New tools for Integrated Sustainability Assessment: The World Cellular Water Game[1]

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1 Paper to be presented at the 2007 Amsterdam Conference on the Human Dimensions of Global Environmental Change "Earth System Governance: Theories and Strategies for Sustainability" on 24-26 May. See http://www.2007amsterdamconference.org/

Abstract

New methods and tools are needed to gain information about social paradigms in order to inform policy-making in the context of sustainable development. Such tools should allow both policy-makers and the broader public to reflect upon the (un)sustainability in the utilization of a critical resource such as water. Furthermore, such tools should allow for reflection upon societal transition patterns - involving issues of conflict and collaboration, and the emergence of new power structures and institutional rules - inherent to sustainable development. Finally, such tools need to be amply used and shared by the relevant publics so that the lessons learnt can become meaningful to stimulate adaptive action. Games are particularly well suited for that purpose. This paper reports on the development of a new gaming tool to support the Integrated Sustainability Assessment of water. The gaming tool forms part of an overall model framework called World Cellular Model (WCM), which gives a multi-scale representation of *agents* (as cells) and their interactions, the uses of water stocks and flows, and the resulting impacts on the socio-ecologic system. Game players are represented as policy actors operating within a society dealing with issues of water management. The goal for each player is to 'survive in a sustainable world'. That is, one has to find a balance between its individual interests and the collective interest of sustainability. Apart from 'standard' negotiation on water management options, this involves a reflection phase in which various assumptions underlying the water management discussion – such as basic needs, and the fundamental trade-offs across functions, space and time – are critically assessed. In this paper we provide the concepts underlying the game design. We furthermore present a first prototype of the game developed for the case of water management in the Ebro river basin in Spain. We discuss the opportunities and pitfalls encountered so far, and discuss the potential of gaming in the context of social learning for sustainable development. Our research is part of the EU project MATISSE.

Key words: Integrated Sustainability Assessment, participatory Agent Based Social Simulation, water management culture.

1 Introduction

Integrated Sustainability Assessment (ISA) is a new, innovative concept for sustainability assessment (Weaver and Rotmans, 2006). It complements existing forms of sustainability assessment by supporting longer term, and more strategic policy process to explore persistent problem of unsustainable development. Rotmans (2006) argues that this new concept requires new tools to overcome three main challenges: 1) representing societal transitional patterns arising from interactions within the institutional, technological, socio-cultural, economic, and ecology systems, 2) represent dynamics across multiple scales, and 3) involve stakeholders in the tool development and application. As a guiding principle, new tools should be developed with the so-called triple *I* approach in mind: *I*nnovative, *I*ntegrative and *I*nteractive.

In this paper we argue that one of the most promising approaches for new tool development is the integration of Integrated Assessment Modelling and participatory Agent Based Social Simulation for the development of innovative games. Integrated Assessment Modelling (IAM) is a modelling paradigm typically aimed at addressing complex problems of sustainable development. IAMs try to describe as much as possible the cause-effect relationship of a phenomenon (vertical integration), and the cross-linkages and interactions between different contextual circumstances and processes (horizontal integration), including feedbacks and adaptations. IAMs generally take the form of a system dynamics computer model, which may or may not include an explicit spatial dimension. Recent examples of IAMs addressing issues of water management are the AQUA model (Hoekstra, 1998), WaterGap (Alcamo, Döll et al., 2003), and QUEST (Carmichael, Tansey et al., 2004).

Integrated Assessment models are typically designed from a holistic view, aiming to address the social, economic, environmental and institutional dimensions of a problem, and their interlinkages, in a comprehensive way. The dynamics of social and institutional change, however, are most difficult to grasp and are often underrepresented. In the AQUA model, for example, human policy-making is represented as an imaginary governmental actor, who allocates financial resources and performs other intervention to influence the human and environment system (Hoekstra, 1998). The approach elegantly incorporates different consistent management styles along different cultural stereotypes, but does not include the dynamics through which this management style may change.

For a better representation of the human dimension in IAMs, Van der Veen and Rotmans (2001), and Moss, Pahl-Wostl et al. (2001) proposed to extend the IAM framework with Agent Based Modelling (ABM). ABM can be considered an umbrella term for various agent based modeling approaches (Agent-based modeling, Agent-based social simulation, Multi-agent-based simulation, Multi-agent simulation, Agent-based social simulation, see (Hare and Deadman, 2004)) in which social entities are represented as computer agents acting upon their social and natural environments. Various practical ABM application have been developed (see Bousquet and Page, (2004), Hare and Deadman (2004), and

Edmonds and Mohring (2005) for an overview). A number of them focus on water management issues, such as household water demand (Barthelemy, Moss et al., 2002; Athanasiadis, Mentes et al., 2005; López-Paredes, Saurí et al., 2005), agricultural water use (Barreteau and Bousquet, 2000), lake eutriphication (Janssen, 2001), river basin management (Delden, Luja et al., 2005), and hydraulics (Valkering, Rotmans et al., 2005; Espinasse and Franchesquin, 2005).

Although some agent based applications are strongly inspired on socio-psychological behaviour theories (Jager, 2000; Valkering, Rotmans et al., 2005), the practical agent architectures of current ABMs remain fairly simple. Hare and Deadman (2004), for example, conclude that decision making models based on simple sets of heuristic rules and that social interactions tends to be implemented in terms of nearest-neighbour imitation algorithms. Due to this property, the models are particularly suited to assess the emergence of complex global behaviour from simple local interactions. However, they seem to fall short to adequately assess fundamental societal changes emerging from complex interactions highly reflexive agents operating at multiple scale levels.

In those cases, the participation of stakeholders in the development and application of the ABM may improve the quality of the results. This approach is referred to as participatory agent based social simulation (participatory ABSS) (Ramanath and Gilbert, 2004; Pahl-Wostl and Hare, 2004), also referred to as companion modelling (Barretau, 2003). Participatory ABSS typically serves two main goals (Barretau, 2003). One the one hand, they are directed towards understanding complex human-natural environments, in which the production of knowledge is the central aim. On the other hand, they are aimed at supporting collective decision-making processes and social learning, in which learning, negotiation, perspective sharing, and the development of adaptive group strategies for problem solving play a central role (Pahl-Wostl and Hare, 2004). One typical example of participatory ABSS is the Zurich water game (Pahl-Wostl and Hare, 2004) – developed as part of the EU FIRMA project - which was used to improve the communication between actors of urban water management. Another example is given by (Gurung, Bousquet et al., 2006), who showed that their companion modelling approach helped to resolve water sharing conflict between farmers in Bhutan.

In this paper we aim to further develop the approach by developing a gaming tool for the case of the Ebro river Basin in Spain. The gaming tool forms part of an overall model framework called World Cellular Model (WCM). This conceptual framework gives a multi-scale representation of *agents* (as cells) and their interactions, the uses of water stocks and flows, and the resulting impacts on the socio-ecologic system. The specific aim of the gaming tool is to facilitate a structured dialogue amongst stakeholders using the modelling tools provided with the WCM framework. In this dialogue, stakeholders are stimulated to reflect upon the un-sustainability in the utilization of water, and on the dynamics of social and cultural change underlying possible changes in water use behaviour.

