The AquaStress Integrated Solutions Support System: I3S

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1. Introduction

Computerized frameworks have become essential in integrated assessments, using individual models that can be linked, re-used and maintained through a software infrastructure using state-of-the-art developments from information technology (van Ittersum and Wery, 2007). In current Integrated Water Resources Management (IWRM) they play an important role as well (e.g. Wien et al, 2006). For that reason, it was decided to give the development of such a framework a prominent role in the European AquaStress project (www.AquaStress.net).

AquaStress (2005-2009) is a research project funded by the European Commission (EC). 38 European partners (including Morocco and Tunisia) participate in the project. AquaStress generates scientific innovations to improve the understanding of water stress from an integrated multi-sectoral perspective to support:

- diagnosis and characterisation of sources and causes of water stress;
- assessment of the effectiveness of water stress management measures and development of new tailored options;
- development of supporting methods and tools to evaluate different mitigation options and their potential interactions;
- development and dissemination of guidelines, protocols, and policies;
- development of a participatory process to implement solutions tailored to environmental, cultural, economic and institutional settings;
- identification of barriers to policy mechanism implementation;
- continuous involvement of citizens and institutions within a social learning process that promotes new forms of water culture and nurtures long-term change and social adaptivity.

The project aims to deliver enhanced multidisciplinary methods enabling all those involved in the delivery and use of water to participate in the mitigation of water stress. Both the environmental and social aspects of water stress and the remedies available are covered. The project is organised around eight test sites which have their own problems and stakeholders, with the consequence that the results will be specific to the study areas and stakeholders involved. Nevertheless, it is hoped that it will still be possible to draw a number of general conclusions from the project.

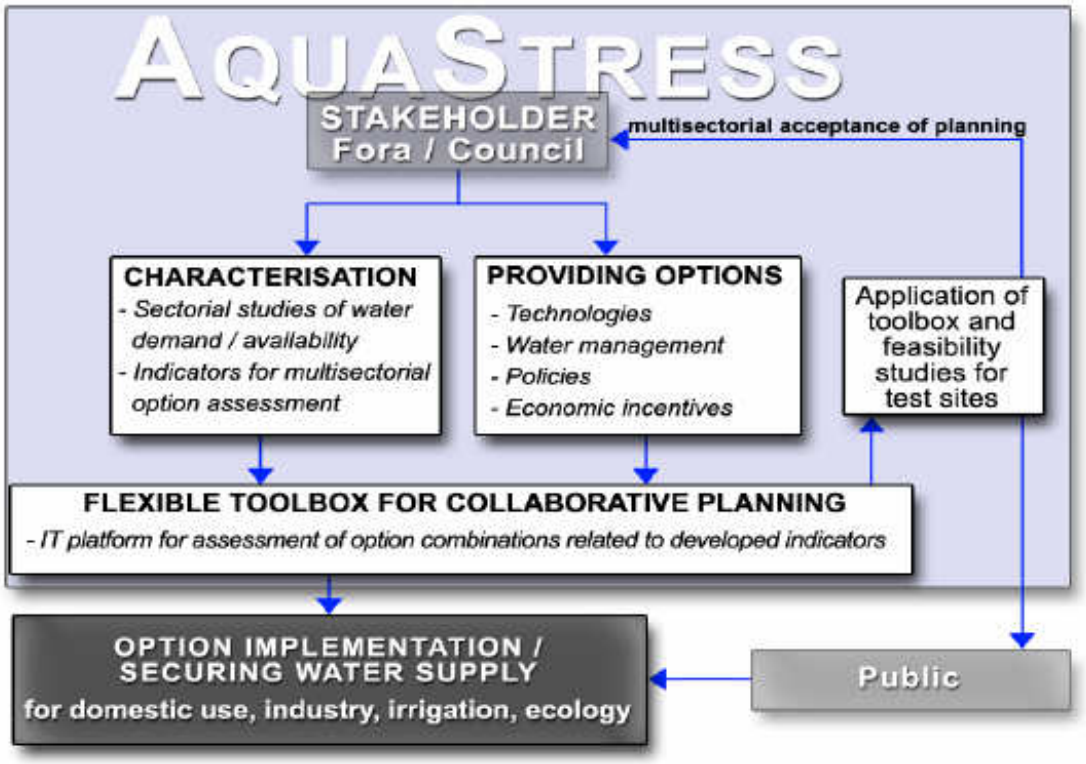

Figure 1. Schematic overview of the AquaStress project.

