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# Modelling Cultural and Behavioural change in Water Management: An integrated, agent based, gaming approach

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### Abstract

Our objective is to develop new ways of modelling the dynamics of water management that provide for exploration and representation of cultural and behavioural change in relation to changes in a water system. Our approach is to develop an interactive computer game. In the game, the water system is modelled using spatially-explicit integrated assessment models, and water management is represented as the dynamic outcome of interactions between water culture, water policy and autonomous actor behaviour. The purpose of the game is to explore future pathways of water management in the Ebro River Basin in Spain, and contribute to a social learning process amongst the players involved. The paper reports work in progress, but the conceptual approach has already been translated into a game format, which has been tested and shows promise.

**Keywords:** Integrated Sustainability Assessment, Integrated Assessment Modelling, Participatory Agent Based Social Simulation, Water Culture.

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# 1   Introduction

Integrated Sustainability Assessment (ISA) is a new concept for sustainability assessment (Weaver & Rotmans 2006, Weaver & Jordan 2008). It complements existing forms of sustainability assessment by supporting longer term, and more strategic policy processes to explore persistent problems of unsustainable development. Rotmans (2006) argues that those persistent problems can only be overcome through fundamental societal changes referred to as societal transitions. Amongst others, this involves a co-evolution of practices (autonomous behaviours and policy) and culture (shared values, norms, and beliefs), in relation to some domain system (for example water, energy, tourism, or health). To facilitate the understanding of such processes IA models can help. However, although IA models adequately represent developments in the domain system, they tend to under-represent the aspects of cultural and behavioural change. One of the challenges in IA modelling is therefore to develop new types of models that better represent all salient features of societal change in a single modelling framework.

The objective of this paper is to explore such a new approach for a better understanding of societal transitions in the water domain, focussing on the interactions between a water system, autonomous behaviours, water policy, and cultural change. The approach entails the development of an interactive computer game for the case study of the Ebro river basin in Spain. The game combines various modelling approaches—such as system dynamics and GIS to represent the water system, and agent based modelling to represent autonomous stakeholder behaviours—while water policy and cultural change is subject to the game itself. Apart from water policy negotiations, the game explicitly involves reflection phases, in which various cultural assumptions underlying the water management discussion are critically assessed. Also, the game allows for reflection upon conflict and collaboration, and on the emergence of new power structures and institutional rules inherent to a sustainability transition.

This work builds upon various methodological strands. It departs from a perspective based Integrated Assessment Modelling approach (Rotmans & De Vries 1997, Hoekstra 1998, 2000, De Vries 2001, Van Asselt & Rotmans 2002). In this approach, the typology of perspectives of Cultural Theory (Thompson et al. 1990) is used to develop consistent model explorations of, for example, the global water system that illustrate the implications of distinct worldviews and management styles. This approach is complemented with a participatory Agent Based Social Simulation (ABSS) approach (Pahl-Wostl 2002, Barretau 2003, Ramanath & Gilbert 2004) to better represent the processes of behavioural and cultural change. Finally, the game's design is inspired by recent literature on socio-technical and (broader) societal transitions (Rotmans 2005, Geels & Schot 2007, Loorbach 2007) in which fundamental societal change is interpreted as the outcome of a competition amongst a dominant actor network (the 'regime') and emerging alternative networks ('niches').

The focus of this paper lies on the modelling concepts and the design of the game. Section 2 presents a short overview of the previous work on integrating

social dynamics in IAMs up to the current state of the art. In Section 3, the conceptual models underlying the game's design are developed on the basis of well-known model concept of Pressure State Impact Response (PSIR). This concept is elaborated upon with an explicit representation of actor dynamics as part of the 'Response'. A discussion of the response dynamics follows, on the basis of a literature review on cultural, behavioural and policy change. Section 4 links the model concepts to a concrete game design and presents a first prototype of the game developed for the case of water management in the Ebro river basin in Spain. The discussion and conclusion (Section 5 and Section 6) highlight the limitations and potential of the approach, discuss its role in the ISA, reflect on the developed approach and summarize key lessons learned.

## 2   Social dynamics in 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 subsystems and processes (horizontal integration), including feedbacks and adaptations (Martens 2006). IAMs generally take the form of a system dynamics computer model, which may or may not include an explicit spatial dimension. Relevant examples of IAMs addressing issues of water management are the AQUA model (Hoekstra 1998), WaterGap (Alcamo et al. 2003), and QUEST (Carmichael et al. 2004).

One of the main challenges in IAM is to achieve a better representation of the 'human dimension' (i.e. policy making and human behaviour) in the models (Rotmans 1998, 2006). One interesting approach in this context is the perspective-based modelling approach (Rotmans & van Asselt 2001, Van Asselt & Rotmans 2002) developed for the global change model TARGETS (Rotmans & De Vries 1997, De Vries 2001), including the water module AQUA (Hoekstra 1998, 2000). In this approach, the uncertainty surrounding global change and human behaviour is linked to the human perspective. Following a typology of perspectives of Cultural Theory (Thompson et al. 1990), fundamental beliefs on 'how the world works' (worldview) and 'how the world should be managed' (management style) are translated to consistent viewpoints in the water management debate (see Table 1). These, in turn, are implemented in the model in the form of consistent interpretations of model uncertainty (regarding various model parameters and equations), and rules for water policy (e.g. regarding alternative rules for inter-basin water transfer) and autonomous behaviours (e.g. regarding alternative equations for water demand). These so-called 'model routes' show diverging trends of the global (water) system and illustrate the implication of distinct worldviews and management styles. However, they do not include the dynamics through which these worldviews and management style may change.

For a better representation of the human dynamics in IAMs, several scholars

(Janssen & De Vries 1998, Moss et al. 2001, Van der Veen & Rotmans 2001) have proposed to extend the IAM framework with Agent-Based Modelling (ABM). ABM can be considered an umbrella term for various agent-based modelling approaches (Agent-based modelling, Agent-based social simulation, Multi-agent-based simulation, Multi-agent simulation, Agent-based social simulation Hare & Deadman (see 2004) in which social entities are represented as computer agents acting upon their social and natural environments. Various practical ABM application have been developed (for overviews see Bousquet & Page 2004, Hare & Deadman 2004, Edmonds & Mohring 2005). A number of them focus on water management issues, such as household water demand (Barthelemy et al. 2002, Athanasiadis et al. 2005, López-Paredes et al. 2005), agricultural water use (Barreteau & Bousquet 2000), lake eutriphication (Janssen 2001), river basin management (van Delden et al. 2005), and hydraulics (Espinasse & Franch-esquin 2005, Valkering et al. 2005). Of specific interest is the 'Battle of Perspectives' application of Janssen & De Vries (1998) that illustrates the dynamics of worldviews and management styles in a multi-agent system in response to agent observations from an economy-energy-climate model.

Although some agent-based applications are strongly inspired on social scientific theory (Jager 2000, Valkering et al. 2005), practical agent architectures of current ABMs remain fairly 'simple', representing reactive, rather than deliberative behaviour. Hare & Deadman (2004), for example, conclude that decision making models are based on simple sets of heuristic rules, and that social interaction tends to be implemented in terms of simple nearest-neighbour imitation algorithms. Due to this property, the models are particularly suited to assess the emergence of complex macro-level behaviour from simple micro-level interactions. However, they seem to fall short of adequately assessing fundamental societal changes emerging from complex interactions among highly deliberative and 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 and validity of the results. This approach is referred to as participatory agent-based social simulation (participatory ABSS) (Pahl-Wostl & Hare 2004, Ramanath & Gilbert 2004), also referred to as companion modelling (Barretau 2003). Previous participatory ABSS applications have shown the value of the approach, both in terms of social learning tools and social simulation models. For example, the Zurich water game—developed as part of the EU FIRMA project—was used to improve the communication between actors of urban water management (Pahl-Wostl & Hare 2004). Gurung et al. (2006) showed that their companion modelling approach helped to resolve water sharing conflict between farmers in Bhutan. Guyot & Honiden (2006) and Briot et al. (2007) describe a number of simulation experiments to study issues of power and negotiation amongst agents involved in the coffee market (SimCafe), renewable resource management (SimComMod), and biodiversity conservation (SimParc)[1].