This approach complements the existing work on participatory ABSS in two ways. First, and in-line with the ISA requirements, it aims to including transition patterns in the field of water management. Here, we focus on the issue of cultural change within such a transition, in relation with competition, collaboration, and evolving power structures amongst the main stakeholders involved. Second, our approach explicitly addresses the issue of multi-scale by including both individual and collective actors in the assessment.

There are a number of practical reasons why the specific format of a game is chosen to support the Integrated Sustainability Assessment process:

- Stakeholders are *represented* in the game as *game players*, so they can observe and reflect upon their own and each others behaviour.
- Stakeholders *interact* with each other in a structured way through the *rules of the game*
- Stakeholders are *motivated* to play the game and to *display real-life behaviour*, because of a clear *goal of the exercise* (winning the game), and the *mix of fun and seriousness*. At the same time, players may explore *risk situations* which they would not explore in reality
- Stakeholders can potentially be provided with *sufficient information* to support their judgements and decisions by including information from *computer models, databases (e.g. GIS)* and other sources
- Results can be easily *documented and analysed* because of the *structured way the interaction* takes place

The structure of the paper is as follows. The next section 2 describes the conceptual game design and some of its underlying methodologies. Section 3 describes the implementation of the game on the AnyLogic Java platform, as well some concrete idea on how the game should be played. In the fourth section we describe some preliminary results from first game application with the Ebro stakeholders. In Section 5 the conclusions are presented. In the appendix some more background is given on the Ebro case.

2 Conceptual game design

2.1 The World Cellular Model framework

The gaming tool forms part of an overall model framework called World Cellular Model (WCM) (Tabara, Wallman et al., 2007). The WCM –displayed in Figure 1 - is a conceptual model of the socio-ecological water system aimed at exploring and communicating current and plausible future developments in the use of water resources. It gives a multi-scale representation of *agents* (as cells) and their interactions, the uses of water stocks and flows, and the resulting impacts on the socio-ecologic system.

Some key characteristics of the WCM approach which are reflected in the game are:

It is agent based: The WCM takes ‘agents’, rather then ‘the environment’ as its point of departure. The agents are intrinsically linked through their interactions with a common environment and their dependencies on a minimum share of the stocks and flows of water, referred to as ‘kinetic water’. Trade offs between economic, social and ecological water functions are thus essentially perceived as a trade off amongst interdependent agents.

It takes a systemic perspective: The interface between the agents and their water environment is described using the different components of the so-called *SEIC* model. The water use strategies of each agent in response to environmental pressures depends on its availability of energy *E* (e.g. to transport water), its institutional context and social structure *S*, and its information base about the environment *I*. In turn, the water and energy use of agents create new pressures on the environment (for instance, increasing CO_2 emissions), eventually leading to new co-evolutionary impacts on the agent network in the form of socio-ecological change *C*.

It shows agent responsibility for socio-ecological change: The agents’ environmental impacts such as water use and pollution are represented in terms of the agents’ size. This shows the sustainability of current practices, and the relative agent contributions to resource use and environmental and social impacts. It thus makes clear the responsibility of environmental (and social) degradation.

It is multi-scale: In the WCM the agents are hierarchically organized along multiple scale levels (generally geographical) with individual agents forming collective agents, forming higher order collective agents within a single total earth system. Multi-scale interactions are mediated by different types of water flows, including natural flows (upstream to downstream), pumping (downstream to upstream), inter-basin transfers (between neighbouring cells) and flows of virtual water (between distant cells) contained in the production of water services (Hoekstra and Hung 2005).

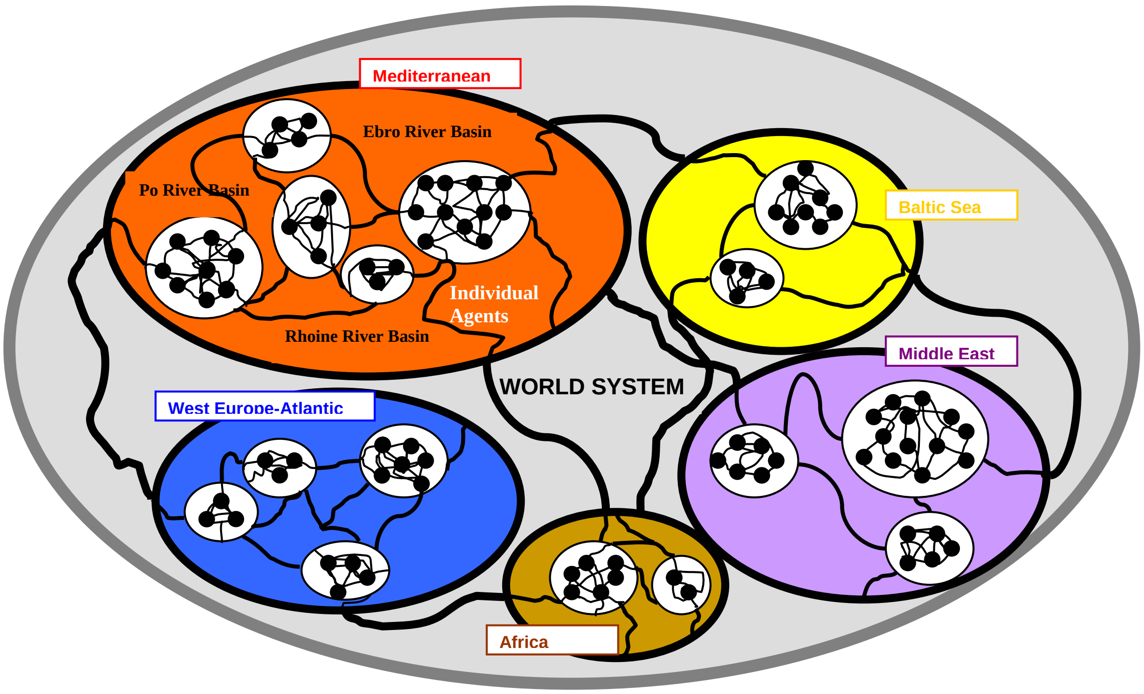

Figure 1: The World Cellular Model. After (Tabara, Wallman et al., 2007).

2.2 The concept of the game

The world cellular game aims to implement the WCM concept as an operational participatory agent based model capturing the relevant dynamics of the Ebro case study described in the Appendix. For that specific case, the complexity of the WCM is reduced by focussing on three hierarchical scale levels. At the highest scale we consider the Ebro river basin. Within the Ebro basin we distinguish a set of collective agents representing policy-making institutions and stakeholder groups. These institutions, in turn, each represent a set of individual water consuming agents.