Aquastress adopts a Case Study - stakeholder driven approach and is organised in three phases; (i) characterisation of selected reference sites and relative water stress problems, (ii) collaborative identification of preferred solution options, (iii) testing of solutions according to stakeholder interests and expectations (see figure 1). It makes a major contribution to the European Communities objectives stated in the Framework Programme 6th, and supporting the Community Directive 2000/60/EC and the EU Water Initiative.

To draw together the results of the AquaStress project and deliver them in a usable form, a computerized framework, called "Integrated Solutions Support System" (referred to as I³S), is being prototyped and tested. I³S is a web based software environment that brings together data, information, knowledge, new tools and legacy software which are all being used or developed by the partners and stakeholders within the AquaStress project.

The purpose of this paper is to report on the development of I³S to date. After defining the objectives of I³S in chapter 2, in chapter 3 the concepts of data sharing followed in I³S as well as the development requirements in the setting of an international consortium are described. Chapter 4 provides a description of the functionality of I³S and describes the achievements and draw backs in the development process.

2. Objective of I³S

The overall aim of I³S is to enable those who need water of adequate quality and those who are charged with its delivery to find acceptable practical solutions to water stress problems. In the AquaStress project the key science and knowledge outputs of project partners is brought together in I³S, to deliver these outputs to the user community and hence assist stakeholders to resolve problems arising from water stress. Moreover, the selection process of water stress mitigation options is to be facilitated by providing a suite of tools that can effectively support a variety of steps in such a process. This is challenging because the users are often competing for a finite and diminishing water resource and in addition their level of understanding of the problems, the available solutions and their recognition that changes to their current practices will be necessary, varies widely. A similar range of skills and knowledge exists on the deliverers' side.

I³S should be a flexible toolbox that supports the various steps in a collaborative planning process (see 3.2). Some of these steps require tools for stakeholder interaction (e.g. gaming tools), others involve both simple and complex modelling or support a selection of improved sets of options for mitigation (Wien et al, 2005). I³S should enable the stakeholders to work through their water stress problems, arrive at a viable and acceptable solution and then implement it.

3. Methods

3.1. Sharing and connecting data, information and knowledge

In order to manage water resources in an integrated way, the sharing and linking of data, information and knowledge should be facilitated by human interaction and computerized frameworks. The data-to-wisdom pyramid (Ackoff, 1989) explains the concept how data develops to wisdom (see figure 2). Modern solution support systems like I³S make use of all layers in this concept, realizing that different layers of the knowledge pyramid can be seen as layers with increasing value (Clark, 1997).

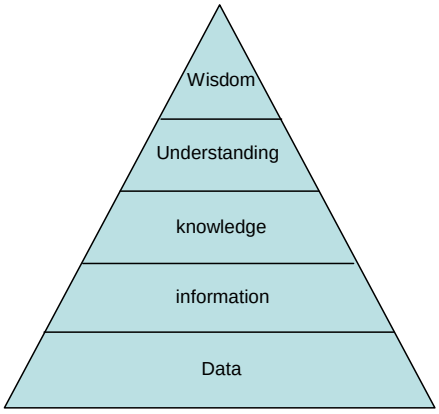

Figure 2. The data to Wisdom pyramid (Ackoff, 1989).

Wien *et al.* (2007) summarised the relationship among these concepts as follows:

"Data can be defined as 'a set of discrete, objective facts existing in symbolic form that have not been interpreted' (Davenport and Prusak, 1998). Data becomes information when it has been shaped by humans into meaningful and useful form (Laudon and Laudon, 1998). Information is meant to shape the outlooks and insights of the receiver (Davenport and Prusak, 1998). So information is data that is enriched by context. Information gives answers to the *what-question*. Information only becomes knowledge after it has been examined and compared to other information or data, and then is applied to describe or predict or adapt a situation (Kock et al, 1997). Knowledge gives answers to the *how-question*."

For the development of I³S these concepts have been translated to the context of the AquaStress project. I³S is made to access, modify and use all these different sources (eg. data, information and knowledge) and to create added value by combining them.

3.2. Description of the development process

In AquaStress a collaborative planning process approach is chosen to achieve shared and acceptable water stress mitigation options. A simple schematization of the collaborative

planning process is presented in figure 3, which in general consists of a closely interlinked 'planning process' path and 'information delivering' (Wien *et al*, 2005).