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[1]Guyot's methodology is referred to as 'agent-based participatory simulation' and is considered a variation of the companion modelling approach

**Table 1:** Three cultural perspectives. General characteristics (upper part) and perspectives on water (lower part). Sources: Hoekstra (1998) and Thompson et al. (1990)

|  | Hierarchist | Egalitarian | Individualist |
|---|---|---|---|
| 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 |
| Myth of nature | Robust within limits | Fragile | Robust |
| Risk | Risk-acceptance | Risk-aversive | Risk-seeking |
| 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 |
| Water demand | A given need | A manageable desire | Price driven |
| Water availability | Stable runoff | Stable runoff in inhabited areas | Total runoff or no limits |
| Water quality evaluation | Functional quality standards | Pristine quality as reference | Economic value |
| Water scarcity | Supply problem | Demand problem | A market problem |
| Water sharing | Meeting various water demands | Basic supply to everyone | Economic optimization |
| Water conserving technology | Large scale technology push | Small scale technology push | Price driven |
| Water price policy | Incremental price increase | Water tax | Market pricing |
| Artificial surface reservoirs | Solution to water scarcity | Undesirable | Desirable if cost effective |
| Wastewater policy | Treatment to meet standards | Treatment and decrease production | 'Polluters pay' principle |

These recent participatory ABSS applications generally focussed on case studies where relatively simple, local, clearly defined management issues allowed a detailed study of specific agent interactions. This paper aims to combine methodologies of participatory ABSS with the perspective-based modelling approach, to address a more complex issue involving the broader social, environmental, economic and institutional dimensions of societal change.

## 3  Modelling concept

### 3.1  Pressure, State, Impact, and Response

The starting point of this analysis is formed by the PSIR model (Rotmans & De Vries 1997) of Figure 1. In the Ebro region (see Torrecilla & Martinez-Gil 2005, Tàbara & Ilhan 2007) the most relevant socio-economic pressures (P) are an increasing water demand over the past century (mainly due to the expansion of agriculture) as well as water pollution resulting from both agricultural and domestic practice. On the environmental side, the reduced sediment load in the river, land use changes (both resulting from the construction of water reservoirs), and climate change are the main factors to be reckoned with. The pressures result in state changes (S) referring to the availability of water (groundwater, soil water, lakes and channel flow), the water quality, and land stability. These, in turn, lead to various impacts (I) on the water-related functions. These include: ecological functions, such as habitat function and biodiversity; economic functions, such as farming, energy supply and industry; and social functions such as household consumption and water related recreation. The responses (R), finally, are divided between water policy and autonomous responses. Water policy in Spain has traditionally taken an approach of water supply management favouring engineering options like reservoir construction, and—more recently—water transfer and desalination. However, the current approach is directed more towards water demand management, advocating water use efficiency, water re-use, water pricing, and awareness-raising. The autonomous responses of stakeholders may include changes in agricultural practices by farmers and changes in lifestyle and migration patterns by the general public.

### 3.2  Elements of the response system

The relations between the pressures, states and impacts of Figure 1 are relatively well understood. They can be modelled with environmental modelling techniques such as system dynamics and GIS, drawing upon knowledge from climate science, hydrology, geography, ecology, economy and so on[2]. The main challenge lies in understanding the dynamical change of the response. The analysis of the Ebro case study (Torrecilla & Martinez-Gil 2005, Tàbara & Ilhan

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[2]By no means, we argue such a modelling exercise is easy. IA modelling involves a number of difficulties, such as information gathering, the choice of aggregation and scale, and the management of uncertainties.
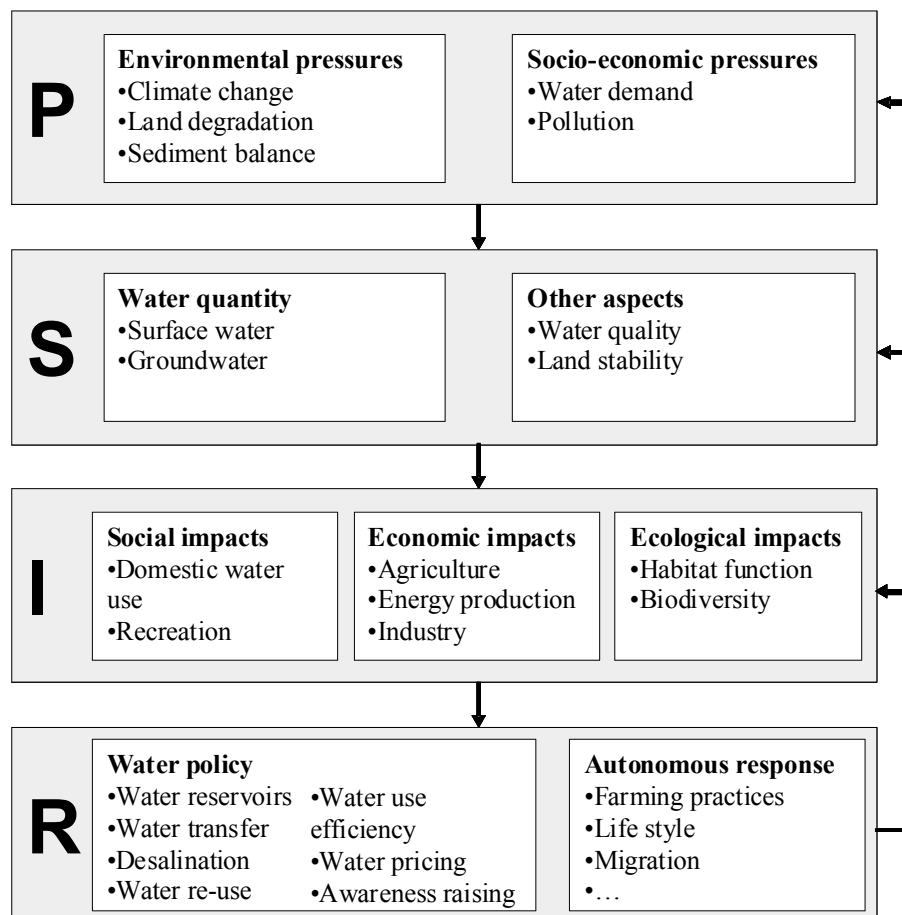
**IAJ**

**P**

**Environmental pressures**
•Climate change
•Land degradation
•Sediment balance

**Socio-economic pressures**
•Water demand
•Pollution

**S**

**Water quantity**
•Surface water
•Groundwater

**Other aspects**
•Water quality
•Land stability

**I**

**Social impacts**
•Domestic water use
•Recreation

**Economic impacts**
•Agriculture
•Energy production
•Industry

**Ecological impacts**
•Habitat function
•Biodiversity

**R**

**Water policy**
•Water reservoirs
•Water transfer
•Desalination
•Water re-use

•Water use efficiency
•Water pricing
•Awareness raising

**Autonomous response**
•Farming practices
•Life style
•Migration
•…

**Figure 1:** The case study of the Ebro river basin framed along the conceptual model of Pressure, State, Impact and Response. Adapted from (Hoekstra 1998).