The detailed concept of the game is outlined in Figure 2. At the highest level of abstraction, the total socio-ecological system is framed as a society - representing human structures, thought and action - interacting with an environment system representing the biophysical environment and its social, economic, and ecological functions[2]. The game players take the role of so-called ‘policy elites’ operating within a **policy arena** in which policy decisions (e.g. dam building, water tax etc.) are being made. The policy elites are assumed to form coalitions within the policy arena (the dotted circles in Figure 2) in order to strengthen their positions. The policy elites - typically interest group leaders such as farmer representatives or city majors - represent the interests, as well as the responsibilities, of specific individual stakeholders (e.g. farmers) and stakeholder groups (e.g. cities). These form part of the **public.** Both the stakeholders and the policy-elites are

[2] This ‘environment’ thus includes both biophysical aspects (i.e. water, land use) and human aspects (i.e. population, economy) and should thus not be confused with a ‘biophysical environment’ alone.

operating within a **society** characterised by a dominant water management culture. This culture comprises dominant core beliefs in relation to water management which are assumed to constrain the behaviours of all stakeholders and policy elites. The society as a whole interacts with an **environment** comprising the relevant pressures (e.g. climate change and water demands), states (e.g. water quantity and quality) and the social-ecological-economical impacts of the water system under concern.

The different subsystems are represented with different model types. The policy-arena is represented with participatory simulation by representing policy-elites with game players. The public is represented with ABM by representing individual stakeholders with computer agents. The environment, finally, is represented with integrated models on the basis of GIS and System Dynamics.

The subsystems are linked through a set of two-way interactions between:

The society and the environment: On the one hand, both the policy-arena and the public will react on perceived information from the environment. This may include gradual changes (a consecutive number of increasingly dry summers), as well as shock effects (a flood)[3]. On the other hand, both subsystems may directly alter the environment through policy (e.g. dam building) or autonomous responses (e.g. change in water use) respectively.

The policy arena and the public: Here, the policy arena may influence stakeholder behaviour by setting appropriate water policy (e.g. taxation). However, they are dependent on stakeholder support of stakeholders (e.g. through democratic voting) to obtain sufficient power in the policy arena.

The water management culture and agency: The interaction between the water management culture and the two agency components is most difficult to grasp. Following Conte and Castelfranchi (1995) we assume that the water management culture constrains agent behaviour through the mechanism of norms: specific social rules specifying the boundary within which policy and stakeholder agents operate. Regarding the feedback relation, we assume that changes in the water management culture are essentially driven by a process of reflection upon culture, policy, and the policy outcomes, and competition among the policy elites. In particular the latter relation is hard to conceptualize and will deserves further attention in future game versions, for example on the basis of stucturation theory (Giddens, 1984).

The concept of Figure 2 concretely frames the historic and future development paths of the Ebro's water management as a co-evolution of the environment, individual agent behaviour, policy-making, and cultural beliefs. The game implements the concept in a participatory agent based model in which these development paths can be assessed and reflected upon. For the game, the policy and culture subsystems are particularly relevant and their methodology is described in the remainder of this section. The agent based model and the integrated model are shortly described in Section 4.

[3] The perception of this information depends strongly on the water management culture in place.

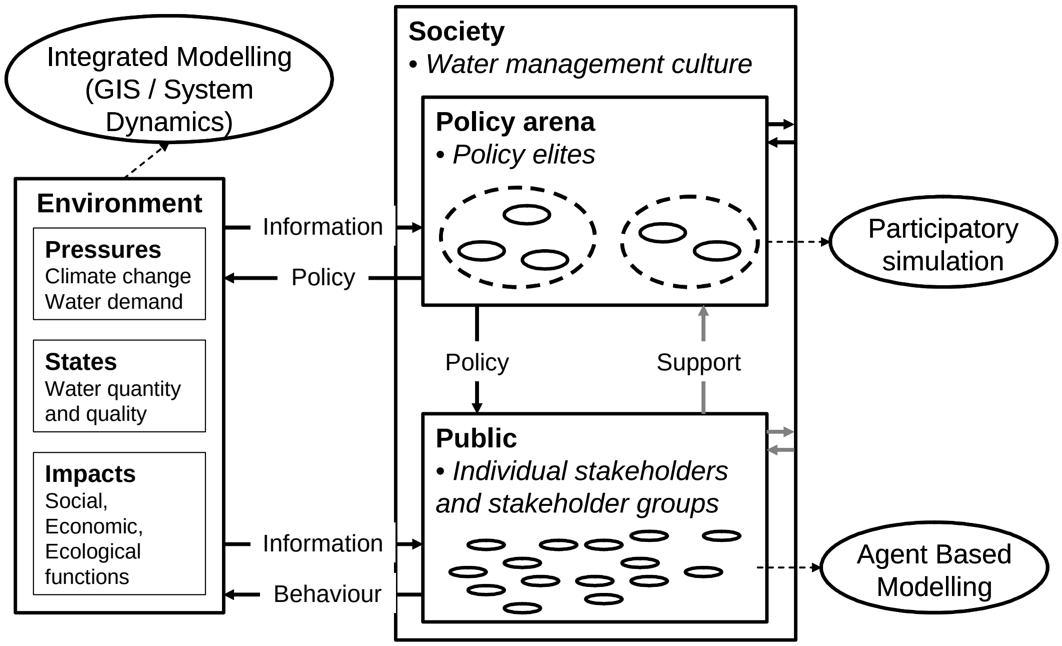

Figure 2: The concept of the game. The grey arrows or not yet implemented in the current prototype.

2.3 Designing the policy arena with the Advocacy Coalition Framework

The design of the policy arena is strongly inspired on the Advocacy Coalition Framework (ACF) (Sabatier and Jenkins-Smith, 1993) which provides a theory of policy change on the longer term “a decade or more”.

In the ACF, a policy subsystem is defined as the set of actors dealing with a policy problem. These actors - referred to as ‘policy elites’ - may be hold various positions, such as public official, interest group leaders, and researchers. The actors’ belief systems are mapped along a three layer hierarchy of beliefs consisting of 1) deep (normative) core beliefs (fundamentally normative and ontological axioms), 2) near policy core beliefs (basic strategies for achieving deep core beliefs, and 3) secondary aspects including instruments and information searches to implement the policy core beliefs. Advocacy coalitions are then formed by a group of policy actors that share a particular set of beliefs and show a nontrivial degree of coordinated activity over time.

The policy process is then modelled as a competition among coalitions. During this competition, coalitions typically seek to improve their understanding of the world (‘policy oriented learning’) in order to further their core policy objectives. Although policy oriented learning is an important aspect of policy change (altering secondary aspects of a coalition’s belief system) it is not the primary driver of policy change. Changes in the policy outcome are usually the result of changes in the relative strengths of advocacy coalitions driven by changes in the external factors. In particular changing socioeconomic conditions and technology – undermining the causal assumptions of present policies or altering the support for various coalitions - are important external drivers for policy change.

