed at the selection of project partners that can contribute to water stress mitigation in the test site.

Phase 4. Design of the case study

The JWT members suggested quantifying water stress using the Water Exploitation Index (WEI) of the European Environmental Agency (EEA, 2003), which determines that water stress exists if WEI >0.4 and there is severe water stress if WEI >0.6:

$$WEI = \frac{\textbf{Total consumption } (annual)}{\textbf{Total available water resources } (annual)} \qquad \text{(Eq. I)}$$

The WEI for the Upper Iskar was estimated between 0,41 and 0,46 for the years 2000 to 2005, which indicates water stress in the region, even though these were normal years in terms of climatic characteristics. However, the 100 year data series shows that there are many periods with less than average precipitation (Figure 27), when severe water stress is indicated.

The DPSIR analysis and the WEI value elucidated the need for efficient sharing of

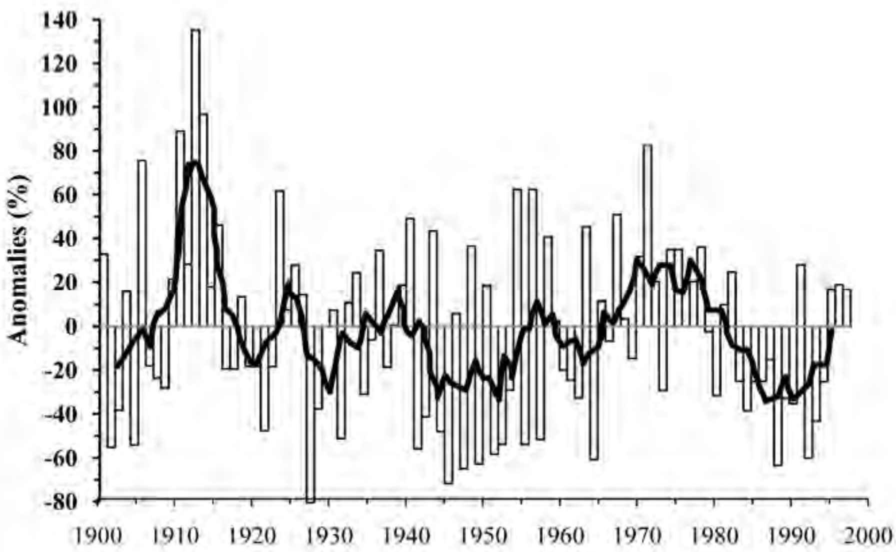


Figure 27: Histogram, showing variation in precipitation (in summer and autumn) from the average in the Upper Iskar between 1900 and 2000 (taken from Knight et al, 2004)

Figure 28: Extreme conditions in the Iskar River basin area - flood

Figures 29: Extreme conditions in the Iskar River basin area - drought

water in Iskar test site considering the local conditions of scarcity and stress (Figures 27, 28, 29).
To decrease the Water Exploitation Index either reducing of the total water consumption and/or better management of the available resources should be achieved (eq.1). The Iskar case study considered both possibilities. From one side, it focused on investigations on efficient water use by the main water consumers – the industry and the households with average of 44,9% and 54,6% of the total water consumption (Figure 25). From another side, it dealt with improving risk (drought and flood) management. As the water is a common value, a multi-level (from citizens to ministers) participatory approach was a core element of the whole Iskar case study.

Water stress mitigation
Five mitigation options were selected to be investigated in terms of their feasibility for the Iskar case study (Table 10).

Table 10. Mitigation options of Iskar case study

Mitigation options	Sector addressed	Contribution to water stress mitigation
Saving water in industry	Industrial	Mitigation of the first focal problem; Decreasing the numerator in Eq.1
Reducing pollution from industrial waters	Industrial	Mitigation of the second focal problem
Saving water in the domestic sector	Domestic	Mitigation of the first focal problem; Decreasing the numerator in Eq.1
Participatory modeling for water management and planning	Horizontal	Management under stress conditions (floods or droughts); Increasing the denominator in Eq.1
Integration of technical and non-technical options	Horizontal	Management under stress conditions (floods or droughts); Increasing the denominator in Eq.1

The results from the analysis and evaluation of the five options for the Iskar test site are summarized below. More details can be found in the quoted scientific publications.

Option 1: Saving water in industry

Kremikovtzi is the biggest steel manufacturing plant in Bulgaria and in the Balkan Peninsula. It is also one of the biggest water users in the region with about 85% share of the total industrial use ($50x10^6$ to $61x10^6$ m^3/year fresh water consumption). The industrial water supply scheme is very complicated and consists of both fresh water and reused water sources. In spite of the many measures taken recently, the amount of industrial water reuse and recycling is still unsatisfactory, considering the state of the art of the technology available. The method of water balance was used to identify the major bottlenecks of the industrial water use (Dimova et al, 2007; Tarnacki et al, 2007). The results were analysed and the conclusions were summarised in the Program of measures for the optimisation of the industrial water utilization in Kremikovtzi. System

Dynamics Modelling has been applied for the simulation of the overall Kremikovtzi water system as well. The SDM for Kremikovtzi was built in stages in a participatory context (Experts ➠ stakeholders ➠ experts ➠ stakeholders…), starting with simpler versions that gradually increased in detail. The SDM model simulated the system, on a monthly basis, considering 23 operational scenarios, corresponding to "normal", "dry" or "very dry" years; varying treated waste water recycling rates, operational rules, priorities and reduction or cessation of production for specific industrial units (Vamvakeridou-Lyroudia et al, 2007, 2008).

*Option 2: **Reducing pollution from industrial waters***

Kremikovtzi has been considered the biggest polluter in the region. The industrial water is used either for indirect cooling of the technological equipment (clean cycle) or for direct cooling of the hot metal and cleaning of the released gases (dirty cycle). The available water quality data were not sufficient for the development of a general water quality balance. Therefore three short-term water quality monitoring programs were developed in the framework of the AquaStress Project, including the main industrial water supply sources (1.02.07- 10.03.07) and wastewater flows from certain industries (May-June, 2007 and December, 2007 – June, 2008). The first two programs monitored the water quality with respect to the following parameters: water flow, pH, oils, SS, COD, NH_4, NO_3, NO_2, total alkalinity, total hardness, Ca, Mg, DS, chlorides, cyanides, Fe, sulfates and manganese. The last monitoring program also included measuring of PAHs and heavy metals: lead, copper, zinc, cadmium, nickel, cobalt, manganese and mercury in certain industrial wastewater flows. 25 monitoring points were selected based on the results of the water balance and the previous analyses of the water quality. The conclusions of these analyses were summarised in recommendations presented in the Program of measures for the optimization of the industrial water utilization in Kremikovtzi.

*Option 3: **Saving water in the domestic sector***

The water saving potential in the Sofia region was examined using a Bayesian networks-based support tool that was gradually developed based on a participatory approach:

- Expert consultation: Ten experts from relevant ministries, academic institutions, the local water company and engineering consultants with experience in water demand management (WDM) in Sofia were interviewed. A semi-structured questionnaire was used to elicit expert knowledge and the interviews were recorded so that the content could be analyzed to provide information suitable for constructing causal maps of WDM issues specific to Sofia. They were further used for the construction of Bayesian network models integrated in the computer-based support tool developed.
- Household surveys: 600 household surveys were undertaken. The survey outputs have been used to populate a number of Bayesian network models for describing

implementation conditions in the Iskar test site.
- Workshop for testing the tool: Ten experts involved in water demand management in Sofia participated in a workshop in July 2007, which was organized in order to test the Bayesian networks-based support tool. The tool was used to support the analysis of three demand management issues: security of water supplies, household demand forecasting, and economics of demand management.
- Support tool evaluation: Following the testing workshop the tool was evaluated on the basis of seven indicators and twenty-six statements in the form of questionnaires. The aim was to elicit the practitioners' perceptions of the tool effectiveness in addressing demand management issues.

The results are in more detail reported in several scientific papers (Inman et al, 2007 and 2008).

Option 4: Participatory modeling for water management and planning

One group of national policy makers, including deputies and ministers, three groups of regional secondary stakeholders (mayors, NGOs,etc.) and two groups of citizens participated in a series of workshops on participatory water management (Daniell et al., 2008, Ribarova et al., 2008). The process established a step by step dialogue among the groups, supporting the expression, exchange and convergence of viewpoints, based on causal models formulation. The steps are as follows:

- The entire protocol was designed based on preliminary experiences and on the expected feasibility in the Bulgarian context;
- All participants were individually interviewed, to collect information on their perception of the water system, the flood and drought associated issues and its control by stakeholders. Results were gathered in semi-open questionnaires or cognitive maps. A knowledge engineering process was used to extrapolate cognitive maps from the interviews, using semantic processing, generalisation with ontologies, and redrawing of maps;
- A series of workshops were organized with the five groups that resulted to a model representation of the water system, identification of the main actors and of preventative actions, definition of actions for the management and adaptation to flood and drought events, description of the visions for the future, design of management options and finally development of strategies;
- The last phase included a distributive vote for all the options, leading to a series of preferred actions to be pushed in a submission for European structural funds.