2007) suggests that the response dynamics originate from three strongly related societal subsystems:

- In the water culture subsystem, deeply rooted, and broadly shared beliefs in agricultural development as the engine of Spanish economy, in water as an economic good, and dams as a symbol of progress, are slowly being replaced by beliefs in the spiritual value of water as a source of well-being, in the importance of water ethics, and the necessity of holistic water management.

- In the water policy subsystem, traditional institutions and organisations (river basin authorities, large scale farmers, and farmer organisations) are competing with emerging ones (COAGRET[3], the platform of the Defense of the River Ebro, and the New Water Culture (NWC) foundation) on the development of the new AGUA water management plan.

- In the system of autonomous response, local farmers, citizens, and other stakeholders play an important role in supporting (or not supporting) the various institutions and organisations, and by adopting (or not adopting) new water related practices (e.g. small-scale biological farming).

These three subsystems feed into the further development of the response module within the PSIR frame. The PSI-R model of Figure 2 frames the Ebro water system as composed of two main interacting parts: a water system—including the pressures, states and impacts—and an elaborated response system (hence, PSI-R model). In the response system, water policy and autonomous behaviour is framed as the outcome of multi-actor processes. More specifically, water policy is framed as the output of a policy process amongst representatives of water management institutions and organisations (e.g. operating within a 'policy arena'). The autonomous response results from the behaviour of individual stakeholders such as local farmers, citizens and small-scale companies (e.g. operating at the 'individual level'). Various interactions are included between water system, water policy, and autonomous response. The water policy may be aimed at changing the water system (e.g. through reservoir construction) or influencing the autonomous response (e.g. through water pricing). The autonomous response influences both the environment (e.g. through a changing water demand) and the policy-arena (e.g. through voting). Both water policy and autonomous response are influenced by the actors' perceptions of the water system on which their actions are generally based.

The actors within the policy arena and individual level are assumed to hold a socially-bounded autonomy (Conte & Castelfranchi 1995). They can autonomously decide which goals to achieve and act accordingly. However, they are operating within, and influenced by, a societal context. In the conceptual model of Figure 2, this context is characterized by a dominant water culture. The water culture comprises dominant shared societal beliefs in relation to wa-

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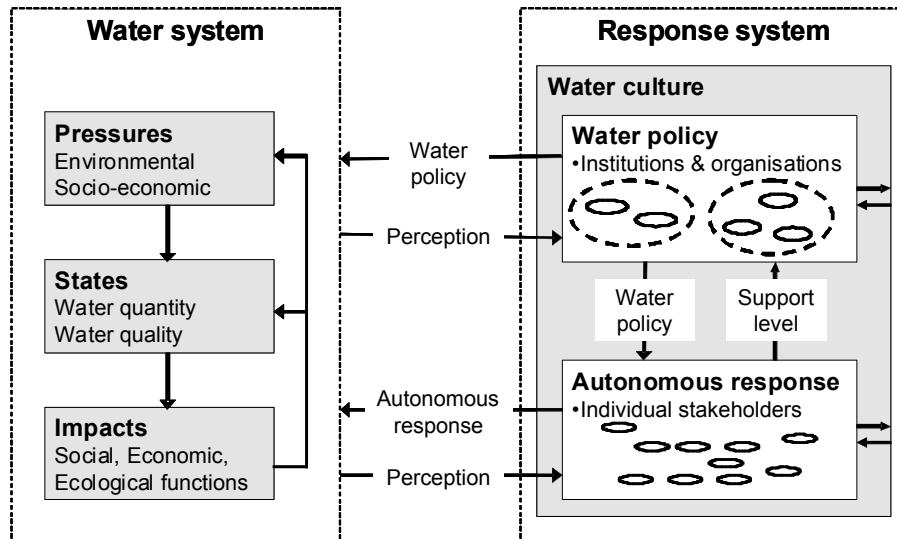[3]Association of People Affected by Big Reservoirs.

**Figure 2:** The elaborated PSI-R model of the Ebro water system frames the societal response as the outcome of interrelated processes of policy-making, individual behaviour and cultural change in relation to changes in the water system.

ter management, such as the ones listed in Table 1[4]. These beliefs are assumed to constrain the behaviours of individual stakeholders and policy actors alike. At the same time—considering the duality of structure and agency expressed by Giddens (1984)—it is the same actors who influence what these dominant shared beliefs are. In the conceptual response model this duality is represented as mutual interactions between the water culture (part of Giddens' structure) on the one hand, and the policy-arena and the individual level (agency components) on the other.

Compared to the existing static perspective based modelling approach, our dynamical perspective implies a number of methodological differences in conceptualising the system dynamics. First, it implies that the dominant water culture itself is subject to endogenous changes initiated from within the policy arena or at the individual level. Moreover, the water management culture no longer automatically determines the rules for water policy and autonomous response, it merely influences agency in their adoption. Agents have the ability to reject the dominant water culture. Finally, it implies that consistency between the dominant water culture and the actual water policy and autonomous responses is no longer a given. On the contrary, we assume that—as a society adapts to environmental change—inconsistencies may well arise between our thinking about water (water culture) and the actual water related behaviour (policy, autonomous response). These inconsistencies may point to undesired

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[4]A dominoant societal perspective is not restricted to either the stereotypical hierarchist, egalitarian, or individualist views. In principle, any combination of beliefs is possible.

lock-in situations that form an interesting item for study.

## 3.3 The dynamics of the response system

Insights into the dynamics of the response system were obtained by reviewing the literature across a number of social scientific disciplines; political science, social psychology and sociology. Without pretending to be able to give a complete overview of these fields, we describe a selection of conceptual and theoretical insights that we find particularly relevant for our case. For each subsystem—water policy, autonomous response, and water culture—we thereby identify both external drivers of change (e.g. originating from other subsystems), as well as the internal processes that influence the subsystem dynamics. See Table 2 and Figure 2 for an overview.

### 3.3.1 Water policy

A particularly useful approach for understanding and modelling policy change is the Advocacy Coalition Framework (ACF) (Sabatier & Jenkins-Smith 1993). This theory is particularly useful, since—in contrast to other policy theories—it holistically 1) describes policy change over the long term (a decade or more), 2) considers multiple actors involving both public and private organizations, 3) considers actors at multiple levels of government, and 4) it conceptualizes the policy process on the basis of belief systems similar to the ones that Cultural Theory describes. 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 hold various positions, such as public official, interest group leaders, and researchers. Policy actors that share a particular set of beliefs are assumed to form coalitions that advocate certain policy strategies. The policy process is then modelled as a competition among the advocacy coalitions (internal process) whose relative strengths may vary over time.

The ACF distinguishes two main drivers of policy change. The first is referred to as policy oriented learning (internal process). Policy oriented learning refers to the process through which coalitions seek to improve their understanding of the management problem in order to further their core policy objectives. In practice this means that coalitions subjectively seek and absorb that information that supports their argument and improves their position in the policy debate. Policy oriented learning may thus be strongly driven by changes in the water system (external driver) that are typically uncertain, may be perceived differently by each coalition, and therefore be used to underpin rather different points of view. Second—and actually more important—drivers are external factors like socio-economic conditions and technology. Changes in those factors may undermine the causal assumptions of present policies or, by altering the support for various coalitions, may change the relative strengths of advocacy coalitions. These external factors are represented by the external driver 'support level' from the individual level. As a third driver of policy change we add cultural changes (external driver) that may influence the beliefs and values of

the coalition members, or restrict their policy actions through specific social norms.