2.4 Mapping water management cultures with Cultural Theory

The ACF provides a framework for structuring the dynamics among policy-actors as a competition among coalitions, and gives a useful rough design of the belief systems at hand. We further adopt Cultural Theory (Thompson, Ellis et al., 1990) to provide a general typology of beliefs reflecting a wide range of possible belief systems existing in society.

Cultural Theory (CT) originated from earlier work of Mary Douglas on the relation between the perception of risks and social structure. Douglas and Wildavsky (1982) indicate that this social structure can be characterized along two axes. The vertical grid axis refers to the degree in which individual choices originate from your position within society; the horizontal group axis refers to the degree of solidarity within a society. To each quadrant a worldview typology can be connected, consisting of four perspectives: the fatalistic, individualistic, hierarchical and egalitarian perspective (Thompson, Ellis et al., 1990). These typologies have been used frequently within environmental management and Integrated Assessment to analyze and simulate future developments and expectations (Hoekstra, 1998; Van Asselt and Rotmans, 2002). Within the egalitarian perspective, nature is seen as fragile and people have to decrease their needs in order to secure a sustainable environment. Individualists, on the other hand, perceive nature to be robust and although people have the ability to decrease their needs, there is no need to do so. Hierarchists also think that nature is robust, but just within certain limits. Government and experts exactly know what these limits are and how people should behave in order to stay within these limits. The fatalist perspective is generally ignored as it discards in principle the possibility of environmental management.

For each typology, the core beliefs are translated to core beliefs and core policy (see Table 1) in an approach previously performed by (Hoekstra, 1998; Van Asselt and Rotmans, 2002). The next step then, is to translate the specific water related beliefs, to rules of the game. Thereby observed changes in the rules of the game during the game can then be considered ‘markers’ of a broader cultural change (shift between typologies). The hypothesis is that the observed cultural dynamics during the game give insights in possible future real-life cultural change.

		HIE	EGA	IND
Deep Core Beliefs	*Human nature*	Sinful	Good & malleable	Self-seeking
	Position of man	Man partially dominates nature	Man is part of nature	Man dominates nature
	Primary motives for action	Expert norms	Collective interests	Self-interests
	Value priorities	Security & Benevolence	Universalism & Conformity	Self-direction & Achievement
	Criterion of distributive justice	Equity among primary group	Equity among all people and generations	Individual responsibility
	Myth of nature	Robust within limits	Fragile	Robust
Core Policy Beliefs	*Attitude towards risk*	Risk-acceptance	Risk-aversive	Risk-seeking (risk is considered a challenge)
	Attitude towards authority	Authority-acceptance	Authority-aversive	Discarding authority
	Attitude towards development	Technological and process optimization to fulfil human needs	Awareness raising to moderate human needs	Technological innovation to fulfil human needs
	Management philosophy	Control	Prevention	Adaptation
	Management objectives	Social stability and safety	Environmental protection and equity	Economic growth and self-realization
	Management mechanism	Government regulation	Participatory decision-making	Free market

Table 1: Deep core beliefs and policy core beliefs interpreted along three stereotype Cultural perspectives.

3 Game implementation

The principles of the game design can be illustrated along a first conceptual prototype called 'surviving in a sustainable world'. This prototype is currently being implemented on the AnyLogic platform (see http://www.xjtek.com/). This platform proves to be very useful for our purposes by including systems' dynamics modelling, GIS, Agent based modelling, and interface design in a single software package.

In the game, players are invited to take the role of what Sabatier calls 'policy elites'. These policy elites are typically interest group leaders who are responsible for a specific water function and the associated stakeholder agents represented in the ABM. In line with the main water use functions of Table 2 we may include a *farmer representative* (representing agriculture), the director of *power supply company* (representing energy production), an influential environmentalist (representing the ecological function), a city mayor (representing domestic water use), a wealthy *entrepreneur* (representing industry), and a leading *tourist organisation* (representing recreation).

The goal for each player is to ‘survive in a sustainable world’. That is, one has to find a balance between its individual interests (satisfying its individual needs) and the collective interest of sustainability. To this end, the players can take individual actions, such as investing in water use efficiency and a specification of their water demands. Moreover, they can form coalitions with the other players to achieve favorable policy options (such as building water reservoirs or impose a water tax), and to achieve favorable changes in the water management culture.

3.1 Set up

The set up of game – displayed in Figure 3 – consists of a number of components:

- *A WCM representation* representing the policy players embedded in a larger water environment. The players’ size indicates their environmental impact in the form of the accumulated water use of the individual stakeholders they represent. Their color represents their satisfaction level at a scale from green (satisfied) to red (dissatisfied). The size of the environment represents the volume of the remaining of the resource stock, for example the Ebro’s water availability.
- A visualization of *coalitions* indicating their members and accumulated power.
- *A sustainability indicator* measures the system’s sustainability on the basis of the respective players’ satisfactions (‘Stakeholder satisfaction’) and a total environmental impact. (i.e. related to the speed at which resource is being depleted).
- *En exploration button* with which the players are linked to the spatial interface of the environment-agent model.

Furthermore, main interface includes the list of players, water management options, and elements of the water management culture which can be further explored from the main interface.

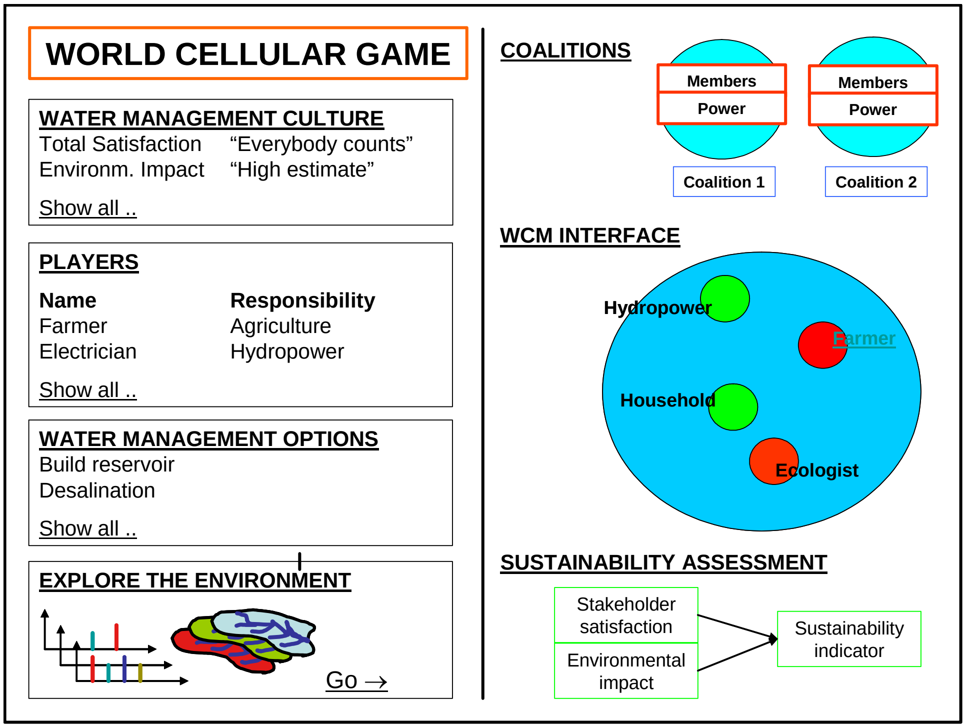

Figure 3: A first conceptual prototype game called ‘Surviving in a sustainable world’