Option 5: Integration of technical and non-technical options

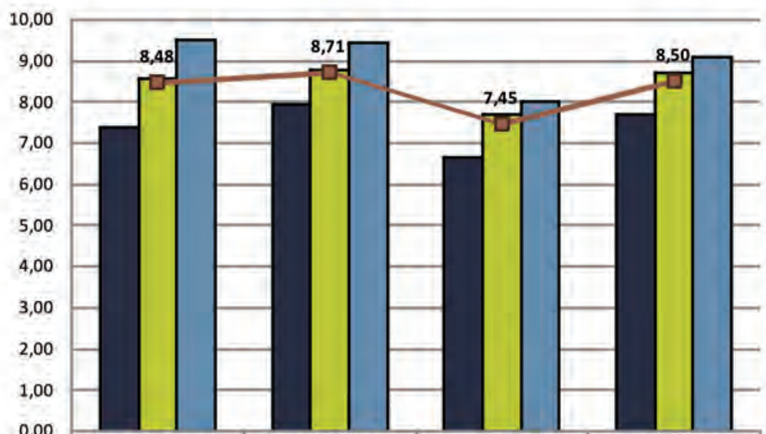
The main aim was to design a methodology which could lead to integrated, operational sets of technical and non technical water stress mitigation options. The notion of integration, which is addressed hereafter, includes three dimensions:

- The combination of the different sub-options is required to achieve water stress mitigation;
- There are dependencies and adaptations of the different sub-options in the set, including synergetic effects; parallel or sequenced activation of the options would not bring about the same effects;
- The options are integrated in space, time and activity sectors.

Evaluation of options

To evaluate the mitigation options, a set of three criteria has been selected by the AquaStress task group and a value in the scale 0-10 was given to the criteria. Fourteen members (out of 14) of the LPSF gave their evaluations. The results are summarized in Figure 30, given below.

This evaluation shows that the "Added value" is ranked with the higher scores for all mitigation options. Also, for all of them the "Innovative character" is ranked between the "EU relevance" and the "Added value", while the "EU relevance" of the options appears as the lowest scored criterion. These results indicate that for the local stakeholders the results are more important at the local level, than at the EU level.



	Options 1 and 2	Option 1 - SDM	Option 3	Options 4 and 5
EU relevance	7,38	7,93	6,64	7,71
Innovation	8,57	8,79	7,71	8,71
Added value	9,50	9,43	8,00	9,08
Average Score	8,48	8,71	7,45	8,50

Figure 30: Evaluation of the options, done by the members of the LPSF

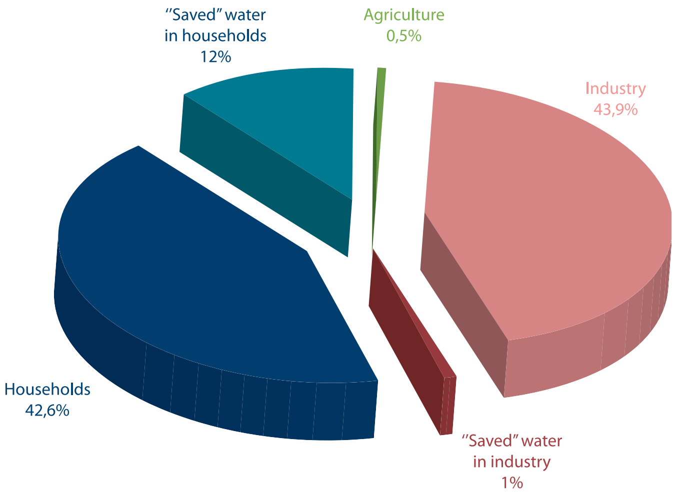


Figure 31: Calculated water saving potential of Iskar test site

Outcomes

The most important practical local level achievement is the assessed potential to save water. The calculations show that if the recommended measures are applied, 1% of the industrial water use and 12% of the household water use could be saved (Figure 31). This amount could be used in agriculture in normal years (scarcity conditions) or can be stored to address water supply problems under drought conditions.

Other significant local achievements include:

- Clarification of the inter-relationships and cause-effect connections among water related problems and identification of the water stress focal problems;
- Development of SDM model for the water flows of Kremikovtzi, which allows fast calculations of different operating and climate scenarios;
- Development of a program of measures for the reduction of aqueous emissions and water use in Kremikovtzi;
- Exploring water saving potential in the households through the developed forecasting household demand and decision making model for Sofia;
- A common action plan adopted by the local stakeholders to cope with floods and droughts in the region.

Added value to EU water stress diagnosis & mitigation

The study of the Iskar test was carried out in the frame of an international project and brought together the expertise of several European research Institutions. It contributed to the enhancement of the knowledge on integrated water management in a rapidly urbanizing and industrial catchment, based on a combination of stakeholder participation and technical expertise. In addition to that, there are EU added value results, such as:

- Extension of the EU industry database: data from Kremikovtzi are submitted for updating of the BREF data base;
- The first ever vertical participatory process jointly addressing floods and droughts, which is transferable.
- Developing SDM for complex water systems and applying for potential water saving scenarios in industry. The model will also appear at a website for System Dynamics Modelling (www.simulistics.com) as an example for water recycling modeling with SDM;
- Two contributions to the development of tools for supporting participatory planning: I) End-user evaluation of Bayesian networks to facilitate participatory planning for water demand management; 2) Development of a methodology to allow end-users (water managers, policy makers, academics) to test and evaluate computer-based support tools.

Lessons Learnt

- When a participatory process is running, the human factor is of first importance. The selection of the individuals to be included in Iskar LPSF and JWT determined the successful realization of the study;
- Integration of practitioners (LPSF) and researchers (JWT) in a collaborative case study group proved to be an effective approach;
- Water stress mitigation is a long lasting process. In this case, the project efforts of four-year resulted in the identification of the focal problems, the selection of appropriate mitigation options and the analysis and evaluation of the applicability of these options in the local conditions. The practical implementation of the research findings requires future resources and time.

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Synergies of water management and ecosystem protection in industrial regions

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Przemsza is the first class tributary of the Vistula river– the biggest in Poland. Its catchment (red spot in Figure 32) is situated at the Silesian Upland and administratively belongs to the śląskie and małopolskie voivodeships. Czarna Przemsza (river length: 64 km: catchment area: 1046 km^2) is considered the source river. In Mysłowice it meets Biała Przemsza (river length: 64 km; catchment area: 875 km^2) and from there the river gets the name Przemsza. Although Przemsza is only 24 km long the entire system is named after it. The whole Przemsza catchment area is 2121,5 km^2 and river length is 88 km. The simplified representation of the river network is shown in Figure 33.

Figure 32: Przemsza catchment

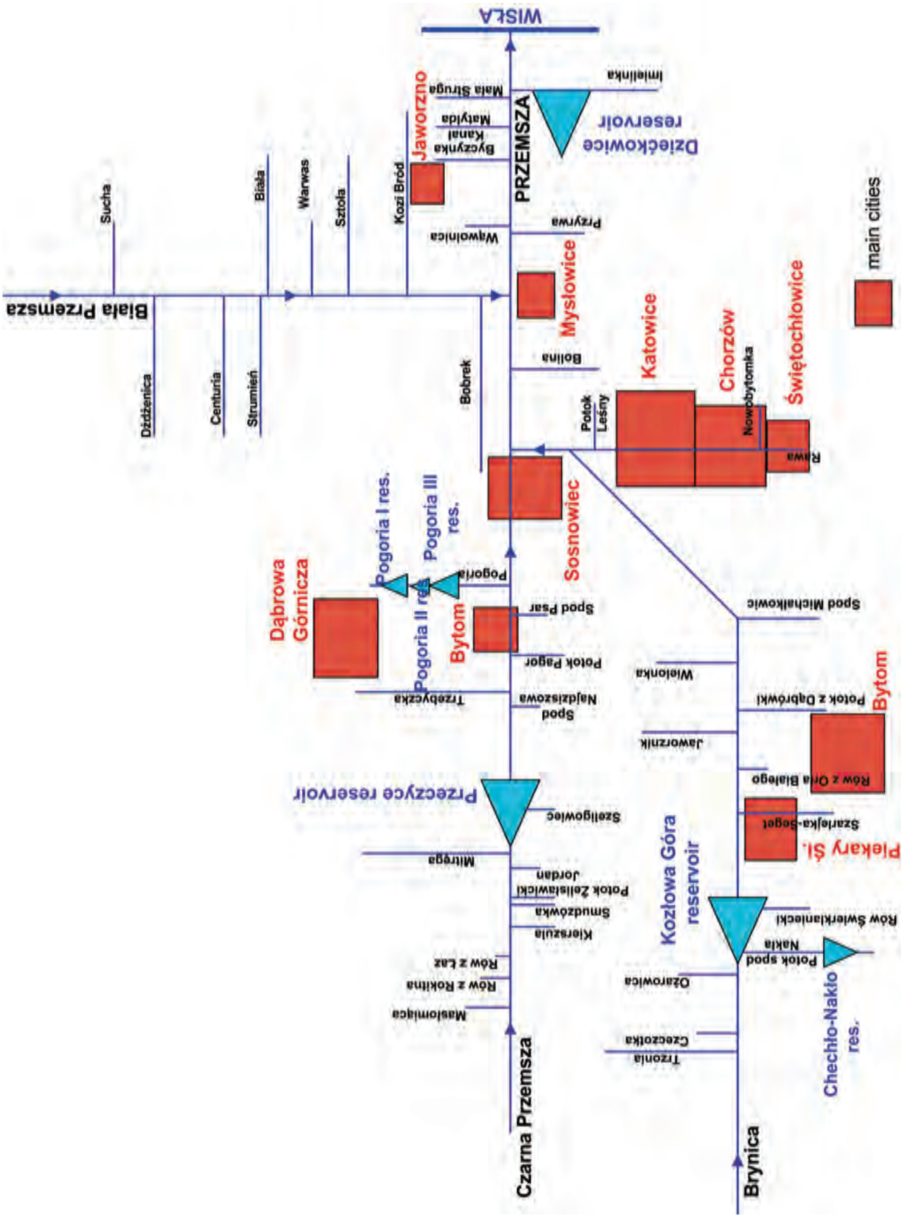

Figure 33: River network in the Przemsza catchment.