### 3.3.2   Autonomous response

For understanding change of autonomous behaviour at the individual level, insights are drawn from social psychology. Social psychology highlights a variety of factors on the basis of which human behaviour in different contexts may be explained (see Jager 2000, Van den Bergh et al. 2000, Jackson 2005, for three excellent overviews). A first group of theories thereby focuses on (various forms of) reasoning (internal process). Reasoning implies that agents are actively involved in reflecting upon one's goals and ways to achieve them. Some theories thereby focus on the individual. Rational Choice and Expectancy-value theories, for example, indicate that individual interests are an obvious main driver of human behaviour. Also, the availability of behavioural options, the perceived ability to perform a specific behaviour, as well as the perceived uncertainty in determining the outcomes of ones behaviour may play an important role (Ajzen 1988, Jager 2000). Other theories highlight the importance of the social and environmental context. In Ecological Value Theory, for example, altruistic and environmental values are considered influential factors, while Conte & Castelfranchi (1995) highlight social norms as important constraints for individual behaviour as well. A second group of theories highlights automated processes (internal process) as the explaining factor of human behaviour. This is illustrated by the role of habits (repetition of ones own behaviour) and social imitation (the imitation of someone else's behaviour). The latter is related to theories on social imitation such as Bandura's Social Learning Theory and also Social Identity Theory that highlight the influence of role-models on individual behaviour[5].

Concerning the external drivers we consider social, economic, and ecological developments (i.e. changes in the water system) to be a main influence (external driver). These developments can be gradual (an increasing income level, environmental degradation, increasing water stress) and also be manifested in sudden events (flood, market crash, spreading disease). According to the rational model of behaviour, such developments will force individuals to change behavioural strategies in order to optimize over their individual interests (e.g. in response to a drought a farmer decides to increase irrigation to maximize his profit). However, as the environmental changes become more pronounced, more fundamental behavioural changes—in the form of goal adoption and goal rejection (Conte & Castelfranchi 1995)—can be expected as well. Some examples are emerging interests (after a two-day water cut, the farmer starts to realize the importance of a secure drinking water supply), triggering environmental and altruistic values (after observing the devastating drought impacts downstream the farmer decides to reduce his irrigation), and a changing perceived ability to reach one's goals (after realizing it is impossible to run a profitable business the

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[5]Jager (2000) uses similar dimensions of automated versus reasoning processes, and individually-determined versus socially-determined processes to delineate different modes of agent behaviour in the 'consumat' approach.

farmer gives up farming altogether).

Another external driver is water policy. Water policy may rely on various approaches for influencing human behaviour and stimulating more sustainable water related practices (Jackson 2005). It may provide economic incentives, such as taxation and subsidies, issue rules and regulations about water use, or provide information about the (water-related) problems at hand. However, Jackson argues that these measures all draw upon a rather self-oriented rational model of behaviour. If—in contrast—one considers social norms to be of main influence on human behaviour, then policy should take a different angle. In that case, policy stimulated changes in the socio-cultural context (i.e. the water culture) (external driver) may be a better approach. Similarly, if one assumes automated process, like repetition, to be a key behavioural mechanism, then role models and government example might be a main external driver of behavioural change.

### 3.3.3 Water culture

The notion of cultural change is probably most difficult to grasp. The conceptual model of cultural change is based on the following assumptions. Following Giddens (1984) we first assume that cultural change eventually originates from changes on the level of individual stakeholders operating within the policy arena or at the individual level. The water culture—being defined as the dominant shared core beliefs of the individual stakeholders involved—changes when the core beliefs of those individual stakeholders change. Following Thompson et al. (1990) we also assume that within one society multiple distinguishable water cultures co-exist[6]. Also in a stable state, these cultures are in constant interaction with each other (dynamic equilibrium). Cultural change is then interpreted as a change in the relative importance of the different water cultures (i.e. a shift of dynamic equilibrium), rather than a homogeneous change of core beliefs of all individual stakeholders involved.

For understanding changes in core beliefs at the individual level Cultural theory (Thompson et al. 1990) highlights the importance of surprise (external driver). A surprise is defined as a mismatch between ones world view and an observed real-life event, which potentially may change the worldview of the individual involved. Typical surprises in the water management domain would be 'a collapse of the water market' (for the individualist), 'climate change being a complete hoax' (for the egalitarian), and 'a water supply cut in a carefully planned water transfer' (for the hierarchist). Similarly, the failure of reproduction mechanisms (those observations that support one's perspective as being correct) contribute to perspective change. However, perspectives are inherently

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[6]In Cultural Theory, the socio-cultural world is conceptualized in dynamic terms as constituted by multiple perspectives that co-exist and mutually interact. It is argued that each one of the perspectives—although possibly dominant in society—cannot exist without any one of the other perspectives around. The other perspectives are required to fill up the flaws in each particular one and alliances between the perspectives may exist. Cultural change is thus not considered as a sudden revolution, but as a natural process occurring within a viable society.

**Table 2:** External drivers and internal processes considered for modelling the dynamics within and between the subsystems of water policy, autonomous response, and water culture.

|  | External drivers | Internal processes |
| --- | --- | --- |
| Water policy | • Perceived environmental changes<br>• Changing public support<br>• Changing water culture | • Competition and coalition forming<br>• Policy oriented learning |
| Autonomous response | • Perceived environmental changes<br>• Water policy<br>• Changing water culture | • Automated processes: imitation, repetition<br>• Reasoning: goal and strategy formation focussing on the self and/or the social and environmental context |
| Water culture | • Perceived surprises<br>• Failed reproduction | • Competition between the water culture regime and new water culture niches |

robust to change, since events and developments are filtered through a perceptual screen. Those observations that support one's perspective are embraced to prove oneself right; observations that challenge one's perspective are moderated and, if possible, ignored. It is an accumulation of surprises and failure of reproduction mechanisms that will force individuals to adopt perspectives that are better suited to the reality around them.

The internal process of cultural change is interpreted as a process of niche accumulation (Geels & Schot 2007). Niche accumulation basically implies that 'fundamental changes start small'. Fundamentally different viewpoints from the current status-quo (the regime) are assumed to arise at individual and local levels forming small networks (niches). Under certain conditions—e.g. 'windows of opportunity' at the regime level—these networks may grow to become the dominant one themselves. Following the niche accumulation concept, the internal process of cultural change is represented as a competition between the water culture regime and new water culture niches. This competition is assumed to be strongly influenced by the occurrence of surprise.

The most relevant external drivers and internal processes discussed above are summarized in Table 2. Most of the external drivers mentioned in the table are also indicated in the conceptual model of Figure 2. The surprises and reproduction mechanisms are not explicitly in the figure, but implicitly contained in the 'perception' arrows originating from the water system. Surprises regarding human behaviour—i.e. originating from policy arena or individual level—are imaginable as well, but not highlighted in the current analysis.

# 4 From concept to implementation: an interactive computer game

## 4.1 The concept of the game

The conceptual model of the previous section forms the basis for the design of an interactive computer game. The concept of the game, presented in Figure 3, closely follows the conceptual PSI-R model of Figure 2. Each subsystem is represented with a different model type. The water system is modelled with IAM techniques such as system dynamics and GIS. The environment model is linked to an agent based model representing autonomous stakeholder responses. Water policy and cultural change are subject to a participatory simulation in the form of the game itself. The water system and agent-based model are a closely linked stand-alone application called LASY model and is described in (Wallman 2008). Here we focus on the process of playing the game.