3.2 Game Players

A typical player is displayed in Figure 4. Players are characterised by:

- *Targets*: Each player sets targets, e.g. for the quantity and quality of its water function. Quantity denotes, for example, the total area of agricultural land, and quality the water related quality characteristics for its crops. The real quantity and quality values (calculated by the system’s model) are displayed as well, to show whether the targets are met.
- *Environmental impacts*: The game shows the environmental impacts of each player in terms of its water use and pollution.
- *Performance*: The performance section summarizes the player’s performance in terms of its satisfaction (a measure of the extent to which the players targets are met) and its size (indicating the player’s environmental impact). The performance indicators ‘satisfaction’ and ‘size’ are also displayed in the WCM interface as the colour and size of their representative circles in Figure 3.

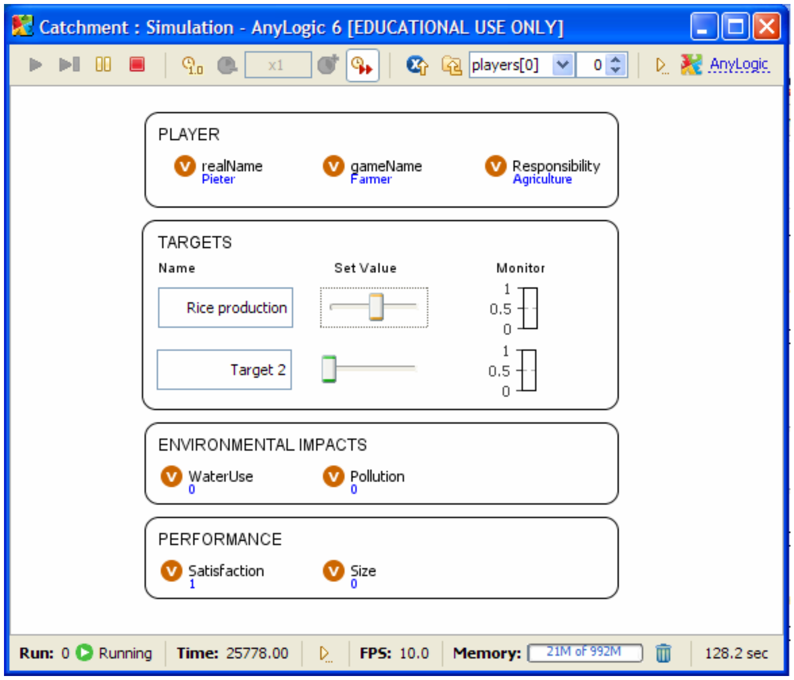

Figure 4: A typical player (in this case the farmer representative) in the conceptual prototype

3.3 Exploring the agents and the environment

Players can decide to explore the physical environment and the status of the agents it includes. The physical model represents the stocks and flows of water in the river basin. The river basin is divided into uniform cells, currently 5 by 5 km, in a grid. Each cell has its own characteristics that influence both the hydrology of the cell and the information conveyed to the agents, e.g. land use, erosion risks etc. This hydrological system is modelled using a system dynamics (SD) approach, see Figure 5. In each grid cell this simple hydrological SD model is calculating the water balance in that particular cell. The input to each cell is water from the upstream cells and precipitation and the output is water flowing to the downstream cells and water use, including evapotranspiration.

The physical model is linked to an ABM representing the individual stakeholders. In the first prototype we focus on *water consumer* agents. In line with the main water use functions of Table 2 we distinguish *farmers* (representing agriculture), *power supply companies* (representing energy production), *frogs* (representing the ecological function), *cities* (representing domestic water use), *entrepreneurs* (representing industry), and *tourists* (representing recreation). Agents decide directly on their water demand, or on various other autonomous actions such as crop changes, migration, adopting water use efficient technology and so on. In the first prototype, the agents are modelled as *simple rational agents*, aiming to maximise the fulfilment of their needs. In future prototypes, more advanced behavioural modes (e.g. imitation, repetition, social comparison) may be included as well.

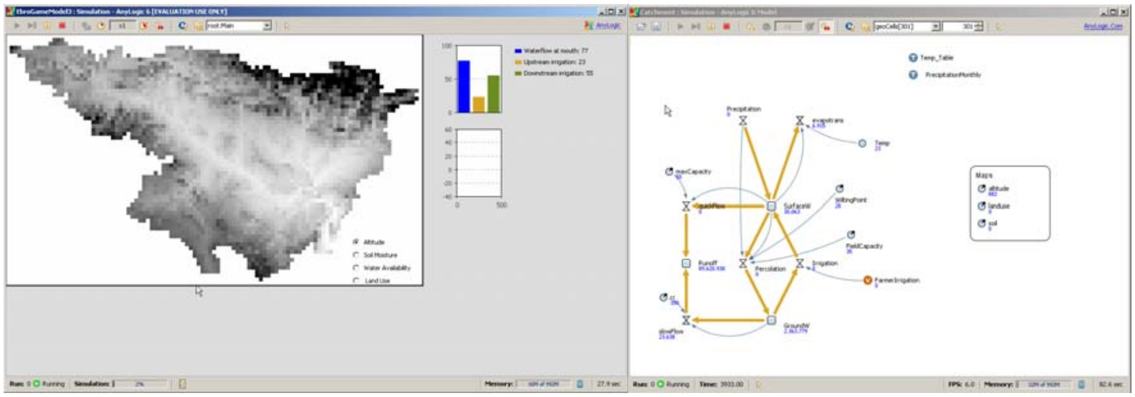

Figure 5: A GIS representation of the Ebro River Basin including agent representations, and a system dynamics model that calculates the water balance in each grid cell.

3.4 Representing the water management culture

The water management culture is represented as a set of positions on a selection of specific rules that influence the dynamics of the game. Each rule is related to deep core / policy core beliefs such as the ones displayed in Table 1, and for each rule in general three options are provided corresponding to a hierarchical, egalitarian, or individualist view. The rules are particularly important in relation to the explicit aim of sustainability expressed in the goal of the game, because the rules determines to a large extent *what sustainability is* and *how sustainability should be achieved*. *What sustainability is*, for example, depends strongly on the interpretation of equity, which differs strongly amongst different cultural stereotypes. *How sustainability should be achieved*, for example, depends on an inherent preference for the management of water supply or water demand that equally differs. In other words, the choice of rule will influence the value of the sustainability indicator in the game, and may restrict certain policy options from being taken. The rules presented in Figure 6 from an initial illustrative set which will be further developed in future prototypes.