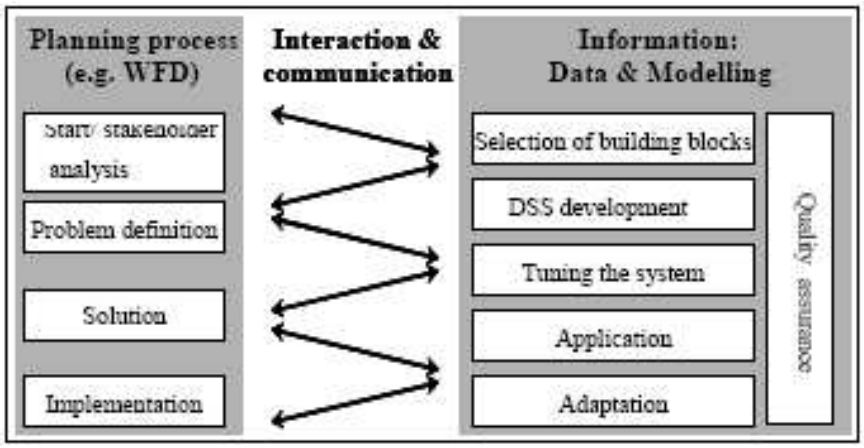

Figure 3. Simplified representation of the participatory planning process.

For partners of the AquaStress project this means that there is the need to share agreed definitions of water stress mitigation options, water stress indicators and test site descriptions. These shared concepts can be stored in the knowledge base for future use. However, populating the knowledge base is something which can take place before any participatory process starts. There is a wealth of information available of scientific value, which can help during the participatory process. In addition to that, all stakeholders (water managers, affected citizens, NGO's, competent authorities, modellers, etc) should be able to collaborate and learn from each other in defining the participatory processes and to play a part in simple and complex modelling. To match this with the software development process, influence on the project planning and management is required and regular contact amongst stakeholders and system developers is a prerequisite.

A complicating factor within the AquaStress project is that the system development of I³S is done within a consortium of eight European partners in accordance with all 38 project partners and joint working teams in eight different countries. Although optimal use of technical infrastructure (internet, Email and teleconferencing) is helpful, frequent human interaction (like conferences, workshops and informal work sessions) is an essential, but costly, requirement for successful development. The concept of interaction design (van der Wal et al, 2003) is used for system development in AquaStress.

3.2 System requirements

The I³S functionality is largely determined by the sharing and process requirements as described above. The design of I³S provides a framework, allowing existing technologies and knowledge to be brought together to provide a structured problem solving support system. It has three main components: *i)* a system for guiding the stakeholders through

the process of analyzing and solving their problem, *ii)* an interface to manage data, information and knowledge, and *iii)* a set of (linkable) tools and stand-alone applications which the stakeholders may need in the process of solving their problem. Linkable means that information can be passed directly among the tools or through a common database and/or knowledge base. Stand-alone means here that the application has no connection to other applications, nor does it share information through the common knowledge base and/or database.

An overall architecture has been designed. It is component based, with each component having very clearly defined interfaces. This has made it possible to assign the development of new or existing components to individual partners within the project, allowing the project to exploit their strengths. Two aspects of standardization are essential for this: a common interface and a common ontology.

The OpenMI standard (Gijsbers and Gregersen, 2005), developed by the HarmonIT project (http://www.harmonit.org), can be adopted as the means of real-time data exchange among relevant components. To enable the exchange of semantically enriched data ontology is used to define the main concepts in AquaStress. Based on the assumption that existing components should also be usable by I³S, an xml based query and presentation tool is developed as well data exchange format based on XML is defined. By adopting a framework approach in which all the components are replaceable, it will be possible to produce a version of I³S that is tailor made to the specific needs of the AquaStress stakeholders.

For the use of a common ontology, experiences from the HarminQua project are used in I³S. A common ontology helps to formalize the knowledge captured in and/or between models, in order to subsequently facilitate model development, testing and documentation (Scholten et al, 2007), model reusability and exchangeability (Rizzoli et al, 2005), separates knowledge captured in the model from the actual implementation in a modelling language or software e.g. Java, FORTRAN, Mathlab, STATA, etc. (Gruber, 1993) or from the data in a database (Zander & Kächele, 1999).

4. Results

4.1. Architecture and design of I³S

I³S is a web-portal application that provides entry points for the various components of the system. These can be fact sheets on the tools and information available in the system, but where appropriate, it will directly connect to specific web-services, or it will provide a link to stand-alone application. Within AquaStress a variety of data, models and other tools are used to collect data and knowledge and to conduct research. I³S brings these scientific outputs together as a mixture of web-based and stand-alone applications. Figure 4 shows a screen dump of the web portal application.