Players are typically representatives from policy, interest groups, and businesses having a role in the policy arena. They are responsible for one or more specific water functions and the associated stakeholder agents represented in the ABM. In line with the main water use functions in the Ebro basin we may include a farmer representative (representing agriculture), the director of a power supply company (representing energy production), an influential environmentalist (representing the ecological function), a city mayor (representing domestic water use), an entrepreneur (representing industry), and a leading tourist organisation (representing recreation).

The players interact with the LASY model through an interface. This interface allows players to explore the water system and investigate the satisfactions and behaviour of agents. The goal for each player is to 'survive in a sustainable world'. That is, one has to find a balance between one's individual interests (satisfying one's individual needs) and the collective interest of sustainability. To this end, players aim to meet the policy targets that they specify, indicating their individual interests and the ones of the individual agents they represent. Also, each player is responsible for maintaining a high value for a sustainability indicator included in the interface, which relates, for example, to the satisfaction of stakeholder agents and the speed of water resource decline. The exact value of this indicator, however, is not objectively defined, but depends on the dominant water culture.

The water culture is implicitly represented in the interface through the so-called rules of the game illustrated in Figure 4. These rules reflect dominant water management beliefs, values, and norms such as the ones expressed in Table 1. The rules are particularly important since they determine to a large extent how sustainability is interpreted or 'defined', and how sustainability should be achieved. For example, a water availability rule may impose a projection for climate change and water that players are obliged to adopt; a management approach rule may indicate a preference for supply or demand management options; a voting rule may prescribe the way the negotiation process and voting is
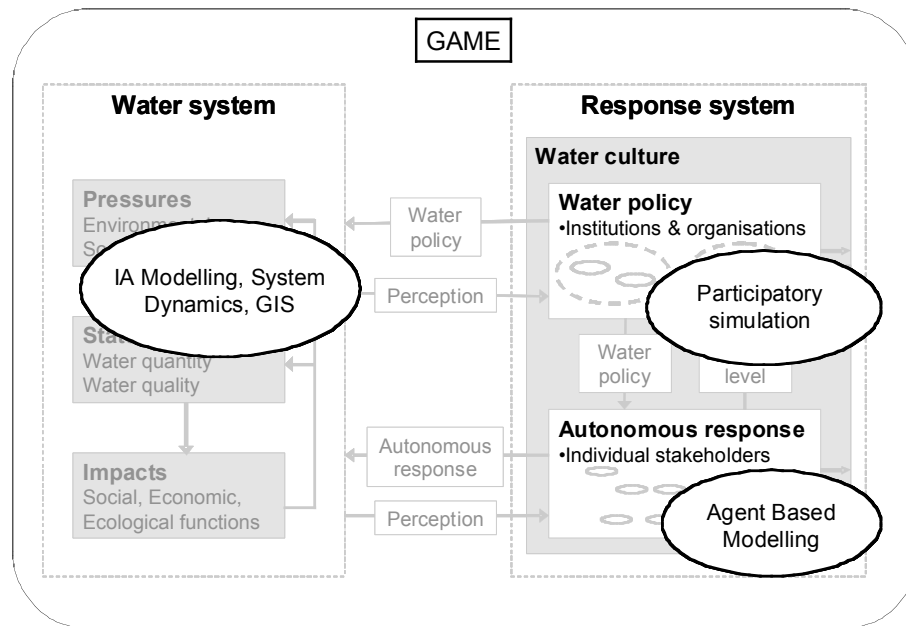
**Figure 3:** The concept of the game closely follows the PSI-R model of Figure 2.

carried out; and an equity rule may specify how individual player's satisfactions are aggregated to an overall value for social sustainability. In other words, the rules of the game may impose interpretations of model uncertainty, set preferred management styles, prescribe aspects of the management process, and directly influence the value of the sustainability indicator.

Initially, the game unfolds similar to existing policy games (Mayer & Veeneman 2002). The players discuss and negotiate water policy options—under the restrictions of the rules of the game—using the LASY model to explore their effects. Players engage in networking and coalition-forming to strengthen their policy positions and eventually come to a shared policy-decision through some voting scheme. As the game unfolds, however, players may realize that they are dealing with a persistent problem. They may realize that they are 'loosing the game', either because they repeatedly fail to meet their own interests, or observe a persistent downward trend in the value of the sustainability indicator. Since (apparently) this problem is not being solved through the type of policy negotiations they are currently in, players are encouraged to make a more fundamental change: a reflection on their water culture in the form of a modification of the rules of the game.

The procedure of rule change is similar to the procedure of policy-making and follows out of a process of coalition forming and voting amongst the policy actors (see Subsection 4.2). However, the process of rule change is assumed to involve a more profound 'clash' between players than the rejection of water policy, since
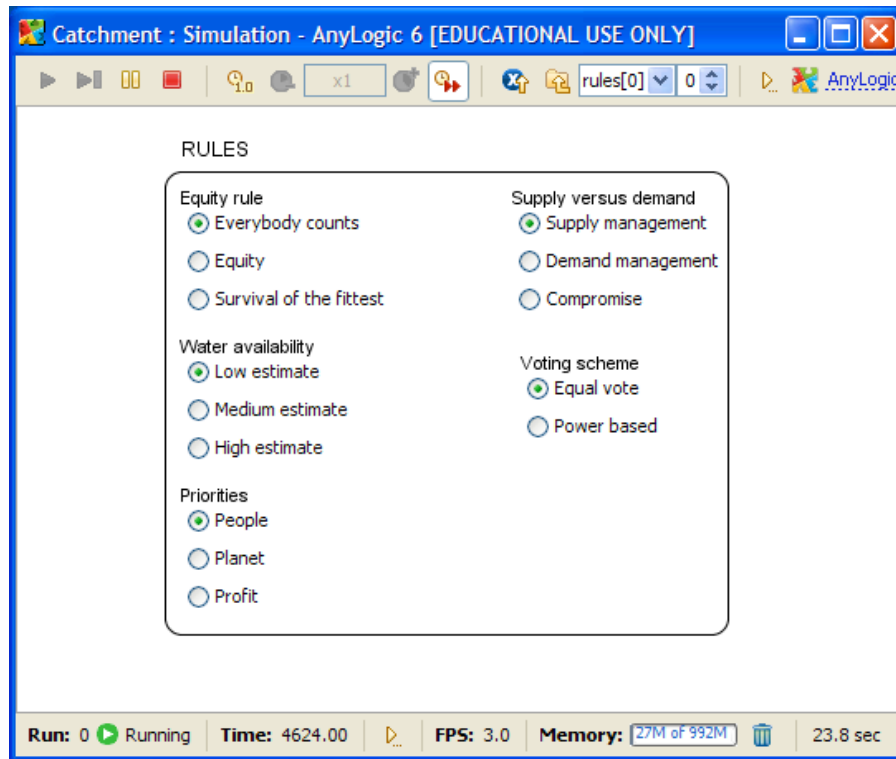
**Figure 4:** Implementation of a water culture in the form of the rules of the game. The rules presented in the figure are illustrative and will be further developed in future prototypes.

it refers to more fundamental change. Presumably, it will be niche players that will take the initiative for proposing rule change. Through deliberation—and using the evidence provided through the LASY model—they aim to attract more and more players to join their rule change coalition, reflecting the growth of their niche. When the niche grows strong enough it will succeed in getting the rule change across, reflecting a transitional step. The players may thus be actively involved in pursuing rule changes as part of their water management strategy. The observed rule changes during the game can then be considered 'markers' of a shift in water culture.