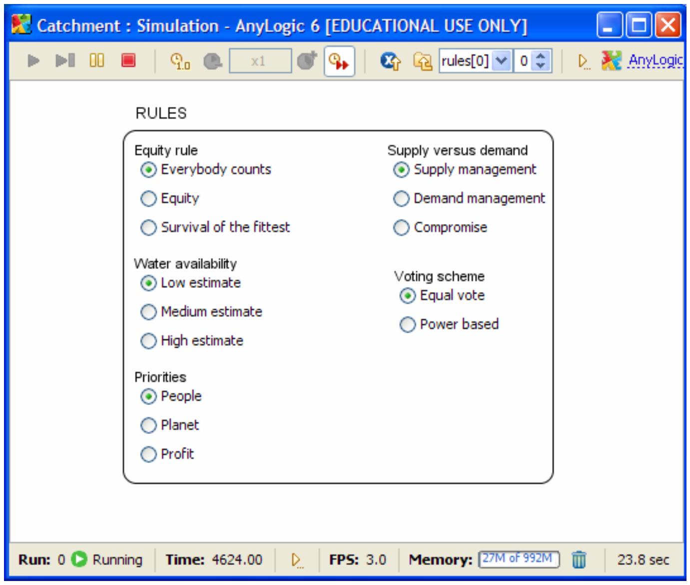

Figure 6: Implementation of stereotype core beliefs and core policy beliefs in the form of game rules

3.5 Game dynamics

The game is intended to be played in an open fashion, with the computer tool supporting a broad discussion amongst the players extending the variables of the game. The game dynamics is structured along four main stages – each containing one or more sub-tasks - carried out in a cyclical manner, in total covering a model time period of typically 50 years. The following stages are distinguished:

1) Scoping

Current state assessment: In this stage involves an open discussion regarding the current state of the system. For example, how do we evaluate water availability and water quality? Are we subject to a water stress? Why did the problems arise? Are the current water management practices sustainable? What future developments are to be reckoned with?

2) Policy design and coalition forming

Goals and measures: In the second stage each player individually expresses its goals and ideal type water management options (see Table 3 for a set of water management options to be included in the game.). After a reflection round all players decide their final standpoint. The goals are translated to concrete targets and are implemented in the game.

Towards a common action plan: The players are asked to design a common action plan. The policy options are freely discussed among the players, but the policy choices will result from a power weighted vote.

Coalition forming: Each player can form a coalition with one or more other players. The power of a player thereby increases, since the number of votes for the coalition is higher than the sum of the votes of its members. However, coalition forming also increases the player's dependency, since an action plan must be supported with a unanimous vote.

3) Exploration of impacts

Environmental impacts: The integrated model is explored to assess the environmental impacts of the chosen action plan: changes in water availability, water quality, and impacts for water functions.

Social impacts: The agent model is explored to assess individual stakeholder satisfactions and autonomous stakeholder responses. The social impacts among the players can be observed from the main interface from the players colour and size.

4) **Reflection**

Sustainability assessment: The players will reflect on the sustainability of their water management practice on the basis of the sustainability indicator of the game. Since the value of the sustainability indicator depends strongly on the reflection on the water management culture, these tasks are carried out in parallel.

Reflection on the water management culture: The game players are asked to reflect on the water management culture by discussing the rules of Figure 6. Just like with policy options, an open discussion can take place. Actual changes in the rules, however, will result from a power weighted vote in which the coalitions can play a decisive role.

Finally, a next cycle is started with the scoping stage based on the basis of the results so far, and possibly by including new events and drivers in the game that were previously not considered. After a number of cycles, it will become more and more clear if the system's state can be considered sustainable or not, and which players have managed to 'survive' (maintained a high satisfaction level). Winner(s) and loser(s) are identified.

4 Playing the game: preliminary results

Preliminary results were obtained through a stakeholder session held in Tortosa within the Ebro basin. A small, diverse group of stakeholders were present, including two members of the NWC foundation, one member of an NGO for the protection of the Ebro River, a representative from a rice producing organisation, a scientist dealing with agricultural issues, and an officer from the Catalan water agency. The stakeholders were involved in a role-playing game following the game dynamics described above. In the process they reflected on the prototype game, which - although too preliminary to be used as a stand-alone application – showed the participation how the application would work.

Three main results were obtained fro the participatory process. First, information was obtained on the improvement of the model. For example, stakeholders indicated that the quality issues should be highlighted more, as well as the issue of channel flow. Second, insights in the game dynamics were obtained. The process of coalition forming and competition worked well and stimulated discussion. During the game, the players realized more and more that they are part of a broader social system wherein collaboration is necessary. They realized that collaboration was possible and that a joint plan could be made without becoming unsatisfied. Also, water use and policy conflicts seemed to catalyze the need to talk, negotiate and to give incentives for cooperation. Finally, the game was perceived as a useful tool by the stakeholders to be able to learn from past mistakes, too reflect upon the future of the Ebro, the future of policy-making, and to assess changes in power structures required for change.

Figure 7: Playing the game

5 Conclusions

New methods and tools are needed to gain information about social paradigms in order to inform policy-making in the context of sustainable development. Such tools need to be amply used and shared by the relevant publics so that the lessons learnt can become meaningful to stimulate adaptive action. Because of their capacity to represent complex social interactions in a simple way, such as conflict and cooperation, or the factors that lead to the emergence of power coalitions and institutional rules, games are particularly well suited for that purpose.

This paper reports on the development of an innovative game to support the Integrated Sustainability Assessment of water. Two main goals of the game were identified. First, it is aimed at supporting collective decision-making processes and social learning. It does so by facilitating reflection on the (un)sustainability of water use, on issues of competition and cooperation necessary to facilitate change, and on (often persistent) core beliefs underlying the water management paradigm. Second, the game is targeted at the production of knowledge. By playing the game, new insights may be drawn on the drivers and development of societal transitions, in particular on the role of cultural belief change and power issues.

On the basis of the design process so far, and a first participatory experiment with the developed prototype, the following conclusions can be drawn. First, the development of the game is feasible and the main conceptual issues have been addressed. In particular a mechanism was designed to link cultural change with the development of the power of policy coalitions. Second, the first participatory experiment shows that the game dynamics works. Players are actively involved in coalition forming in the formation of policy design. Third, the best way to pay the game is in an open fashion, with the computer tool supporting a broad discussion amongst the players extending the variables of the game. Fourth, the game is considered a useful tool by the main stakeholders involved.

As the implementation of the game is currently work in progress, many issues still need to be addressed. First, the mechanism of reflection on cultural change has not been tested yet. A second round of participation will address this issue. Second, we implicitly assume that players exhibit real-life behaviour, a hypothesis which will require further underpinning in our future work. A final point is that the dynamics of belief changes at the individual level and its relation with power distribution among coalitions at the policy level has not yet been sufficiently addressed. Clearly, the evolution of belief changes at the individual level is enormously complex, involving the diffusion of ideas in response to – for example – environmental awareness, media influences, role-models, and so on. For modelling this process in future prototypes, we believe the transition models developed as part of MATISSE can play an important role.