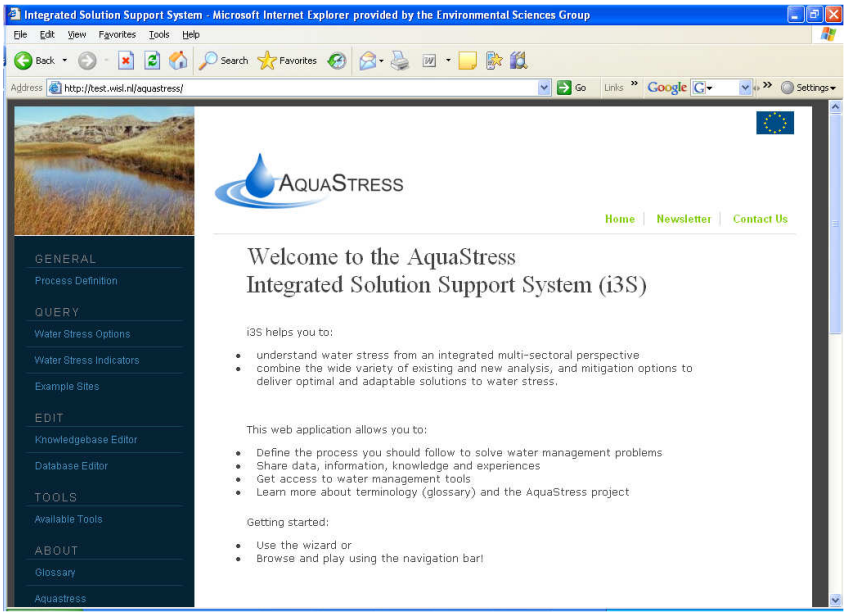

Figure 4. Screenshot of the i3S prototype web application.

The functional design of the I³S is given in figure 5. Documentation on use cases and the logical design is given in a separate AquaStress report (Gijsbers *et al.*, 2006).