## 4.2 Playing the game

The game dynamics are structured along four main stages. In line with the ISA cycle (Weaver & Rotmans 2006, Weaver & Jordan 2008) we distinguish scoping (problem definition), envisioning (coalition forming and policy design), experimenting (assessment of policy effects) and learning (reflection on sustainability

and culture). Some general remarks apply:

- Although the stages correspond to the four stages of ISA, they are not intended to cover a fully fletched ISA cycle. See also the discussion.

- The four phases are a guideline for structuring the process of the game. It is not intended to be a rigid structure and players may choose to deviate from it.

- The game covers a long-term time horizon ($\sim$50 years) involving multiple iterations of the various phases.

- 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.

In the following, each phase is described and linked with the internal processes and external drivers of Table 2.

### 4.2.1    Scoping: Defining the problem

This stage involves an open discussion regarding the current state of the various subsystems. It is intended to specify the starting point of the game and to stimulate a first reflective discussion amongst the players. Typical questions to be addressed include:

- How do we evaluate water availability and water quality? Are we subject to a water stress? Are these aspects represented in the model of the water system?

- Which individual stakeholders exist in relation to the water system? What are their needs and are those needs satisfied? What is their level of support for current water management practice? Are they all adequately represented as agents in the game?

- How would we describe our current water management culture? Is this culture properly reflected with the current rules of the game?

- What future developments are to be reckoned with? Are the current water management practices sustainable? What does sustainable development mean in this context?

In this stage one thus reflects on the current state of the external policy drivers; i.e. perceived environmental changes', 'changing public support', and 'changing water culture'.

### 4.2.2 Envisioning: Coalition forming and policy design

This phase represents the process of collaborative or competitive policy design amongst the players. Three sub-stages are distinguished:

**Targets and water management options:** Each player individually expresses his/her policy position in terms of water management targets and ideal water management options. These policy options may be aimed at altering the water system (e.g. dam building), or at changing the behaviour of the stakeholder agents (e.g. taxation). Players are stimulated to reflect on each other's policy positions before a final stance is taken.

**Coalition forming:** The players are stimulated to form coalitions to increase their power position in the upcoming design of a 'common action plan'. Coalition-forming is advantageous, because the unanimous vote of a coalition weighs stronger than the individual votes of its members.

**Towards a common action plan:** The players design a common action plan including—or excluding—the various water management options discussed so far. Only water management options that are in line with the current rules of the game are allowed to enter in the action plan. In the end, the action plan results from a power-weighted vote amongst the different coalitions (again, as specified by the rules of the game).

This policy design and coalition forming phase thus involves the internal policy processes 'competition and coalition forming' and (possibly) 'policy oriented learning'. Its output in the form of a common action plan represents the external driver 'water policy'. Finally, the constraints of the process in the form of the rules of the game represent the external policy driver 'changing water culture'.

### 4.2.3 Experimenting: Exploring the policy effects

The common action plan is entered into the game and the various models are used to calculate the effects on the water system and individual stakeholder behaviour:

**The water system:** The water system is explored to assess the social, economic, and ecological impacts of the chosen action plan. This includes changes in water availability, water quality, and may include various impacts for water-related functions.

**The agents:** The agent model is explored to assess individual stakeholder satisfactions, their support level and (changes in) other autonomous stakeholder responses.

This phase thus involves the external policy drivers 'perceived environmental changes' and 'changing public support'. Furthermore, 'surprises' may occur when the effects turn out differently from those expected. These surprises might

be further accentuated in the game by adding probabilistic 'events' both in the water system (e.g. droughts) and the agent system (e.g. public uprisings).

### 4.2.4   Learning: Reflection on sustainability and culture

In the learning phase the players are stimulated to reflect on the assumptions underlying the water policy and water management debate. They discuss the sustainability of the water system on the basis of the sustainability indicator, which is explicitly constructed on the basis of the rules of the game. They reflect upon the rules of the game to address the water management culture. Since the value of the sustainability indicator depends strongly on the rules of the game, these tasks are carried out in parallel. **Sustainability assessment:** The players will reflect on the sustainability of their water management practice. Relevant questions are: Have the targets specified before been met? What is the satisfaction and support level of the agents in the game? Is the stock of freshwater sufficiently stable or sharply in decline? Are developments in the water system sustainable in terms of how sustainability is interpreted and how this interpretation has developed in the course of the game? **Reflection on the water culture:** The game players are asked to reflect on the water culture by discussing the rules of the game, see Figure 4. Typical questions to be addressed are: How to deal with the issue of equity? Is it acceptable that one of the parties becomes completely dissatisfied or even 'dies' in the game, or do we design an action plan where satisfaction amongst parties is most equally distributed? What is our water management style? Do we support only water supply management, only water demand management, or should we allow for a mix of approaches? How do we organise the voting process for designing the action plan? Is there an equal or a power-weighted vote? Inspiration for other questions can be found in Table 1.

Actual changes in the rules of the game result from a vote amongst the game players, similar to the design of the action plan. However, stricter conditions may be applied for a change to be adopted (e.g. a large majority supports the rule change). To get a change in the rules across, a strong coalition is thus required. Game players are thus stimulated to actively build up a network around them or to engage with the network that seems most suitable for them. The game dynamics in the reflection phase thereby represent the internal process of cultural change referred to as 'competition between the water culture regime and new water culture niches'. Its output in the form of a rule change represents the external policy driver 'changing water culture'.

## 4.3   Preliminary results

The description of the game in this paper reflects work in progress. The concept is well defined, but the computer tools required to play the game in the fashion described above are still under development. In the process of developing the game, the underlying concept has been tested twice with Ebro stakeholders in March 2007 and February 2008 (see Tàbara et al. 2008). During these tests, the

**Figure 5:** Playing the game

project-team aimed to facilitate a structured discussion amongst stakeholders along the game phases described above. It focussed notably on the scoping and envisioning phase of problem definition, coalition forming and the design of action plans. The LASY model could not yet be used to facilitate this discussion, but was presented to the stakeholders for reflection.

The preliminary tests indicate that the game dynamics in the envisioning phase work well. Players are actively involved in coalition forming and in the formation of policy design. The overall impression was that game players are willing to cooperate, but resistant to change their views in a fundamental way[7]. Also, the game and the prototype computer models presented were considered useful tools by the main stakeholders involved. Thorough testing and more elaborate social experiments are still required, which will be the subject of future participatory applications.

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[7]This observation is in line with hypotheses from Cultural Theory and the ACF and needs further attention in future work.

# 5   Discussion

## 5.1   Limitations and potential

Capturing complex societal processes with an analytical modelling approach obviously implies that major simplifications and crude assumptions have to be made. One limitation to the conceptual approach so far is that it is strongly focussed on the internal dynamics within and between the various sub-systems. However, a number of external drivers—such as technological changes, broader socio-cultural and economic developments, institutional changes, and individual role models—may play an important role as well. Furthermore, we implicitly assume that players exhibit real-life behaviour, a hypothesis which will require further underpinning in our future work. Finally, since the implementation of the game is currently work in progress, thorough testing is required to refine the approach and evaluate its results.

However, with these limitations overcome, the approach might offer a great potential for better understanding the dynamics of societal change. For example, it may be used to analyse the main drivers of the societal change. In particular we may assess how environmental changes 'external' to the human system and cultural innovations 'internal' to the human system mutually interact to become a strong driver of the societal response, as an attempt to bridge the gap between the ecological realist and social constructivist views (Tàbara & Ilhan 2007). Also, one may further assess the response characteristics. Under which conditions are responses non-linear in time, as the transition model suggests? Or are linear responses possible as well? And given a non-linear societal response, one may assess thresholds (e.g. the level of climate change) at which such fundamental shifts occur.