Acknowledgements

This research is part of the EU project MATISSE (Methods and Tools for Integrated Sustainability Assessment) for the domain of water (Contract 004059-GOCE-MATISSE).

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Appendix - Cultural transition in the Ebro river Basin: An emerging 'New Water Culture'

The Ebro River basin covers some 80.000 km2 and is located in Northern part of Spain, see Figure 8 and (CHE, 2005) (Tàbara, 2005) for a general description. The river originates in the Western, mountainous part of the basin and flows over a length of some 900 km towards its mouth on the Mediterranean Sea. The basin includes both mountain areas to the North, West and South of the Basin and flatlands in the central part and towards the Ebro Delta. Land use is dominated by natural land (51%) and agriculture (44%), with minor contributions of urban/industrial (1%) and other land use types (4%). Total population amounts to 2.9 million people, mainly concentrated in urban areas in the central (e.g. the city of Zaragoza) and Northern part of the catchment. Under a temperate warm climate, the water availability in the Ebro river basin can be considered quite reasonable for Mediterranean standards. With an average discharge of some 400 m^3/s at its mouth, the Ebro River is actually Spain's most voluminous river. However, due to high inter- and intra-annual precipitation variability, long dry spells frequently occur notably in summer causing significant stress on water functions.

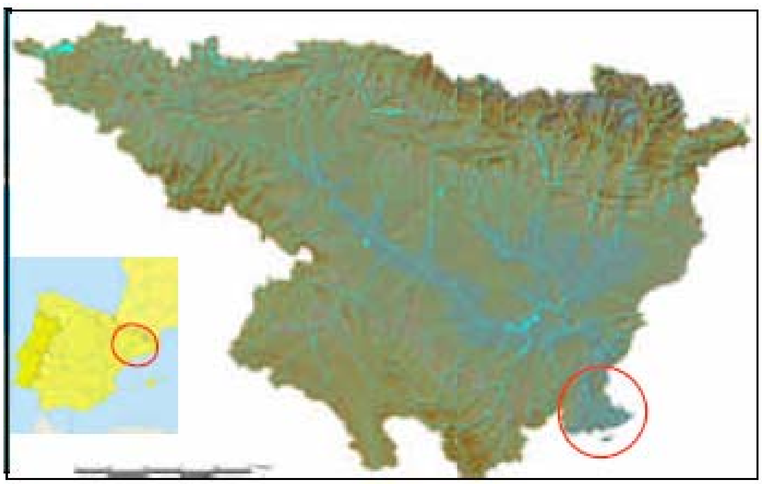

Figure 8: The Ebro River basin

One can distinguish various social, economic and ecological water functions. The main water user is agriculture (including livestock) with a largely consumptive water use of some 6300 hm^3/year. A second main water user is energy production, which requires some 41100 hm^3/year to maintain a total energy production. A third main water user is ecology. The Ebro River Basin has a diverse flora and fauna and important value is in terms of biodiversity. Of specific importance is the Ebro delta, which constitutes one of the moist important wetland areas of the Western Mediterranean. Although ecological water use is relatively hard to quantify, the Spanish government considers a minimum flow of some 100 m^3/s (i.e. some 3000 hm^3/year) necessary to maintain the ecological functioning along the river. Other relevant water functions are industry, domestic use, recreation, and aquaculture, as described in Table 2.

Water functions	**Water demand** (hm^3/year)	
	Total	*Consumptive*
Agriculture	6.310	6310
Energy	41.100	0
Ecology	3.156	0
Industry	470	120
Domestic use	286	286
Recreation, navigation and water transport	300	0
Aquaculture	1.000	0
Total run-off	18.000 hm^3/year	

Table 2: Indicative values for water demands for various water functions, after (CHE 2005). Total run-off is shown for comparison.

To meet the water demands, the Spanish government has traditionally relied on the use of dams and reservoirs. Under pressure of increasing water demands over the past decades (mainly due to the expansion of irrigated agriculture), the number and capacity of these reservoirs in Spain has steadily increased. With a five-fold increase since 1950, the current number of dams per head of population rates among the highest in the world (Tàbara, 2005). The increasing number of dams has led to significant pressures on the water system, because of a disruption of natural erosion and sedimentation processes (endangering in particular the existence of the Ebro delta) and negative impacts on the landscape. Also pollution can be considered a problem, with a significant discharge of fertilizers, pesticides and herbicides from agriculture, and a discharge of oils and detergents originating from industries and urban areas. Looking into the future a third problem is related to climate change. With a projected decrease of water availability op to 10% by 2030, the Ebro's water stress is expected to significantly increase moving towards severe levels of water stress (EEA, 2005).

Despite these pressures on the water system, the National Hydrologic Plan (NHP) of July 2001 expressed a continuation of traditional policy by proposing the construction of new dams and the modernisation of traditional irrigation areas. Moreover, it appeared to deny a water scarcity problem by proposing a water transfer from the Ebro basin (~ 1000 hm^3/year or 9% of today's flows) to the South of Spain to support agricultural and tourist developments there.

The NHP caused a wide social upheaval manifested in the largest demonstrations on socio-environmental issues carried out in Spain for over two decades. This resulted in the creation of new collaborative networks of action, eventually forming a new social movement which was named 'New Water Culture'. The New Water Culture is a social and scientific movement advocating a new water ethics (Torrecilla and Martinez-Gil, 2005). It highlights the spiritual value of water as a source of well-being for current and future generations, rather than considering water merely as a resource for economic activities. A number of concrete policy options and strategies are proposed, including water demand management, efficient water efficiency, intelligent and prudent application of modern technologies, the improvement of water and ecological quality, the educational and recreational use of rivers, and a water ethics observance which would guarantee the rights of minorities affected by the construction of a dam.

Under pressure of the growing movement the NWP was eventually cancelled by the new left-wing government after the national elections in 2004. As an alternative, a new plan AGUA was developed including large programme of building desalination plants have been approved (amounting up to 621 hm^3 of water/year) together with the improvement of water management, reutilization of available water resources, and modernization of water infrastructures (up to 437 hm^3/year in water supply savings).

The evolution of the water management strategy proposed in Spain can be interpreted as an ongoing shift from one paradigm to another. The traditional style water management style can be characterized as one of pure water supply management through the construction of dams. The NHP of 2001 can be considered an even more extreme form of water supply management, as it is intended to cover demands outside the basin as well. The NWC movement proposes a radical change towards water demand management focussing on water use efficiency, water re-use, water pricing, and awareness raising. The AGUA plan, finally, can be considered a compromise between the traditional water management style and the NWC.