The test site area encompasses some of the most populated regions in Poland. Average population density is 584 inh/km^2 but there are several big cities located in the basin with a population density higher than the average (Świętochłowice – 4309 inh/ km^2, Chorzów – 3507 inh/km^2, Siemianowice Śląskie – 2941 inh/km^2, Sosnowiec – 2527 inh/km^2, Katowice – 1953 inh/km^2).

Water stress conditions

Water stress problems in the Przemsza test site are related to the high population density, the high concentration of industrial users and the low public awareness on water stress. The water related problems in the region are extremely difficult to cope with as the decision makers not only have to address residual issues from past failings, but they are also forced to solve a new set of problems generated by the multi - sector transformation of the country.

Available water resources

Average (1977-2001) surface water resources in Poland are 62.0 km^3, which means approximately 1,598 m^3 per capita. This is three times lower than the European and five times lower than the world average. In the Przemsza test site the situation is even worse since the river network is composed of small rivers with naturally low flow capacities whilst the area is very densely populated. Water resources in the test site are influenced by complex hydrological conditions, mainly by draining activity of coal, zinc and lead ore mining as well as by intensive exploitation of groundwater.

The availability of water resources is increased by storing water in artificial water reservoirs. Some are located directly on rivers: Przeczyce (Czarna Przemsza, 20,7 mln m^3) and Kozłowa Góra (Brynica, 15,8 mln m^3) and some are built on sand excavations: Kuźnica Warężyńska (51,1 mln m^3), Pogoria III (12 mln m^3), Dziećkowice (52,5 mln m^3). The total capacity of artificial water reservoirs in the test site is 152,1 mln m^3.

Water use in the domestic, industrial (tourism & production) and agricultural sector

Water demand in Poland has been decreasing the past years, a general trend, especially visible since 1990, for all water users. Permanently raising water prices critically influences water consumption and forces the industrial sector to introduce water-saving technologies in the production process and households to save water and install water meters. The industrial (50,6%) and domestic (46,5%) sectors are the main water consumers in the Przemsza catchment. Agriculture plays a marginal role and accounts only for 2,9% of the water consumed. Water consumption per capita in the domestic sector is 90 lt/day in the cities and 60 lt/day in the villages.

Quality and quantity issues

For many years heavy industry has been changing the quantitative and qualitative parameters of water resources – consequently limiting their availability. The amount of industrial sewage per year is 254 hm^3 and about 10 hm^3 of sewage is directly discharged to water without treatment. Indicative pollution loads in the catchment from the industrial sector for 2006 are: 447502kg/year BZT5, 102225kg/year nitrates, 14945kg/year phosphorus. Extremely intensive anthropogenic drivers affect the ecological status of water resources. In the Przemsza river basin 41 surface water bodies were identified (WFD) [Maciejewski et al, 2005]: 10 of these are classified as artificial and 13 as heavily modified. The majority of the surface water bodies are at risk of not reaching good ecological status by 2015.

Institutional capacity

The new administrative division introduced in 1999 has created conditions more favourable to the regional development and self-government capacity building, by decentralizing authorities and shifting more responsibilities to the local level. It implemented a three-level administrative division: voivodeships, poviats and gminas and gave certain responsibilities to these institutions, also in the field of water management (e.g. water supply, wastewater treatment, maintenance of networks). In addition to these institutions, water authorities are also operating at the catchment scale. Since 1991, water management in Poland is performed by 7 Regional Boards for Water Management (RZGW): water management in the Przemsza catchment is supervised and coordinated by RZGW in Gliwice. The area of RZGW Gliwice jurisdictions is presented in Figure 33.

Infrastructure

Regulations of the early 1990s transferred the responsibility and ownership of water and wastewater utilities from the central state to the municipalities. There are only few exceptions in the country where private investors are involved in the water sector. Water supply in the test site is based mainly on an inter-basin system of regional-scale that was built in late 60s. The system imports water from outside to the Przemsza catchment and is operated by a non-profit enterprise - Upper Silesia Water Enterprise (GPW)- which operates 11 water abstraction units (7 from surface water and 4 from groundwater). GPW abstracts, treats, stores, distributes and sells water to other smaller utilities which distribute water to individual consumers. Besides GPW, there are also 85 local surface and 5 groundwater intakes operated by local water supply enterprises.

Social and economic equity

Even though people in the test site are on the average younger than in other regions in Poland, the local population ages more rapidly than in other regions,

due to the low birth-rate. Registered unemployment rate (2007) is 6,3 %, one of the lowest values in Poland. Living conditions are good; the average monthly gross wages and salary (about 1000 Euro) reaches 120% of the domestic average.
Houses and flats are well equipped with standard sanitary infrastructure and the exemplary costs of living (1 Euro~3,6 PLN) are:
- Cold water from municipal water-line system, 1m^3 – 3,56 PLN
- Electricity for households, 24h tariff, 1kWh -0,43 PLN
- High-methane natural gas for households from gas network, 1m^3 – 2,03 PLN

Environmental protection
Environmental status of the Przemsza basin is extremely diversified: some areas have been completely devastated by chaotic urbanization, industrialization and mining activities, but designated NATURA 2000 Special Protection Areas also exist. It should also be noted that some most valuable nature resources arose there as a result of human activity. Spontaneous regeneration of ecosystems occurs in formerly devastated areas, such as hundreds of incidences of subsidence due to local mining and surface excavations transformed into lakes (Pogoria I, Pogoria III, Morawa, Gliniok, Rogoźnik). Numerous mine spoil-heaps and other wastelands underwent forestation (spontaneous or by planting). In vicinity of Dąbrowa Górnicza and "Katowice" ironwork a large complex of wetlands and meadows has developed with numerous protected plants, including orchids. The ecological status of forest resources in the Przemsza basin has improved in the last decade.
The budget of local self-government entities in the test site is estimated at 778,93 euro per capita, of which 27 Euro are spent for environmental issues.

Water stress analysis and mitigation

Water stress analysis
The draft idea of an AquaStress case study was discussed with the stakeholders during the first official meeting with the LPSF Pilot Group. Since then the definition of the case study underwent refinements but always reflected two prevailing features of the test site: high urbanization and industrialization. The problem tree was created according to the DPSIR framework. On one hand, industry is a key driving force causing serious impacts on water resources but on the other hand its condition strongly depends on national policy and economy and it reflects any changes in these spheres. Therefore, the challenge for the AquaStress project was to provide methodological and technical support for the transition towards more sustainable, integrated and adaptive water management in a region experiencing spectacular transformation of industrial sectors. Within this global objective, 3 sub-objectives were defined that address the regional problems built around water quality, water quantity

and flooding – each one a consequence of industrial activities in the area. The fourth sub-goal was dedicated to the strengthening of the public understanding of water stress and the promotion of stakeholder participation in the water management process.
The Przemsza test site is the extreme example of regions suffering from anthropogenic disturbances. The present state of water resources is the result of many drivers, among which urbanization and industrial development play the most significant role as well as the lack of public participation processes in water management and the limited public knowledge on water stress issues. The situation is seriously complicated by a complex institutional structure of water management as well as unclear and overlapping competencies and responsibilities.
All the above aspects can be met and addressed in the catchment of Biała Przemsza (biggest tributary of the Przemsza River), selected as the focal study area. Territorially the area of the Polish case study is a closed hydrographical unit of 875 km2. Biała Przemsza catchment is an extreme example of conflict between wealth of nature and disastrous human activity.

Water stress mitigation
The Case Study goal was to support the transition to more sustainable, integrated and adaptive water management in a region that undergoes industrial transformation caused by economic and political drivers. Special attention was given to the following issues:

1) Support the modernization of the local water supply systems, which are at present supplied with "clean" mine waters, in view of the foreseen closure of mines.