With the approach being developed for the field of water, its application may well be extended to other fields such as energy, mobility, tourism, or health. Any field that involves clear interactions between policy, autonomous responses, cultural change, and the development of some domain system (e.g. water, energy, tourism, or health system) may be suitable to address. It seems particularly interesting to incorporate the gaming approach into existing IA models of those domains. Especially for PSIR based models this procedure could be feasible. Simply put, this would involve decoupling the response relations from an existing model, and replacing them with agent-based and/or game-like responses.

## 5.2   Role in the ISA cycle

Although the four stages of the game are similar to the stages of the ISA cycle, it is not intended to cover a full ISA. The game alone can impossibly cover the extensive tasks—in terms of process and substantive assessment—required for a full ISA. The game (both its development and application) should be perceived as part of the ISA process, and should generally be complemented with other participatory tools and more detailed water models. In different stages of the ISA cycle, the game may play different roles:

- It may be used in the scoping stage, when the game focuses on initiating a collaborative process amongst stakeholders, to acknowledge each others interests and concerns, and to make different perspectives on the problem explicit.

- It may be used in the envisioning stage, when the focus lies on the development of a shared sustainability vision and a first assessment of different possible pathways onto the vision.

- Also, it may be used as part of the experimenting stage, when the focus lies on a better understanding of the social dynamics underlying the implementation of sustainability visions and pathways, to assess under which conditions a successful sustainability transition can be carried through.

## 5.3   Points of reflection

The discussion is concluded with some points of reflection on the gaming approach, relating to its goal, interpretation and conceptual design:

### 5.3.1   A model or a learning tool?

In general, the goal of the gaming approach can be twofold (Barretau 2003). On the one hand, it may be aimed at the production of knowledge for 'the researcher'. The game is then interpreted as a model representing (aspects of) the complex dynamics of real-life social-ecological systems. On the other hand, it may be aimed at learning and decision support for the stakeholders involved. The game is then considered as a tool to make people aware of their social-ecological interactions, their own impacts on the whole system, their own motives and what drives their own actions, and the limitations and opportunities to adapt them to sustainability requirements. The focus in this paper has been clearly on the first purpose, describing the game's development and application from a modelling perspective. The aspects of learning deserve special attention.

### 5.3.2   An explorative or normative approach?

In relation to the previous point, one may distinguish two modes for interpreting the game. On the one hand, it can be interpreted as a normative approach. In this interpretation, one would stress the need for a sustainability transition, and the need for fundamental cultural change. The game is then be perceived as a tool to empower relevant (niche) agents. On the other hand, it can be interpreted as an explorative approach. In that case, the need for a sustainability transition is not a priori implemented in the game. Nor does it prescribe that players will design a shared interpretation of sustainability, a common vision, and implementation pathways. It rather aims to assess the conditions under which such a collaborative process might take place[8]. Each mode has different

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[8]Of course admitting that the game does impose the (normative) structure to allow fundamental change to happen in the game.

advantages and may be useful in different settings and for different purposes. The game described in this paper follows rather an explorative approach. However, a similar game format has been developed (the 'transition play') (Tàbara & Haxeltine 2008) that is more in line with the normative approach.

### 5.3.3    Multi-system or multi-scale?

The conceptual model of Figure 2 represents the water policy, autonomous behaviours and water culture as distinguishable, strongly related, societal subsystems. These subsystems, one might argue, reflect different societal scales, from the individual, to the organisational, to the societal level. Consequently, an alternative approach could be to represented a society with a nested or 'cellular' structure of socio-ecological agents (Tàbara & Pahl-Wostl 2007). In such an approach, one distinguishes at multiple scale-levels individual agents (representing autonomous behaviours), collective agents (representing coordinated responses of individual agents similar to water policy), and a system agent representing the dominant water culture. The elegance of this approach, amongst others, is that it explicitly acknowledges that culture is essentially a multi-scale phenomenon pertaining not only to a societal level, but also to organisations, local communities and down to the individual level (Erez & Gati 2004). A thorough multi-scale conceptualisation would be an interesting step to take.

## 6    Conclusion

In this paper a new integrated, agent-based, gaming approach is proposed for modelling cultural and behavioural change in a meaningful way for a complex water management case like the management of the Ebro River basin. This paper primarily focuses on the question how this could be done. The conceptual model developed constitutes a framework for understanding processes of change and mapping the interactions across dissimilar subsystems of water, culture, policy, and autonomous behaviour. It is used as a framework for designing the game and constitutes a 'lens' to analyse the interaction processes observed while playing the game. The presented overview of external drivers and internal processes is particularly and generically useful as an inventory of potential mechanisms to be included in models of societal change. Also, we showed how the different processes and interactions can be implemented in a practical game design, as a tool to study them further. Thorough testing of the concept is left for future work.

One of the main lessons from the exercise is that the combination of modelling and participation is promising for understanding the complex nature of societal change. Playing the game with stakeholders in an open fashion allows for a broad discussion between the game players on all the potential aspects of societal change, possibly extending the variables included in the game. The strength of the gaming approach is then that it combines the structure and scientific underpinning of analytical modelling with the richness of participatory

methods so as to address real complex issues of societal change in a consistent and meaningful way.

# 7 Acknowledgements

# 8 Bibliography

Ajzen, I. (1988), *Attitudes, Personality and Behavior*, Open University Press, Buckingham. 29

Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T. & Siebert, S. (2003), 'Development and testing of the WaterGAP 2 global model of water use and availability', *Hydrological Science* **48**(3), 317–337. 21

Athanasiadis, I. N., Mentes, A. K., Mitkas, P. A. & Mylopoulos, Y. A. (2005), 'A hybrid agent-based model for estimating residential water demand', *SIMULATION* (81), 175–187. 22

Barretau, O. (2003), 'Our companion modelling approach', *Journal of Artificial Societies and Social Simulation* **6**(2). 20, 22, 40

Barreteau, O. & Bousquet, F. (2000), 'SHADOC: a multi-agent model to tackle viability of irrigated systems', *Ann. Operation Research* (94), 139162. 22

Barthelemy, O., Moss, S., Downing, T. & Rouchier, J. (2002), Policy modelling with ABSS: The case of water demand management, Technical Report 02-92, Centre for Policy Modelling, Manchester Metropolitan University. 22

Bousquet, F. & Page, C. L. (2004), 'Multi-agent simulations and ecosystem management: a review', *Ecological Modelling* **176**(3-4), 313–332. 22

Briot, J.-P., Guyot, P. & Irving, M. (2007), Participatory simulation for collective management of protected areas for biodiversity conservation and social inclusion, *in* F. Barros, C. Frydman, N. Giambiasi & B. Ziegler, eds, 'AIS-CMS '07 International Modeling and Simulation Multiconference (IMSM'07)', The Society for Modeling & Simulation International (SCS), pp. 183–188. 22

Carmichael, J., Tansey, J. & Robinson, J. (2004), 'An integrated assessment modeling tool', *Global Environmental change* **14**, 171–183. 21

Conte, R. & Castelfranchi, C. (1995), *Cognitive and social action*, UCL Press ltd, London. 26, 29

De Vries, B. J. (2001), 'Perceptions and risks in the search for a sustainable world: a model-based approach', *The International Journal of Sustainable Development* **4**(4), 434–453. 20, 21

Edmonds, B. & Mohring, M. (2005), 'Agent-based simulation modeling in social and organizational domains', *SIMULATION* **81**(3), 173–174. 22