		Traditional	NHP	AGUA	NWC
Supply management	Reservoirs	■	■		
	Water transfer		■		
	Desalination			■	■
Demand management	Water use efficiency			■	■
	Water re-use			■	■
	Water pricing				■
	Awareness raising				■

Table 3: Shift in water management policy in Spain

The specific case of the Ebro is well illustrated using the DPSIR model of Figure 9 (see for example (Hoekstra, 1998)). Here, the drivers (D) include both environmental changes - such as climate change and land use changes - and on the other hand socio-economic developments such as population and economic growth. The drivers are causing a pressure (P) on the water systems – in the form of an increased water demand, a reduced water regeneration capacity, and pollution. The pressures result in state changes (S) referring to the reduced availability of water and a decreased water quality. These, in turn, lead to impacts (I) on the water related functions such as aquatic ecology and biodiversity, economic functions such as farming, industry and energy supply, and social functions such as household consumption and water recreation. The potential societal responses (R) to these impacts may be broadly divided between water supply management (meeting a given demand by improving water supply), water demand management (moderating water demand on the basis of a given, limited water supply), and autonomous responses of individual stakeholders.

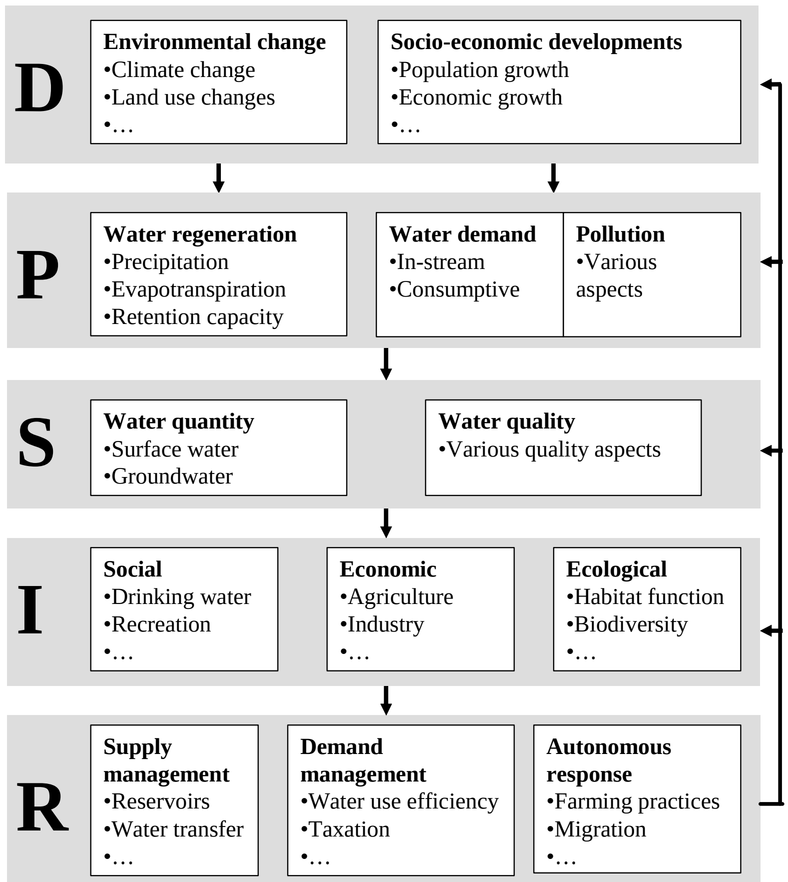

Figure 9: The water scarcity and pollution issue of the Ebro river basin represented with a generic DPSIR conceptual model.

The relations between drivers, pressures, states and impacts of Figure 9 are relatively well understood and can be modelled with environmental modelling techniques such as system dynamics and GIS. The main challenge lies in understanding the societal response. Tabara and Ilhan (2007) show that this societal response in the Ebro case can be framed as an ongoing sustainability transition (Rotmans, 2005) involving fundamental innovations in the dominant structures, cultures and practices regarding water management in Spain. In this transition the dynamics originate from interactions between agents and structural aspects across three scale levels (see Figure 10):

Cultural level: The notion of culture is essential to understand the societal response and the New Water Culture movement observed in the Ebro river basin. On the one hand, culture is considered one of the most important mediating mechanisms of the transition dynamics. It can, for example, be considered a trigger for the transition as well as determining its speed and direction. On the other hand, the cultural aspects themselves are subject to the transition.

Institutional level: Here, power structures play an important role in mediating the transition. Traditional government authorities and strong corporate interests typically compete against new paradigms supported by institutions like the New Water Culture Foundation.

*Individual leve*l: At the individual level (changes in) consumption practices play an important role, as well as the diffusion of the ideas on new water management paradigms within a broader public.

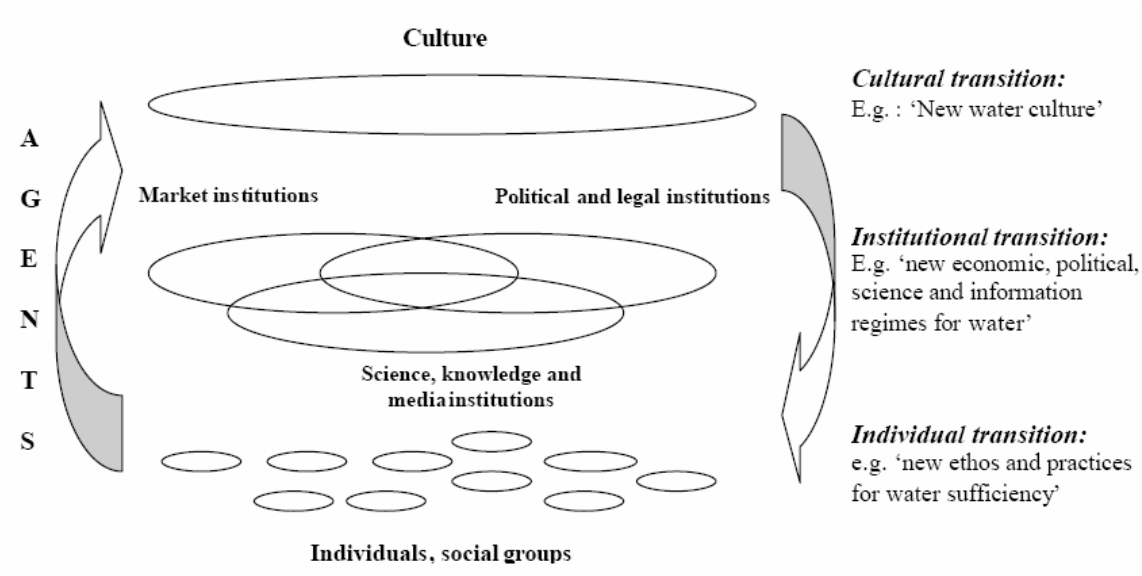

Figure 10: Understanding societal response in the Ebro river basin as a sustainability transition involving agents at the different levels of individual action, institutional regimes and general cultural beliefs and values (Tabara and Ilhan, 2007).

The current water management transition in the Ebro can be considered to be in a take-off phase. The future development of the transition, however, is highly uncertain. The development may lead to a successful transition, in which water supply principles are effectively replaced by new principles of water demand management. On the other hand, the transition may fail when - due to resistance from existing power structures and deeply rooted traditional practices - the traditional water management regime is kept in place.