At present clean waters from zinc/lead mines are the source of drinking water for about 90000 inhabitants. It is foreseen that in the near future (6-8 years) the mines will be closed, and therefore a substitute system of drinking water supply should be developed. Moreover, mine waters are being discharged to the nearest rivers which results in higher flow capacities and better quantitative condition of surface waters. It is estimated that ceasing pumping of mine waters may reduce the flow capacity in some cross-sections down by 70%. It is also foreseen that in case of filling the mines with water the groundwater table will reach its original level, which will cause local submergence of the terrain.
The objectives of AquaStress in this field were to stimulate local stakeholders to undertake activities for defining a new drinking water supply system and to build stakeholders' capability to perform multicriteria decision analysis in order to cope with future real tasks of this kind.
The following steps were undertaken to meet the objectives:
- Identification of a target group: the task involved the identification of the stakeholder groups that are affected by the closing of the mines. These are

local self-government authorities, water supply enterprises, the Regional Board for Water Management; organizations financing water management investments, managers of the zinc/lead mine, environmentalists, NGOs and the local community.
- Formulation of the multicriteria problem: The set of feasible variants, the evaluation criteria as well as the hierarchy of their importance were discussed with the stakeholders in an effort to frame the process of selecting the best alternative water supply system
- Selection of MCA tool: The AquaDT software developed within the AquaStress project was used for performing the multi-criteria analysis. Both the software and the manual were translated into Polish and distributed among stakeholders. In addition, two training sessions were organized with representatives of the Regional Board for Water Management and from 3 out of four self-governmental authorities (gminas) involved in the project.

2) Improvement of the effectiveness of industrial wastewater treatment
The analysis of industrial water use and waste water production was performed using three tools:
- A quantitative – qualitative model for the identification of impacts on water resources. The model was used to identify the present state of water resources as well as to simulate the what-if scenarios that correspond to various water quality improvement measures. The results were visualized in the form of hydro-chemical profiles presenting water quantity and quality parameters along the river course.
- Monitoring of water bodies. Control studies of the surface waters were performed in the basin, using a sample protocol, considering the expected

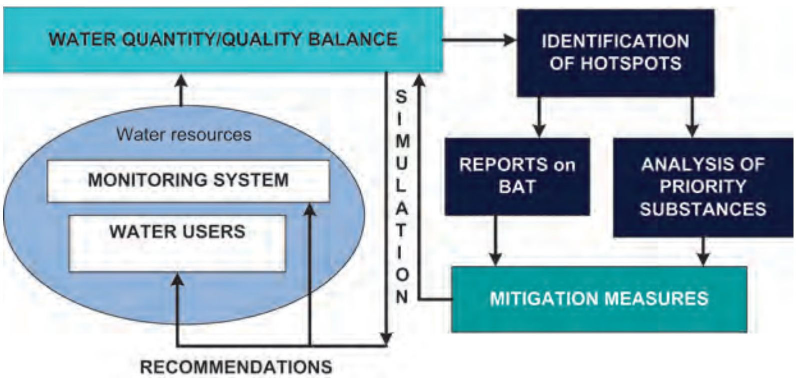

Figure 34: Conceptual framework to water stress mitigation in an industrial catchment

pollution with certain priority substances (cadmium, nickel, lead, mercury, PAH), and other parameters (pH, CODCr, specific conductivity, chlorides, sulphates, general iron and volatile phenols). Additionally, two samples were collected from river sediments in the Bobrek River, which inflows high volumes of industrial waste to Biała Przemsza. The analytical study was performed by the accredited Laboratory of the Central Mining Institute in Katowice (Korczak et al, 2007), and

- Use of the BREF/BAT documents that characterize the best available techniques in various industrial sectors in order to define and implement an integrated strategy for preventing industrial pollution. The analysis was performed for a tannery plant representing an industrial sector with potential water pollution risk.

Specific objectives were the identification of the focal points and ineffective users, making recommendations for efficient wastewater treatment and reuse, and the proposal of a suitable monitoring network. These tasks are integrated as illustrated in Figure 34 and concluded to a set of recommendations which were grouped into 4 categories based on: (i) quantitative-qualitative balance model, (ii) water monitoring, (iii) BREF/BAT documents, (iv) others (Druzynska, Nachlik eds, 2008).

3) Strengthening local authorities with legal and administrative capacity to resolve the 'Flood Protection vs. Ecology' conflict

It was a challenge for the AquaStress experts to help local decision makers to answer the following questions:

- What are the benefits for the general public from reducing flood risk, maintaining biodiversity and improving recreational river access?
- From which of the above (flood prevention, protection of biodiversity and recreation) does the Polish public derive the greatest improvement in welfare?
- Which are the necessary conditions for economically efficient policy making regarding their management?

The answers were provided through the application of an economic valuation technique known as the Choice Experiment Method (DEM) [Birol et al, 2008]. Initially the survey questionnaire was commonly prepared with the LPSF and subsequently 192 households were interviewed, resulting in 1536 choices. In addition to the choice experiment, the survey also collected socio-economic data of the respondents. The data were used to calculate the increase in welfare derived from improving each of the attributes and particularly the marginal WTP.

The results revealed that there are significant welfare improvements from flood risk reduction, which are higher than those from improving river accessibility for recreational reasons and conserving biodiversity. This can be translated as the local population preferences for use values derived from

flood reduction rather than use and non-use values from recreation or biodiversity conservation. Aggregation over the population of Sosnowiec shows that local residents are willing to incur an increase in local taxation of 2,693,416 zloty per year to reduce flood risk.
The results of the CEM and WTP methods were used for making recommendations about the necessary technical and legal changes for developing a reasonable (environmentally, economically and socially accepted) strategy for the investigated area

4) Strengthening of public understanding of water stress and building capacity for integrated water management
The scope of this activity was to:
- Involve stakeholders and the public in the decision making processes regarding water management;
- Develop a common understanding of water stress in the test site and to reach agreement on the key issues; and
- Provide examples of good practices for integrated water management.

Training and dissemination workshops were organized that covered the issues of "Setting Up Strategies for Strengthening Gender Integration in Water Management" and "Decision Support System for Integrated Water Resources Management (IWRM)". Furthermore, two summer schools were organized to educate young people on water management issues.

Outcomes
The crucial outcome of the Polish case study is that the stakeholder based approach assured the definition of rational and acceptable water stress mitigation options. In particular, the Przemsza Case Study process contributed to:
- The enhancement of stakeholder and public involvement in water management:
> Increased awareness on the importance of water stress and the urgent need for its mitigation;
> Creation of the local initiative. The cooperation among the internal stakeholders consortium partners is on-going;
> Promotion of good examples of local initiatives focused on water stress mitigation;
> Involvement of the public in the process of solving the "flood protection versus environmental protection" conflict;
- The training of water managers and stakeholders on tools applied in integrated water management:
> Ability to formulate and solve a multicriteria decision problem;
> Training for applying the in AquaDT tool;

> Popularization of a catchment scale balance model as a tool that enables the assessment of the present water quality state and the identification of all hazardous polluters;
- The compilation of guidelines and recommendations for water stress mitigation in the test site:

> Definition of best practices for the industrial sector, based on the BREF/ BAT documents;

> Recommendations for the improvement of the existing water quality/quantity monitoring system (conclusions based on the results of the balance model for the Biała Przemsza).
- Application of economic analysis for solving the 'Flood Protection vs. Ecology' Conflict.

Added value to EU water stress diagnosis & mitigation

The activities undertaken within AquaStress were focused on providing methodological and technical support for solving local water stress problems that are related to water supply, water quality and flood protection in a region experiencing spectacular transformation of the industrial sector. The Case Study resulted to the development of tools and guidelines of European relevance:

- A Balancing Model of Pollution Loads – a tool, addressed to water manages, that enables the assessment of the ecological state of water resources under different what-if scenarios;
- Guidelines on "Integration of Catchment Modeling and Industrial Pollution Control to Mitigate Water Stress" dedicated to the integrated mitigation of water stress in a catchment affected by industry;
- Guidelines for the application of a non-market valuation study to equip local authorities with the capacity to address conflicts involving the protection of unique ecosystems in areas affected by mining activities.

Lessons learnt

- The contribution from sociologists is important during the design of a participatory process, in order to take into account the special characteristics of each stakeholder group.
- The commitment of stakeholders to the project declined during the case study process and, as a result, new means of involvement were used in order to ensure their participation.
- Industrial users are reluctant to open their databases just for research needs; thus, it is difficult to form a comp2

Further reading

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Participatory planning in water management

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The test site area is the service area of the water board Velt en Vecht, which is part of the Dutch Vecht Basin. Figure 35 shows the Vecht Basin, which is situated partly in the Eastern Netherlands and partly in Germany. The service area of Waterboard Velt en Vecht covers an area of 900 km2 and includes two specific areas of interest (indicated in green in Figure 35): the Natura2000 areas of Bargerveen and Vecht/Lower Regge.
The area is mostly rural; half of the 200 thousand inhabitants live in the towns Coevorden and Emmen (province of Drenthe), and Hardenberg and Ommen

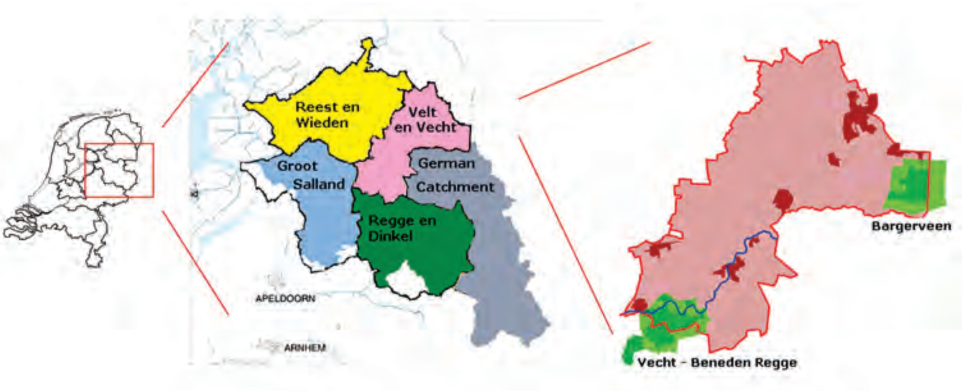

Figure 35: The Netherlands (left), the Vecht Basin (middle) and water board Velt en Vecht (right). Highlighted in green (right) are the specific areas of interest.