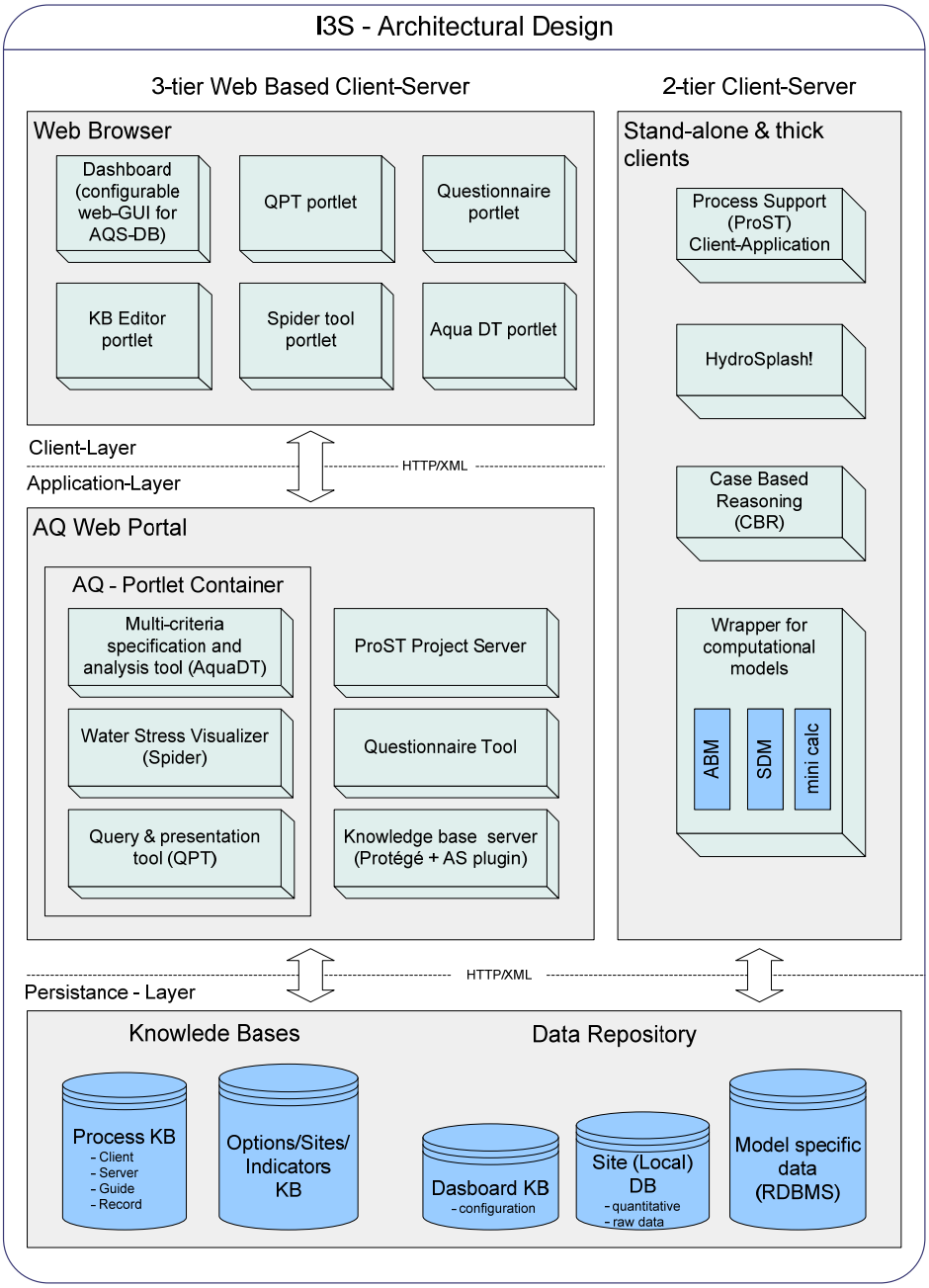

Figure 5. Conceptual view on the I³S Architecture (Kassahun et al., 2008)

To implement this functional design, it has been chosen to develop the different components at different places, making agreements on the standards for data exchange and communication between different components. In most cases, it concerns the development of existing software and database structures towards the I³S environment.

In this project, a knowledge-based and process-based approach is being followed. The knowledge bases enables gathering, structuring and sharing of semantically rich

information while the process definition guides the stakeholders through their problems. To define the process, the Process Support Tool, ProST, which is a more generic version of the MoST-tool developed by the HarmoniQuA project (Scholten, 2007) is used. AquaStress specific data and information is opened up by a newly developed tool, called the Query and Presentation tool (QPT). QPT is an xml based application that allows for distributed database and knowledge base consultation and editing and simple modelling.

Standalone applications and (loosely) tools that are incorporated in I³S are the Questionnaire tool, Case Based Reasoning, Multi Criteria Analysis (AquaDT), Systems Dynamic Modelling (SDM), Data Uncertainty Analysis (DUE), Water Management Game (Splash!) and Cognitive mapping (De Zeeuw *et al.*, 2007).

4.2 Process results

In practice, the collaborative planning process within the AquaStress is less structured and successful than anticipated. The following aspects complicate the development process:

- The need to share and use data, information and knowledge by project partners in the context of a European project, is not always seen by the parties involved. In many cases these parties are heavily involved in their own sites and related problems without realising that there is much to learn from similar areas. This seems especially valid for the local stakeholders;
- Although data has the lowest value in the data-wisdom pyramid (see 3.1), it seems the most difficult layer to share, as it very often concerns the property of non-project partners, not allowing for in kind contributions.
- A particular challenge in developing the I³S was the involvement of end-users. In our vision, much generic expert knowledge and some tools required early in the process should have been available at the start: work-flow management tools, virtual games and questionnaire functionalities. In the case of AquaStress these needed to be developed (and populated), while the participatory processes started immediately. Hence the I³S was not yet available at the beginning of local site studies. We recommend that in end-user driven projects serious thought must be given whether or not available information needs to be organized prior to starting the participatory process;
- Stakeholder involvement requires the continuous organization of human interaction. Much responsibility was put on what we could refer to as 'self-organizing' teams in test sites. The scientific partners in the Aquastress project were supposed to deliver options and indicators, which then could be integrated in the Knowledge Base. Because of the previous point and the fact that it was difficult to synchronise the activities between the different involved participants and test sites in the project, this resulted in a delay in the information flow towards the knowledge base. As a result of this, the knowledge base has played a less important role than foreseen in the project. However, the concept still stands and is something we see as a strongpoint of the project.
- The concept of interaction design requires a base of trust and understanding which is only obtained through frequent contact between developers;

To account for these observations, modifications have been made to meet these issues. Successful interventions have been:

- Site visits are organized to all eight test sites by a representative of the software developers group. This has stimulated willingness to share and participation in the system design.
- Within 6 months four technical work sessions (three days each) for a small group of developers have been organized, where people physically sit together and work on solving development issues. In practice much time is required to avoid misunderstandings that are never solved by electronic contact.

5. Conclusions

The concept of I3S is innovative in its way to link data, information, knowledge and tools. This makes the collaborative process itself less dependent or hindered by the limitations and inflexibility of many contemporary decision support tools. In practice most constraints in successful integrated solution support are caused by the development process, rather than by technical design. The willingness and awareness for the need to share data, information and knowledge needs continuous attention, human interaction is a key-factor for success and limited freedom in project management complicates the need for an optimal collaborative planning process.

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