Erez, M. & Gati, E. (2004), 'A dynamic, multi-level model of culture: From the micro level of the individual to the macro level of a global culture', *Applied Psychology: An International Review* **53**(4), 583 – 598. 41

Espinasse, B. & Franchesquin, N. (2005), 'Multiagent modeling and simulation of hydraulic management of the Camargue', *SIMULATION* (81), 201–221. 22

Geels, F. W. & Schot, J. (2007), 'Typology of sociotechnical transition pathways', *Research Policy* **36**(3), 399417. 20, 31

Giddens, A. (1984), *The constitution of society: outline of the theory of structuration*, University of California Press, Berkeley. Anthony Giddens. ill.; 24 cm. Includes index. 27, 30

Gurung, T. R., Bousquet, F. & Trebuil, G. (2006), 'Companion modeling, conflict resolution, and institution building: Sharing irrigation water in the Lingmuteychu Watershed, Bhutan', *Ecology and Society* **11**(2). 22

Guyot, P. & Honiden, S. (2006), 'Agent based participatory simulations: Merging multi-agent systems and role-playing games', *Journal of Artificial Societies and Social Simulation* **9**(4). 22

Hare, M. & Deadman, P. (2004), 'Further towards a taxonomy of agent-based simulation models in environmental management', *Mathematics and computers in simulation* **64**, 25–40. 22

Hoekstra, A. (1998), *Perspectives on Water: An integrated model-based exploration of the future*, International Books, Utrecht. isbn 90-5727-018-8. 20, 21, 23, 25

Hoekstra, A. Y. (2000), 'Appreciation of water: four perspectives', *Water Policy* **1**(6), 605–622. 20, 21

Jackson, T. (2005), Motivating sustainable consumption, Technical report, University of Surrey. 29, 30

Jager, W. (2000), Modelling consumer behaviour, PhD thesis, University of Groningen. 22, 29

Janssen, M. A. (2001), 'An exploratory integrated model to assess management of lake eutriphication', *Ecological Modelling* **140**, 111–124. 22

Janssen, M. & De Vries, B. (1998), 'The battle of perspectives: a multi-agent model with adaptive responses to climate change', *Ecological Economics* **26**, 4365. 22

Loorbach, D. (2007), Transition Management: New mode of governance for sustainable development, PhD thesis, Erasmus University Rotterdam. 20

López-Paredes, A., Saur, D. & Galn, J. M. (2005), 'Urban water management with artificial societies of agents: The FIRMABAR simulator', *SIMULATION* (81), 189–199. 22

Martens, P. (2006), Integrated assessment models, *in* P. Valkering, B. Amelung, R. V. d. Brugge & J. Rotmans, eds, 'More puzzle-solving for policy: Integrated Assessment from theory to practice', ICIS, Maastricht, The Netherlands. 21

Mayer, I. & Veeneman, W., eds (2002), *Games in a world of Infrastructures: Simulation-Games for research, learning and intervention*, Eburon Academic Publishers, Delft. 33

Moss, S., Pahl-Wostl, C. & Downing, T. (2001), 'Agent-based integrated assessment modelling: the example of climate change', *Integrated Assessment* **2**(1), 17–30. 22

Pahl-Wostl, C. (2002), 'Participative and stakeholder-based policy design, evaluation and modeling processes', *Integrated assessment* **3**(1), 3–14. 20

Pahl-Wostl, C. & Hare, M. (2004), 'Processes of social learning in integrated resource management', *Journal of Community and Apllied Social Psychology* **14**, 193–206. 22

Ramanath, A. M. & Gilbert, N. (2004), 'The design of participatory agent-based social simulations', *Journal of Artificial Societies and Social Simulation* **7**(4). 20, 22

Rotmans, J. (1998), 'Methods for IA: The challenges and opportunities ahead', *Environmental Modelling and Assessment* **3**(3), 155–179. 21

Rotmans, J. (2005), Societal innovation: Between dream and reality lies complexity, Technical report, DRIFT: Erasmus University Rotterdam. 20

Rotmans, J. (2006), 'Tools for integrated sustainability assessment: A two-track approach', *The Integrated Assessment Journal* **6**(4), 35–57. 20, 21

Rotmans, J. & De Vries, H., eds (1997), *Perspectives on Global Change: The TARGETS approach*, Cambridge University Press, Cambridge, UK. 20, 21, 24

Rotmans, J. & van Asselt, M. B. A. (2001), 'Uncertainty management in integrated assessment modeling: towards a pluralistic approach', *Environmental Monitoring and Assessment* **69**, 101–130. 21

Sabatier, P. A. & Jenkins-Smith, H. C. (1993), *Policy change and learning: an advocacy coalition approach*, Theoretical lenses on public policy, Westview Press, Boulder, Colo. edited by Paul A. Sabatier and Hank C. Jenkins-Smith. maps; 24 cm. 28

Tàbara, J. D. & Haxeltine, A. (2008), The Transition Play©. a participatory tool for exploring opportunities and contraints of sustainability transitions., Technical report. 41

Tàbara, J. D. & Ilhan, A. (2007), Culture as trigger for sustainability transition in the water domain. the case of the spanish water policy and the Ebro river basin, Technical report, Matisse working paper 10. 24, 39

Tàbara, J. D. & Pahl-Wostl, C. (2007), 'Sustainability learning in natural resource use and management', *Ecology and Society* **12**(2), 3. 41

Tàbara, J. D., Roca, E., Madrid, C., Valkering, P., Wallman, P. & Weaver, P. M. (2008), 'Integrated sustainability assessment of water systems: lessons from the Ebro river basin.', *International Journal of Innovation and Sustainable Development* **3**(1/2), 48–69. 37

Thompson, M., Ellis, R. & Wildavsky, A. B. (1990), *Cultural theory*, Political cultures, Westview Press, Boulder, Colorado. Michael Thompson, Richard Ellis, Aaron Wildavsky. 24 cm. 20, 21, 23, 30

Torrecilla, N. J. & Martinez-Gil, J. (2005), 'The new culture of water in Spain: A philosophy towards a sustainable development', *E-WAter* (article nr. 2005/07). 24

Valkering, P., Rotmans, J., Krywkow, J. & Veen, A. v. d. (2005), 'Simulating stakeholder support in a policy process: an application to river management', *SIMULATION* **81**(10), 701–718. 22

Van Asselt, M. & Rotmans, J. (2002), 'Uncertainty in integrated assessment modelling, from positivism to pluralism', *Climatic Change* **54**, 75–105. 20, 21

van Delden, H., Luja, P. & Engelen, G. (2005), 'Integration of multi-scale dynamic spatial models of socio-economic and physical processes for river basin management', *Environmental Modelling & Software* **22**(2), 223–238. 22

Van den Bergh, J. C., Ferrer-i Carbonell, A. & Munda, G. (2000), 'Alternative models of individual behavior and implications for environmental policy', *Ecological Economics* **32**, 43–61. 29

Van der Veen, A. & Rotmans, J. (2001), 'Dutch perspectives on "agents, regions and land use change"', *Environmental Modeling and Assessment* **6**(2), 83–86. 22

Wallman, P. (2008), The LASY model. Matisse Deliverable 6.9., Technical report. 32

Weaver, P. M. & Jordan, A. (2008), 'What roles are there for sustainability assessment in the policy process?', *International Journal of Innovation and Sustainable Development* **3**(1/2), 9–32. 20, 34

Weaver, P. M. & Rotmans, J. (2006), 'Integrated sustainability assessment: what it is, why do it and how?', *International Journal of Innovation and Sustainable Development* **1**(4), 284–303. 20, 34