(province of Overijssel). The area is relatively flat; and surface levels vary from 35 m above m.s.l. in the north-east to 2 m above m.s.l. in the south-west.

Land use characteristics:
The dominant land use is agriculture (67%; 60.600 ha). The rest of the area coverage includes woodlands and nature reserves (14%), regions with combined use of agriculture and nature (14%) and urban areas (5%).

Soil types
The area soils date to the Pleistocene and Holocene. The main soil types are peat soils (ca 45 %), sandy soils (ca 45 %) and clay soils (ca 5 %).

Water stress conditions

The area is situated in a moderate climate zone, with rainfall exceeding evapotranspiration on a mean annual basis, and with possibilities of surface water supply from the Rhine. These characteristics put water stress issues in this area in another league than what is experienced in e.g. the Mediterranean region. Still, water stress plays an important role. Firstly, though water stress is not a yearly, structural event, it does recur regularly during summer periods. Secondly, climate change models point towards increased frequency and severity of such occurrences. And finally, the

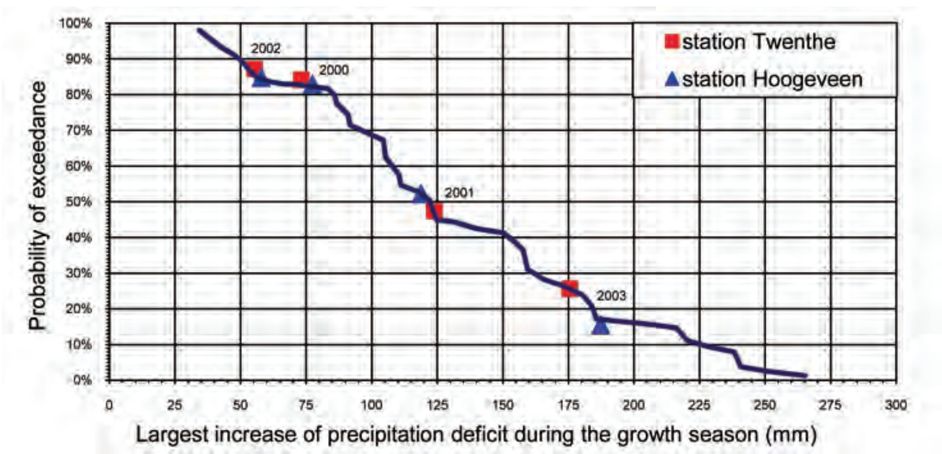

Figure 36: Probability of exceedance as a function of the precipitation deficit for two meteorological stations near the Vecht test site area.

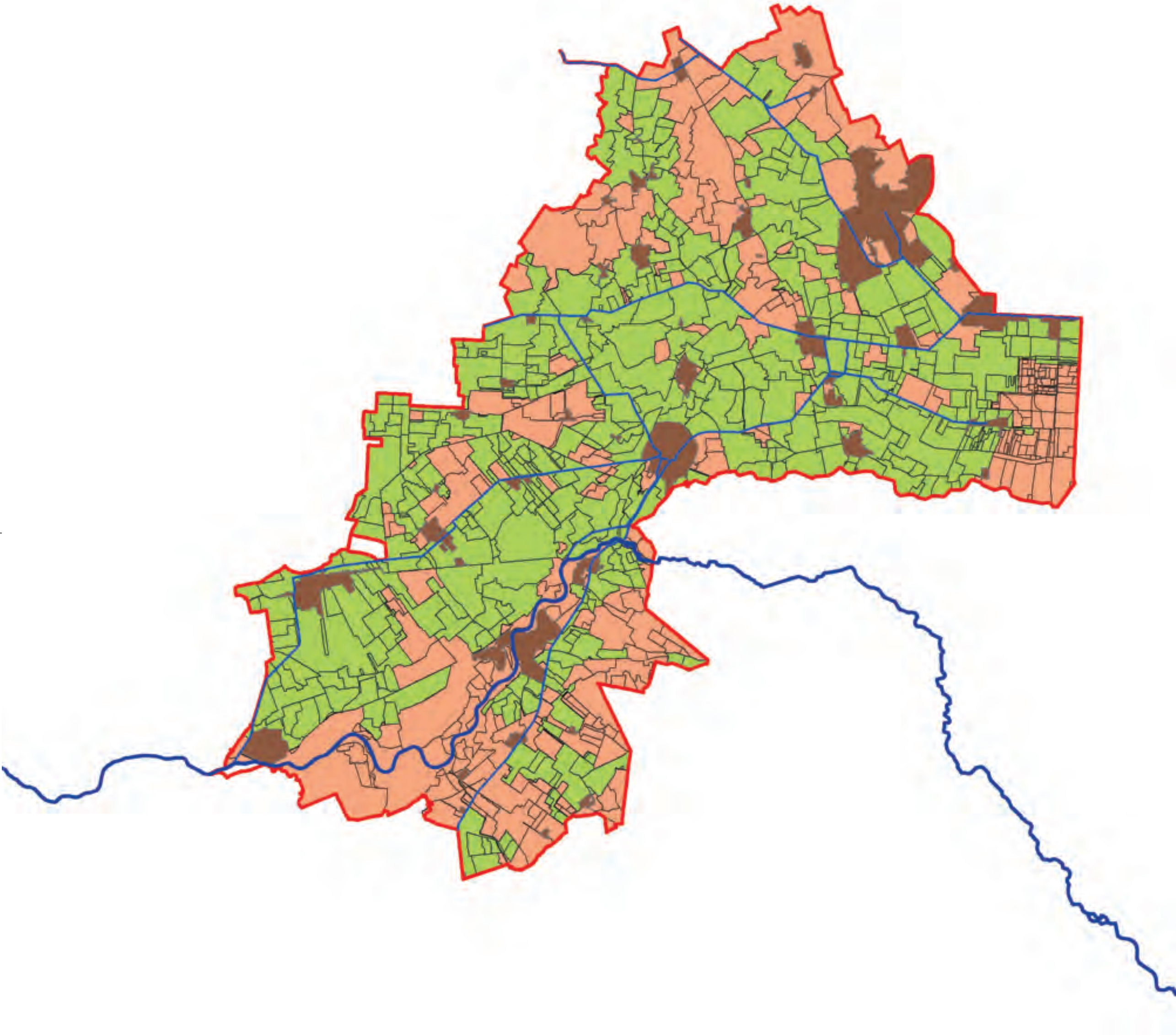

Figure 37: Service area of the water board Velt and Vecht that can (in green) and cannot (in red) be reached by the surface water supply system

intensive land use of the area and the corresponding high economic, ecological and societal values have put water stress and water surplus issues high on the agenda of water managers and land use planners.

Available water resources

The mean annual precipitation is 780 mm and the mean annual potential evapotranspiration 450 mm. So on average, yearly precipitation exceeds yearly evapotranspiration. However, as evapotranspiration mainly takes place during the summer season (April to September) and rainfall patterns can be erratic, summer droughts and the related water stress situations occur at certain intervals. This is illustrated in Figure 36, which shows the probability of exceedance as a function of the maximum precipitation deficit for two meteorological stations in the region.

Subsidiary to the precipitation, a surface water supply system (fed by the Rhine) was constructed. The map in Figure 37 shows the service area of this supply system (in green).

Water use in the domestic, industrial (tourism & production) and agricultural sector

The main water users in the area are agriculture, which is supplied by the surface water system and superficial wells, and nature areas. Groundwater is used for supplying the domestic sector, whereas some smaller abstractions supply water for industrial purposes.
Even when taking these groundwater extractions into consideration, the water use for domestic, recreational and industrial purposes is small when compared to those for agriculture and nature. These types of water demand have never been under threat as a result of prolonged droughts.

Quality and quantity issues

The main water stress problems identified in the Vecht Test Site can be summarized and categorized into issues of:

• Water quality
> Nutrients pollution from agriculture and brown rot (bacterial infection rendering the water unfit for irrigation of potatoes)

• Water quality
> Groundwater shortage for use in agriculture and limitations in the water supply system
> Structural desiccation of natural lands as a result of drainage for agriculture (9.000 out of 12.000 ha are in excessively dry conditions).

The main issue addressed in the Vecht test site was water quantity. By the end of the 20th century, a nation-wide effort was started to re-define the optimal surface and groundwater levels. A uniform and interactive approach was designed for this purpose, the so-called GGOR-process. GGOR stands for Balanced Surface and Groundwater Regime. The main topic of the Case study was the development of a GGOR for natural lands in a Natura 2000 area and their surroundings, namely the Bargerveen area. The second topic was the analysis of the water supply system of the whole service area of the water board.

Institutional capacity

In the Dutch part of the Vecht catchment, four water boards are responsible for the regional operational water management (discharge of water, maintenance of surface water levels, and surface water quality), whereas two water boards are responsible for the management and maintenance of the river Vecht itself.

Since the thirteenth century water boards administer the dikes, local embankments and polders. Twenty six (26) water boards existed in 2007. The water boards have a legally defined responsibility for flood protection and water quantity and quality management in their territory that in some cases incorporates the management of waterways, bridges and roads. Water boards are functional governmental bodies, formed based on the rule 'interest-payment-say'. The distribution of seats in the water board among landowners, residents and wastewater dischargers is defined by this rule.

A number of other organizations in the Dutch part of the Vecht catchment have responsibilities with respect to water management. Rijkswaterstaat, which is part of the national government, is responsible for the national water policy, including flood protection, water supply, water quality and shipping routes. It acts on a strategic level. The Vecht catchment is situated in two provinces, Drenthe and Overijssel. The provinces undertake the regional coordination of large projects such as GGOR and the WFD implementation, and are responsible for groundwater management. The municipalities in the catchment are responsible for the drainage of public areas and the transport of sewage effluents to purification plants. Finally the drinking water companies are responsible for the supply of drinking water.

The German part of the catchment is situated in two 'Bundesländer' ('states' that have their own policy terrains and responsibilities): Niedersachsen and Nordrhein- Westfalen. Each 'Bundesland' has its own water organizations. For strategic management there are the Bezirksregierung Münster and the Bezirksregierung Weser Ems in Meppen. They are called the 'Obere Wasserbehörden'. The so-called 'Untere Wasserbehörden' have a policy making task. These are cities and other groups that have formed 'Kreise': Kreis

Grafschaft Bentheim and Kreis Borken. Finally there is Stadt Gronau (a city not represented in a 'Kreis') and many small 'Wasser und Bodenverbande', that take care of the operational water management.

Infrastructure

The water network in the area is primarily aimed at discharging the rainfall surplus. For this purpose, an intricate system of subsurface drains, ditches and canals, regulated by weirs and pumping stations, has been constructed.
As the area is relatively highly elevated and consists partly of drought-prone, sandy soils, water shortages do occur. To solve this problem, a water supply system for agricultural use was constructed in the 1980s, in reaction to the severe drought of 1976. This system transports water either from the IJssel River (a branch of the Rhine) through a canal system and a number of pumping stations to the southern part of the Water Board's service area, or through a similar system from Lake IJssel through the provinces of Friesland, Groningen and Drenthe to the northern part of the Water Board's service area.
At the farm level, the water that is supplied by the water supply system either infiltrates the soil by gravity, or is pumped and sprinkled. A number of farmers have shallow wells that they may use for sprinkler irrigation from groundwater. Surface water supply to natural areas is not considered an option, because the quality of the supplied water is insufficient.

Social and economic equity

The development of a GGOR (Balanced Surface and Groundwater Regime; see above) follows a procedure authorized by all governmental bodies involved. The procedure formalizes that the water regime should strike a balance among the demands of different users. The GGOR is developed in close co-operation with the stakeholders, but the operational management decisions are taken by the water board officials.

Water demand is managed and regulated by a number of instruments:
- Drinking water fees are paid as a fixed sum plus a price per m^3;
- Farmers connected to the water supply system pay an extra fee to the water board. This sum is not dependent on the amount of water used;
- For large groundwater extractions a fee is due to the Province. Small extractions (including all extractions by farmers) are free of charge; the only obligation is to have them registered;
- The regional water supply is a result of negotiations among neighbouring water boards, the national administration, and water users' associations. The results are reflected in 'water distribution agreements'. However, the scenarios in these agreements only cover the early stages of water shortage

situations, insofar as the administrative measures needed are within the scope of authority of these partners. Examples are suspension of sprinkling from groundwater or surface water;
- When supra-regional appraisals and actions are needed, decisions are made at the ministerial or even government level.

Environmental protection

Environmental protection policies, rules and regulations are of paramount importance in the whole case study area. The province, which has the responsibility of groundwater management, has to deal with the impacts on groundwater of abundant fertilizer use in the past, while keeping groundwater abstractions to a sustainable level. Surface water management has to comply with the WFD provisions and a main issue is the conflict resolution on water allocation among different land uses.

Within the study area there are two Natura 2000 areas: Bargerveen and Vecht/Regge (see Figure 35b). Once the designation of these regions is ratified by the Dutch national government (due in 2009), the exact limits and the management goals will be defined and put down in a management plan for each area. An important aspect of these management plans will be water management, as defined in the GGOR. This implies a European dimension to GGOR, insofar as they are related to Natura 2000 areas.

In 2005 the Dutch Nature Protection Act came into force, in which the protection status of the Natura 2000 areas is defined, amongst others. The Nature Protection Act applies to all activities and plans that may have significant negative impact on the Natura 2000 areas. This includes, for example, agricultural activities such as the use of fertilizers in areas bordering the Natura 2000 areas.

A special feature of the Bargerveen area is that its eastern boundary is in reality the Dutch-German border. As a Natura 2000 area, the Bargerveen is also protected from all activities in Germany that could endanger the ecological status of the area. However, there are no legal instruments available to enforce the implementation of active protection measures on the German side. Therefore co-operation based on a voluntary and synergy-seeking basis was sought.

Water stress analysis and mitigation

Water stress analysis

Despite the highly intricate water management system that has been developed in the past, not all users' demands are always met. Structural lowering of groundwater tables, due to the agricultural water use, has led to desiccation problems for nature; in other areas, water table elevation in nature areas causes yield losses to neighbouring farmers. Furthermore, in the future, increased claims on water and decreased water availability are expected, which could lead to water stress situations during summer periods. The impacts of the sub-optimal state described above, and of the pressures on water resources, are grouped in three main categories:

- Economic impacts, mainly expressed as income losses in agriculture;
- Ecological impacts, mainly referring to quality losses in nature conservation areas as a result of lowering of the groundwater tables;
- Social impacts, here briefly characterized as increasing conflicts among different types of stakeholders who share boundaries.

Therefore, the focal issues identified in the Vecht area are defined as follows:

1) How can water management practices be optimized, taking into account the sometimes contradictory needs of all involved stakeholders.

This issue was addressed in two specific areas, namely two designated Natura 2000 areas (see Figure 35). For these two areas, the Water Board is the leading authority for the design of a new water management plan. This plan should optimize surface and groundwater management to meet the goals for nature development within the area, while at the same time meeting – as much as possible – the demands of land users in the surrounding areas.

2) How does the water supply system exactly function in terms of effect on groundwater in- and outflow, what are the impacts of climate change on water demand, is the present water supply system able to cope with these changes, and if not, what adaptations are needed and on what time horizon.

This issue involves an analysis of the water supply system. This analysis was performed using a newly released integrated groundwater/surface water model called MIPWA.

Water stress mitigation

The issue of optimizing water management was addressed in the two Natura 2000 areas, Bargerveen and Vecht/Lower Regge. The main findings, presented in this report, stem from the Bargerveen area, whereas the Vecht/Lower Regge area was mainly used as a reflective experience. A peculiarity of the Bargerveen study was that in the past three projects dealt with the definition of a water balance among the various users/demands. All of these attempts failed; the most recent effort failing due to the refusal of some decision makers to accept the results of the interactive process. This bad experience led to feelings of mistrust among stakeholders. For this reason, the interactive process in the Bargerveen was designed with utmost care to involve all relevant stakeholders, including future decision makers, and to try to keep them on board. The following options were proposed, tested and evaluated:

Mitigation option 1:
Interactive planning as a tool to develop mitigation plans. This option involved intensive involvement of stakeholders, and monitoring and evaluation of the process. The ex-ante evaluation of this option was performed by the Regional Partner and AquaStress experts. Because of the bad experiences in the past, this option was considered necessary and was accepted without much discussion.

Mitigation option 2:
Hydrological and land use measures to bridge the gap of water demands between different types of land use. Options involved are: creation of a hydrological buffer zone in the Dutch and German neighbouring areas, construction of a vertical screen, closing field ditches, and farm reallocation. The assessment of the hydrological effects of these options was performed by a team of hydrological experts. They updated the available mathematical model and adjusted it to the questions asked in the case study. The results were discussed with stakeholders and based on their comments new calculations were made. Such feed-back took place three times.
For the second focal problem, related to the functioning of the water supply system, the third option was defined as:

Mitigation option 3:
Surface water supply as a tool to reduce groundwater outflow and prevent yield reduction. This option was merely expert-oriented, because only water managers from the region were involved in its organisation and evaluation.

Outcomes

An important result of the project was, that after years of fruitless discussions, finally all stakeholders accepted the plan resulting from it. What is even more important is that the decision makers who are responsible for financing the plan (estimated costs: 20 million euro) are making all necessary efforts to ensure its implementation.

The recommendations from the project are defined at three levels.
At the level of proposed options in the Bargerveen/Natura 2000 project, the most relevant recommendations are to:

- Install a buffer zone of 500 m width in the south rim of the Bargerveen area;
- Re-allocate 2 or 3 farms to find the necessary room to create this buffer zone;
- Optimize water management for agricultural purposes in the area south of this buffer zone;
- Continue the discussions with German authorities to optimize water management on the German side of the Bargerveen.

At the level of interactive planning the most relevant recommendations are to:

- Try to involve the future decision makers in the process and to not underestimate the efforts this requires;
- Observe the 'rules of the game' that were derived from this process (see Bots et al., 2008)
- Adjust the quality and detail of computer models used (if any) to the quality and detail of the answers that are required.

At the level of the water supply system, the most relevant recommendations are:

- To continue monitoring the system and optimize the monitoring network;
- That the water supply system does not require major upgrades in the near future.

Added value to EU water stress diagnosis & mitigation

- Water stress is to a large extent a man-induced problem and in that sense largely independent of climatic conditions. The Vecht case goes to show this, because water stress is felt as a severe problem by nature managers, even though the regional climate would not suggest this.

Water stress problems must be tackled in close cooperation with the stakeholders.

- EU policies, such as in the Vecht case the Natura2000 policy, have a strong impact even before their implementation. This may have paralysing effects on stakeholders during the time in which the consequences of the policy are not clear. This period should be kept as short as possible. For stakeholders it is important to know what they are up to.

Lessons learnt

- Identify the decision makers early on in the process and seek their active involvement. As long as there are big uncertainties and/or conflicts, organize this involvement by inviting members of the decision makers' support staff. The persons having the authority to decide on (funding for) measures should be involved as soon as (but not before) uncertainties and conflicts have been sufficiently resolved and feasible solutions emerge from the debate;
- The Natura 2000 policy, even though not yet fully operational and limited in its direct legal implications, has been an important driver in this project. It cast its shadow over future agriculture practices in areas bordering the Natura 2000 area itself, thus coercing farmers to look for solutions for fear of being worse off;
- Appreciate the interactive process as a social process, rather than a technical exercise;
- Monitor and evaluate the interactive process, and provide timely feedback to the process manager and process sponsor;
- Adjust the efforts for development and application of computer models to the demands and information requirements of the process;
- Surface water management can be an effective way to reduce groundwater outflow;
- Stakeholder participation contributes to the substantive quality of policy development.

Further reading

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Part 3

Conclusions

Contents

AquaStress Case Study results

The AquaStress Case Study approach enabled a stakeholder driven water stress characterization and mitigation process, based on the social, cultural, environmental and economic aspects of the eight Test Sites. The identification of the critical water management problems was performed in accordance with the existing European water and environment-related management policies, in an effort to combine the experiences from the different sites and to define generally applicable solutions for similar water stress problems. In particular, the AquaStress Case Studies yield a number of outcomes, outlined over the following paragraphs.

Promotion of a new water culture

The main aspects of water stress mitigation within the project were the need for integrated, proactive and participatory water management, thus facilitating the introduction of a new water culture to the local societies.
Integration was achieved through the analysis of both demand and supply oriented measures, including technical, economic and institutional options. Stakeholders acknowledged the value of water conservation measures, as a means for ensuring the sustainability of local activities. Furthermore, the participatory process of defining water stress case studies and the public awareness events (e.g. workshops and summer schools) advocated a new water use and management paradigm. The various aspects of valuing water were presented to the stakeholders and the need for a political and social commitment to sustainable water use was emphasized.

Water management at the local level

The guiding policy framework for sustainable water management, the EU Water Framework Directive, defines the basin area as the spatial scale of analysis and promotes participatory water planning. In reference to these

provisions, the project supported water planning at the local level with the establishment of the Local Public Stakeholder Fora.
Community based water management is part of the currently promoted process of decentralization. However, neither decision makers nor the public are aware of the means and the processes for achieving effective local water management. AquaStress contributed to this effort, by introducing the issue and providing appropriate tools to the stakeholders involved in the project.

Definition and analysis of water stress
The Case Studies enhanced the knowledge of project partners and stakeholders on water problems and suitable mitigation options. Indicative mitigation options that were implemented within the project are: Integrated surface and groundwater management; Tailoring crop patterns; Pollution control measures; Promotion of environmentally friendly practices and technology; Water pricing policy implementation; Strengthening of institutional frameworks; Establishment of monitoring networks and enforcement mechanisms.

Improved knowledge sharing and capacity building
The participatory process followed in the project enabled the interaction and information/knowledge exchange among stakeholders, who discussed in depth and reached consensus on commonly acceptable mitigation options. Training sessions on water management issues were organized that were either addressed to stakeholders (workshops) or to young people (summer schools). Furthermore, the stakeholders became accustomed and were trained to use a variety of water management tools, which can assist their efforts towards sustainable and integrated water management.

Test Site specific recommendations for water stress mitigation
The virtual and real implementation of mitigation options produced a series of results; indicative examples are:

Flumendosa: The value attached to water resources (in terms of water quality and environmental flow) by the farmers is low;
Guadiana: Farmers in the Test Site highly value the artificial aquifer recharge and call for EU subsidies for changing crop patterns and irrigation practices;
Iskar: Improving recycling rates of treated industrial wastewater, particularly in dry years, can promote the sustainable operation of industrial units;
Limassol: Aquifer recharge with reclaimed water and the implementation of sustainable agricultural practices can be achievable in combination with an effective public participation process;
Merguellil: Farmers have a strong preference for policy change to stabilize the

water table level (collective systems and water pricing) provided that transparency and independent monitoring are guaranteed;
Przemsza: Local residents are willing to incur an increase in local taxation in order to reduce flood risk;
Tadla: The implementation of a joint irrigation project can enhance cooperation among stakeholders and provide the starting point for a shift towards more sustainable agricultural practices;
Vecht: Water stress is an issue also faced in areas which do not experience water shortage; participatory planning can enhance water management and contribute to policy development in these regions.

These results were integrated in the compilation of Test Site specific outputs, including guidelines and policy proposals for effective water stress mitigation.

Recommendations of wider relevance
The AquaStress Case Study process and results are of wide relevance: (i) the tools and methods applied were selected in accordance to the EU legislation provisions and guidelines (e.g. public participation process based on WFD guidelines, integration of new CAP into agricultural scenarios), (ii) the process followed (e.g. characterization of water stress, selection of mitigation options based on certain criteria, guidelines for applying and evaluating options etc) is coherent and adjustable to any conditions, and (iii) the evaluation results can be taken into account while modifying existing water policies or framing new policy.
Table II below demonstrates the specific topics addressed in the AquaStress Case Studies.

Table II. Issues addressed by the AquaStress Case Studies

Case Study	Waste water reuse	Sustainable agriculture	Economic instruments	Public participation	Water management	Environment	Technical options	Economic options	Institutional options
Flumendosa		×	×	×		×	×	×	
Guadiana	×	×	×	×			×	×	
Iskar				×	×		×		×
Limassol	×	×	×	×			×	×	
Merguellil		×	×	×			×	×	×
Przemsza			×	×	×	×	×	×	
Tadla		×		×	×		×		
Vecht				×	×	×	×		×

Evaluation of mitigation options

Water Stress in agriculture

Agriculture is the main water consumer worldwide and the sector to be most affected by anticipated water scarcity. The conflict among irrigation, urban demand and environmental protection is expected to be more intense in the future, emphasizing the need for developing efficient water use strategies in the agricultural sector.

The AquaStress experience indicates that efficiency of both demand (e.g. best irrigation practices, crop pattern) and supply (e.g. reclaimed water use) measures is required in order to sustain agriculture as an economic backbone in the Test Sites. The majority of mitigation options were assessed as having a medium difficulty in implementation and demand of resources; therefore, the improvement of water use in agriculture is a feasible goal. Options for which a general change in the water culture is a prerequisite (e.g. reclaimed water use) are difficult to implement, due to the long time society and political conditions need in order to adapt to new challenges in the field of water management.

The conflict between water conservation and profit is evident in the case of the option "tailoring cropping pattern". The option was examined in four case studies and had a negative impact on economic aspects in two of these. This result is attributed to the fact that the analysis of the option was mainly oriented to water quantity aspects (for example in the Tadla Case Study the option had a negative impact on water quality).

Table 12. Qualitative summary of mitigation option evaluation

List of mitigation options		Evaluation WQL	WQN	ECN	ENV	DIF	RES
Reduce fertilizer use	Guadiana	+++	-	++	+++	MD	MR
	Flumendosa	++	+/-	++	++	ND	SR
	Merguellil	++		+	++	MD	MR
Tailoring cropping pattern	Guadiana	-/+	+	+	++	MD	MR
	Flumendosa	+/-	+	-	+	MD	MR
	Tadla	---	+++	+	--	MD	SR
	Merguellil	++	+/-	-	++	MD	MR
Best agriculture practices (Removal of undergrowth, Adapt crop locations to soil profiles for a better use of rainfall, Irrigation scheduling)	Guadiana	+	++	++	+++	MD	SR
	Flumendosa	+/-	+	+	+	ND	SR
	Merguellil	++	++	+	++	VD	
Reservoir management	Guadiana	++	+	++	++	VD	MR
	Flumendosa	+/-	--	--	+++	MD	MR
	Merguellil	++	++	+	+	VD	LR

Wastewater/ reclaimed water reuse	Guadiana	-	+	-	-/+	VD	MR
	Limassol	+	+++	+++	+	MD	LR
Conjunctive management of groundwater and surface water	Vecht	+/-	++	-	+/-	MD	LR
	Guadiana	++	+	+/-	-	MD	MR
	Tadla	+	++	++	+/-	ND	SR
	Merguellil	+	++	+++	++	MD	MR
Sustainable irrigation water management (Minimizing water losses in agriculture, irrigation scheduling)	Guadiana	+	++	+	+	ND	MR
	Tadla	--	+++	--	+	VD	SR
	Merguellil	+/-	++	++	++	MD	MR
	Limassol	+	+++	+++	++	MD	MR
Water pricing	Guadiana	-\+	-	-	++	ND	SR
	Merguellil		+	++	+	ND	SR
Improved irrigation system performance in collective systems	Merguellil		+	++	+	ND	SR

Participatory process to support joint irrigation projects	Tadla	---	+++	++	+/-	MD	MR
Fostering the integration of women in agriculture water management	Merguellil		++	++	+	VD	LR

The tables in this section summarize the evaluation results of the mitigation options examined within AquaStress, in terms of:

- Impact on water quality (WQL), water quantity (WQN), economic (ECN) and environmental (ENV) issues;
- Difficulty (feasibility) of implementing the option (DIF); and
- Resources (cost) needed for implementing the option (RES).

These tables were created from qualitative expert opinion and by assessing actual experience in the AquaStress Test Sites.

The divergences in the evaluation results in each case study are indicative of the socio-conditions that prevail in the Test Sites and the policy priorities already set in the regions.

Categories for the evaluation of mitigation options

Evaluation in terms of impact

--- For large negative impact
-- For medium negative impact
- For low negative impact
+/- For neutral impact (none or very low positive impact)
+ For low positive impact
++ For medium positive impact
+++ For large positive impact

Evaluation in terms of difficulty in implementation

ND Not difficult to do
MD Medium difficulty
VD Very difficult to do

Evaluation in terms of needed resources

SR Few resources/small cost
MR Medium resources/cost
LR Large resources/cost

Water Stress in the domestic and the industrial sector

The main issues associated with water management in the domestic and industrial sectors are wasteful use and the discharge of untreated wastewater. Even though determining solutions to these problems may be easy (e.g. water conservation devices, wastewater treatment), their implementation is often difficult, mainly due to economic constraints. That is why all the examined mitigation options have a positive impact on water issues, but also assessed as difficult to implement and with high demand for resources. Both case studies on industrial water demand (Polish and Bulgarian case studies) represent regions that are in a transition period. The experience from these Test Sites can serve as a learning platform for regions facing water stress problems emerging from rapid and intense industrialization under the framework of economic development. The main message is that domestic/ industrial water saving and pollution prevention are feasible and should become a priority in order to achieve water security.

Table 13. Qualitative summary of mitigation option evaluation

List of mitigation options		Evaluation WQL	WQN	ECN	ENV	DIF	RES
Saving water in industry	Iskar	+/-	+++	Not studied	+/-	MD to VD depending on the particular measure	SR to LR depending on the particular measure
Reducing pollution from industrial waters	Iskar	++	+	Not studied	+/-	MD to VD depending on the particular measure	SR to LR depending on the particular measure
	Przemsza	+++	++	+++	+++	VD	LR
Saving water in the domestic sector	Iskar	+/-	+++	Not studied	+	MD to VD depending on the particular measure	SR to LR depending on the particular measure
Alternative water supply systems	Przmesza	+/-	+/-	-	+	MD	SR
Improved industrial wastewater treatment (new waste water treatment technologies, water saving, monitoring network)	Przmesza	+++	++	+++	+++	VD	LR
Enhanced ecosystem protection by using economic instruments	Przmesza	++	++	+++	+++	MD	MR

Participatory water management

Participatory water management is a time consuming process and its effectiveness is highly dependent on the tools and methods used for integrating stakeholder perceptions on water planning (e.g. consultation, active involvement etc). The participation process aims both at informing people on water management aspects and at involving them in the process of solving water problems. The main outcome of the former is a new attitude resulting to more efficient water use, as illustrated by the positive impact participatory options had on water issues. For the latter, stakeholder involvement is based on two main premises: the existence of a policy framework that promotes public participation, and the availability of resources (human, technical and economic) for performing the participation processes. In cases of inadequate institutional frameworks (e.g. some regions in Northern Africa) the participatory options are assessed as very difficult to implement. The evaluation of the resources needed is solely based on the selected tool for participatory planning: single awareness creation events, to frequent workshops, public surveys.

Table 14. Qualitative summary of mitigation option evaluation

List of mitigation options		Evaluation WQL	WQN	ECN	ENV	DIF	RES
Stakeholder involvement in defining optimum surface & groundwater regime per user	Vecht	+/-	++	+/-	++	MD	LR
	Merguellil	+	++	++	+	MD	MR
Evaluation of system robustness under different land use & climate change scenarios	Vecht	+/-	+	+/-	+/-	ND	SR
	Merguellil	+	++	+	+	VD	LR
Inform & educate public on water stress issues	Vecht	+/-	+	+/-	+	ND	MR
	Przmesza	+	+	+	++	ND	SR
Participatory modelling for water management and planning	Iskar	+	+++	++	+++	ND to VD depending on the particular measure	SR to LR depending on the particular measure
	Przmesza	+	+	++	++	MD	SR
Institutional Change and the Role of Community	Tadla	+	+	+	+	SD	LR
	Merguellil		++	++	+	VD	VD

Conclusions

Case study research is widely used in order to describe and analyze the real life implications of policy interventions and measure implementation. The main goals of this Case Study process are (i) to examine the links and cause-effect schemes in a real life context, and (ii) to evaluate the outcomes of these interventions, or even to assess whether there are any outcomes. The analysis of single case studies can yield specific recommendations defining policy priorities in order for the interventions to be successful and acceptable by the wider public.

The AquaStress Case Studies served both aspects and have contributed to the definition and mitigation of water stress in three important respects:

1) Case Studies were analysed using a transdisciplinarity approach, aiming to a mutual learning process between stakeholders and scientists. The interaction of Joint Teams of stakeholders and project partners was designed in a form that promotes cooperation in the analysis of water stress, towards the definition of scientific valid and acceptable by stakeholders solutions.
   - Case studies enabled the use of a common framework for the analysis of water stress. Thus, the results could be compared and analyzed in terms of transferability of the recommendations.
   - Furthermore, they integrated stakeholder perceptions with respect to water stress and increased their awareness on water stress issues.

2) Case studies supported the decision making process. In AquaStress, decision support was viewed as a process rather than a tool, where modeling/ simulation/ computer aided analysis was used for illustrating the effect of water stress mitigation options. Reaching decisions on the most efficient water stress mitigation practices was aided by a multicriteria analysis performed by the stakeholders.
   - The empirical evaluation of mitigation options has been based on a participatory process.

- Decision makers were familiarized with scientific tools that could be of value in their field.
- The tools acted as a means of interaction among scientists and stakeholders.
- The full involvement of stakeholders in the process of defining and analyzing the mitigation options has enhanced the objectivity of the Case Study scientific results.

3) Case Study results formed a preliminary knowledge base on water stress mitigation. Site specific results could be of value for use in any region with similar water stress conditions, whereas the overall assessment of options can pinpoint priorities to be set by water managers in the field of water stress mitigation.

- The effect of a variety of technical and non-technical mitigation options was examined in a wide range of socio-economic and environmental conditions.
- Specific policy recommendations were made in the fields of sustainable agriculture, industrial water use and water pricing policy.

This document has been developed within the framework of the AquaStress project on "Mitigation of Water Stress through new Approaches to Integrating Management, Technical, Economic and Institutional Instruments" (Contract n°: 511231). AquaStress is an Integrated Project funded by the European Commission through the 6th Framework Programme for research, technological development and demonstration (RTD) under the "Global change and Ecosystems" thematic sub-priority. AquaStress, coordinated by CNR-IRSA (Italy), includes 37 partners ranging from research councils and universities to SMEs, NGOs, national and international organizations involved in water resources.

This document belongs to a series of final outputs having a horizontal value across the complete set of project activities, collecting experiences at the Test Sites and defining recommendations to implement integrated water stress mitigation options:

- Guidance on Water Stress Mitigation;
- AquaStress booklet on Water Stress Mitigation Case Studies;
- Quality assurance & Testing of the I3S: an integrative challenge;
- Water saving in industry, agriculture and economical instruments;
- Enabling Water Stress Management by public participation;
- AquaStress folder with thematic flyers.

For further information about the project visit the official web site http://www.aquastress.net

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